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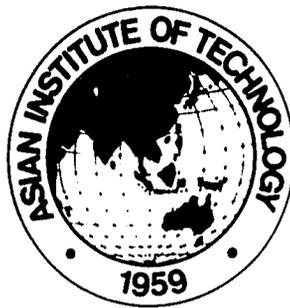
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**ASIAN INSTITUTE OF TECHNOLOGY**

**RESEARCH SUMMARY**

**JANUARY 1975**



## PREFACE

The Asian Institute of Technology is an independent, regional institution offering graduate programs (leading to the Diploma and the degrees of Master and Doctor) in engineering, science and related fields. Research by students and faculty is directed towards the solution of problems encountered in Asia. Research is funded by the Institute itself and, to an increasing extent, through research contracts and grants offered by outside organizations from both the public and private sectors.

This *Research Summary* presents brief reports of projects completed between January 1973 (when the previous edition was published) and January 1975. The reports are grouped into six sections reflecting the administrative structure in being for most of the period covered by the *Summary*:

- Water Resources Engineering
- Structural Engineering and Materials
- Environmental Engineering
- Geotechnical Engineering
- Industrial Development and Management
- Community and Regional Development

Agricultural Engineering is referred to in a separate section, which draws attention to the project reports in this area of study appearing in the main body of the *Summary*.

Reference is also made to the services provided by the Computer Center, the Library and Information Center and the Language and Media Center.

Asian Institute of Technology  
P.O. Box 2754  
Bangkok, Thailand

January 1976

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**DIVISION OF WATER RESOURCES ENGINEERING  
FACULTY AND SENIOR RESEARCH STAFF**

Chairman: *Prof. Anat Arbhahirama*

**Professors**

- Norbert L. Ackermann* B.S., M.S., Ph.D., Carnegie Institute of Technology; former Division Chairman until April 1975. *(Hydraulic Engineering)*
- Anat Arbhahirama* B.Eng., Chulalongkorn; M.Eng., SEATO Graduate School of Engineering; Ph.D., Colorado State. *(Hydraulic Engineering)*
- Ben-Zion Kinori* Dipl. Ing., Technical University of Budapest. *(Hydraulic Engineering)*
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**Assistant Professors**

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- Selvadore Selvalingam* B.Sc. (Eng.), Ceylon; D.I.C., Ph.D., London; *(Water Resources Engineering)*
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- Virgilio A. Sahagun* B.S. Agri. Engg, Philippines; M.Eng., AIT.
- Somchet Thinaphong* B.E., Tasmania; M.Eng., AIT
- Devindar Singh\** B.Tech., G.B. Pantnagar; M.Eng., AIT.

**Research Assistants**

<i>Prinya Pruchayatanawut</i>	B.Eng., Khonkaen.
<i>Somsak Rucha-Charuswong</i>	B.Eng., Khonkaen.
<i>Paiboon Vanich-Adisak</i>	B.Eng., Khonkaen.

\*This list includes all faculty and staff holding appointment in the period since January 1973. Those who no longer hold appointment are indicated by an asterisk.

## RESEARCH PROJECTS IN PROGRESS OR COMPLETED SINCE JANUARY 1973

### COASTAL ENGINEERING

#### 2176 WAVE PRESSURE ON A SLOPING DIKE

- a) Chin-I Liu (Supervisor: Dr. N. Shuto)
- b) Graduate student thesis project
- c) Completed
- d) A theory gives the wave pressure distribution on a sloping dike as follows

$$p = \rho g \alpha x_o \bar{z} + \frac{\rho g \sigma}{\sqrt{g \alpha}} \alpha A J_2 \left( \frac{2\sigma}{\sqrt{g \alpha}} \sqrt{x_o} \right)$$

$$x = x_o \bar{z} + \frac{A}{\sqrt{x_o}} J_1 \left( \frac{2\sigma}{\sqrt{g \alpha}} \sqrt{x_o} \right)$$

Experiments were carried out to investigate the validity of the equation above. Models with the slope angles, 15°, 30°, 45°, 60° and 75°, were used. Maximum wave pressure was measured at several points and compared with the theory. The theoretical values were found to be always a little bigger than the experimental results.

An approximate method to replace the theoretical curve by linear distribution was developed, and graphs were given to make it easy to calculate the pressure distribution.

- e) Thesis No. 537, AIT, 1973.

#### 2184 WAVE CLIMATE FORECASTING IN GULF OF THAILAND

- a) Surasuk Muangman (Supervisor: Dr. N.L. Ackermann)
- b) Graduate student thesis project
- c) Completed
- d) The wave climate in the Gulf of Thailand was determined from a wave hindcasting model which was developed that required knowledge of the wind at several stations in the region where the wave climate is to be determined. This model was calibrated using wind wave information that was available at one location in the southern portion of the Gulf.
- e) Thesis No. 569, AIT, 1973.

#### 2191 SEDIMENT DISTRIBUTION IN THE TAPI ESTUARY

- a) Masahiro Imbe (Supervisor: Dr. Suphat Vongvisessomjai)
- b) Graduate student thesis project
- c) Completed
- d) The research reported herein was conducted to study the sediment distribution in the Tapi estuary. This study was based on the request from the Harbour Department of Thailand which had planned a five-year project to improve the nine harbours in Southern Thailand. The main work in this study was divided into two parts: one is the estimation of the quantity of sediment from the river, and another is the estimation of the movement of sediment material in the sea. The size distribution analysis of the bed material gave the indication of the sediment movement in the estuary. The analysis of the cross-section of the estuary including the navigation channel gave the indications of the changes in depth to be variable from season to season. The relationship between total sediment discharge and water discharge at a certain station was obtained to predict the approximate quantity of suspended load sediment from the river; on the other hand, quantity of bed load sediment was computed by the bed load formula (DuBoys-Straub formula, etc.). It is concluded in this paper that the sediment load, which is mostly in suspended load transported by Tapi river, is approximately  $1.9 \times 10^6$  tons/year. It is also concluded that there exist two currents (longshore current from west and wind wave-induced current from east) which affect the mechanism of the sediment movement in the estuary.
- e) Thesis No. 646, AIT, 1974.

- 2192 **COASTAL SEDIMENT CURRENTS AND WIND CLIMATE**
- a) Akimitsu Inaba (Supervisor: Dr. H. Shi-igai)
  - b) Graduate student thesis project
  - c) Completed
  - d) An attempt is made to hindcast the deep water wave characteristics from wind data of Chumporn Meteorological Station for Sairee Beach, Chumporn, to transform them into wave characteristics at the breaker line, and to estimate the littoral sand drift using formulae proposed by several scholars. The littoral sand drift which was computed was then compared with the results obtained from field measurements which took place in December 1973 and February 1974.
  - e) Thesis No. 647, AIT, 1974.
- 2195 **DEPOSITION AND SCOUR OF CLAY PARTICLES DUE TO CURRENTS**
- a) Pit Teong Lee (Supervisor: Dr. Suphat Vongvisessomjai)
  - b) Graduate student thesis project
  - c) Completed
  - d) Incipient motion of bottom sand due to waves and currents has been extensively studied by several researchers, but that of clay is not yet clearly understood (although it is very important in estuaries in deltaic areas where it causes changes in flow patterns, creates navigational hazards and expensive cost of dredging).  
The critical shear stress for deposition of clay sediments was determined by using paddle type recirculating flume for various salinities. The sediment samples and sea water used in the experiments were taken from the neighborhood of Bandon Harbour, Surat Thani Province, Thailand. A few sets of experiment for the scouring process was also done.  
The critical shear stress for deposition was found 1.05 dyne/sq.cm. for 22 ppt salinity, 1.1 dyne/sq.cm. for 12 ppt salinity and 0.83 dyne/sq.cm. for zero salinity. The critical shear stress was found nearly equal for 12 ppt salinity and 22 ppt salinity because settling velocity of the sediment was found equal for high salinity above 10 ppt salinity.
  - e) Thesis No. 650, AIT, 1974.
- 2198 **FLOCCULATION OF SILT AND CLAY**
- a) Muhammad Ashraf Malik (Supervisor: Dr. Norbert L. Ackermann)
  - b) Graduate student thesis project
  - c) Completed
  - d) The effect of salinity and sediment concentration on the process of flocculation was investigated. In these studies, combinations using different concentrations of sediments and salinity were investigated. A suspension was allowed to settle and average settling velocities at different depths and times were determined.  
Conventional hydrometer and pipette methods were inadequate for testing the conditions of sediment concentrations found in the estuary which was being studied. Therefore, a photo-electric technique was developed. It would measure instant sediment concentration at any depth and time without creating any disturbance. The photo-electric method was suitable for measuring the concentration much less than the minimum required for hydrometer and pipette methods. By such observations, the sedimentation rate as a function of depth and time would be calculated for the suspensions under consideration.
  - e) Thesis No. 653, AIT, 1974.
- 2199 **BUOYANT PLUME FROM A LINE SOURCE INTO A CROSS SECTION**
- a) Pratoom Patarungsi (Supervisor: Dr. Anat Arbhabhirama)
  - b) Graduate student thesis project
  - c) Completed
  - d) The buoyant plume from a line source into a cross section was studied using the integral technique of analysis. Assuming similarity, the jet trajectories and dilution ratio can be predicted; the coefficients can also be found. This information will enable further investigation for the design of sewage disposal system effluent into the ocean or waste gas into the atmosphere.  
The present study is based on assumptions made by FAN and SHUTO. Numerical solutions have been presented for a range of initial conditions. Experiments were conducted for the variation of the dilution ratio and for photographic observations of the

trajectories of dyed jets. The observed jet forms agree well with the calculated trajectories.

The problem of a buoyant jet from a line source into a cross section was analyzed by assuming an entrainment mechanism based upon the vector difference between the characteristic jet velocity and the ambient velocity. Experiments with sinking jet, which are directly analogous to buoyant jet, were performed. Salt solutions were injected into a fresh flowing water at the free surface in the flume. Jet trajectories and dilution ratio were obtained from titrating the samples. The coefficient of entrainment was found to vary from 0.04 to 0.24 and the drag coefficient was between 0.9 to 1.2.

- e) Thesis No. 654, AIT, 1974.

#### 2208 WAVE IMPACT PRESSURES

- a) Mou-Hsing Wang (Supervisor: Dr. Norbert L. Ackermann)
- b) Graduate student thesis project
- c) Completed
- d) This study presents several methods to calculate the impact wave pressures upon a vertical wall. Because of the complications developed from the analytical approach, two simple models are used to describe this phenomena. The study attempts to find the effects of ambient pressure, size of air cushion and wave celerity on the magnitude of impact pressure. Finite difference methods were used to obtain the approximate solution.
- e) Thesis No. 664, AIT, 1974.

#### 2214 STANDING WAVES IN FRONT OF A SLOPING DIKE

- a) N. Shuto
- b) Faculty research
- c) Completed
- d) A solution of two-dimensional long waves on a beach of uniform slope is connected with that in water of constant depth, in order to yield an approximate solution for standing waves in front of a sloping dike. Wave motions are expressed in the Lagrangian description.  
The highest possible standing wave as well as the reflection coefficient are calculated according to the Miche's conception. Theoretical results show a good agreement with the experimental results of Murota and Yamada.  
It is also predicted that there is a relationship between the wave overtopping quantity and the quantity of water of standing waves above the crown height of the dike.  
As for the wave pressure of standing waves, a simple formula in the Eulerian description is derived for relative-dike length  $QL < 0.16$  by allowing 6% error.
- e) SHUTO, N. (1973), Standing Waves in Front of a sloping Dike, *Proc. 13th Int. Conf. on Coastal Engng.*, Vancouver, Canada.

#### 2227 NAVIGATION CHANNEL IMPROVEMENT OF SOUTHERN PORTS IN THAILAND

- a) Faculty, Division of Water Resources Engineering
- b) Sponsored research
- c) In progress
- d) A number of coastal and estuarine ports in the southern part of Thailand are not functioning adequately as a result of the deposition of sand and silt in the navigation channels, which limits the draft of vessels wanting access to these ports.  
It is the aim of this research project to improve and develop the navigation channels of nine harbors in southern Thailand by studying tidal currents, wave climate, coastal sediment movement and river sediment flow – whose complex hydrodynamic inter-relationship would create either favorable or unfavorable navigation conditions.
- e) (i) THIMAKORN, Prida and VONGVISESSOMJAI, Suphat, Navigation Channel Improvement of Southern Ports in Thailand, Progress Reports I–VI.  
(ii) IMBE, M., Sediment Distribution in the Tapi Estuary, Thesis No. 646, AIT, 1974.  
(iii) INABA, A., Coastal Sediment Currents and Wind Climate, Thesis No. 647, AIT, 1974.  
(vi) LEE, P.T., Deposition and Scour of Clay Particles Due to Currents, Thesis No. 650, AIT, 1974.  
(v) MALIK, M.A., Flocculation of Silt and Clay, Thesis No. 653, AIT, 1974.

- 2228 **BREAK WATER STUDIES FOR DEEP WATER TERMINAL, DANANG HARBOR DEVELOPMENT, SOUTH VIETNAM**
- a) Faculty, Division of Water Resources Engineering
  - b) Sponsored research
  - c) Completed
  - d) Coastal model studies were conducted to determine the effectiveness of constructing a breakwater for reducing wave heights in the Deepwater Port of Danang in the Republic of Vietnam. Waves were found to propagate into the Port area from two sources. One source was from swell waves which approached from the Northeast and refracted around the Observatory Point and into the harbor area. The other source was from waves reflected from the shores opposite the harbor area. Two hydraulic models were constructed to investigate these separate phenomenon.  
Siltation problems were also investigated that would result from changes in the currents created by the construction of the proposed breakwater.  
Results indicated that a breakwater of approximately 150 meters in length would reduce maximum wave heights in the deepwater port to acceptable levels of between 0.50 and 1.0 meter.
  - e) VONGVISESSOMJAI, Suphat, THIMAKORN, Prida, ACKERMANN, N.L. and NISHIMURA, H. (1975), Break Water Terminal, Danang Harbor Development, South Vietnam *AIT Research Report No. 50*.
- 2230 **NAVIGATION CHANNEL IMPROVEMENT OF SATTAPHIP NAVAL HARBOR**
- a) Dr. Suphat Vongvisessomjai and Mr. Somchet Thinaphong
  - b) Sponsored research
  - c) In progress
  - d) The Sattahip naval harbor and its navigation channel, situated in South-Eastern Coast of Thailand, is not functioning adequately as a result of active sediment deposition. A comprehensive acquisition of necessary field information of the entire problem area including topography, hydrodynamics and sediment data, has been in progress in cooperation with the Royal Thai Navy, ever since November 1972. Data analysis is made in the assessment of the nature of the sedimentation processes related to the maintenance and improvement of the navigation channel. In this analysis, the erosion/deposition rates are computed for various positions in the main channel and the sediment budget is made.  
The details of sediment balance analysis, a general description of techniques of appraisals of sediment nature in the area, and the effects of waves and tidal action are shown quantitatively in the report.  
Decisions relating to the improvement of the navigation channel await more hydrodynamic, geomorphologic and sediment data. The recommendation measure is expected to be made by January 1976.
  - e) VONGVISESSOMJAI, Suphat and THINAPHONG, Somchet, Sedimentation Processes in Sattahip Bay and Its Navigation Channel (1974), Progress Report, Division of Water Resources Engineering, AIT, Bangkok.
- 2259 **PRACTICAL COMPUTATIONS OF INCIPIENT DEPTHS AND BED LOAD TRANSPORT RATES IN ROUGH TURBULENT-OSCILLATORY FLOW FIELD**
- a) Dr Suphat Vongvisessomjai and Mr. Somchet Thinaphong
  - b) Faculty research project
  - c) Completed
  - d) A review was made of research work on sediment movement due to wave action. The mechanisms as known in unidirectional flow and oscillatory flow conditions are compared. Reanalysis of data indicates a domain of mutual trend from which a simple expression described in terms of wave characteristics is developed and proposed as a criteria for predicting motion of a fine sand size. A simple correlation of bed load transport rate and maximum bottom velocity was found to exist, which permits the order of magnitude of bed load transport rates to be assessed. Both the incipient and the bed load expressions described in the report possess cases of application and are supported by some field information.
- 2260 **PREDICTION OF TIDAL CURRENT FROM TIDE**
- a) Dr. Suphat Vongvisessomjai and Mr. Fuh Yin

- b) Faculty research project
- c) Completed
- d) Observation on current is laborious and costly while tide record is usually available. Twenty five hour current was measured at six locations in a bay in the Gulf of Thailand. The current was measured at neap and spring tides throughout a year at an interval of three months. Harmonic analysis is used to obtain the semidiurnal and diurnal constituents of tide and tidal current. Two functional relationships between tide and tidal current were obtained in order to predict the two constituents of current from the known values of tide and constant lags between tide and tidal current.

## HYDRAULICS & FLUID MECHANICS

### 2168 WAVE IMPACT

- a) Ping Ho Chen (Supervisor: Dr. N.L. Ackermann)
- b) Graduate student thesis project
- c) Completed
- d) The impact pressures produced by waves breaking upon a structure were studied by simulating this phenomenon with a plate striking a water surface. The effect of air entrainment was studied by changing the ambient pressure in the tank in which the experimental studies were conducted. The virtual mass coefficients, as described by Bagnold's theory of this impact phenomenon, were found to be a function of the ambient air pressure. This would indicate that the amount of air trapped between a breaking wave and the structure would affect the impact pressures produced by the wave. These results have implications for improving the design of coastal breakwaters.
- e) Thesis No. 530, AIT, 1973.

### 2169 WIND WAVES IN A FLUME

- a) Hok-Leong Chin (Supervisor: Dr. N. Shuto)
- b) Graduate student thesis project
- c) Completed
- d) Wind energy is transmitted to the sea, producing wind waves, drift current and mean surface gradient. Partition of wind energy transmission, however, is not clearly known yet. Experiments were carried out to separate the wind stress into three stresses responsible for these three phenomena. Wind stress was determined from the wind profile. Measurement of the variation of wave energy spectrum gave the stress which developed the wind waves. Velocity profile in the water was measured to determine the stress which produces the drift current, assuming that the molecular viscosity is used in the thin surface layer. Mean surface gradient was also measured. Experimental results show that major part of the wind stress (more than 90%) is used to develop wind waves.
- e) Thesis No. 531, AIT, 1973.

### 2175 WAVE EFFECTS ON BUOYANT PLUME

- a) Huu Ti Le (Supervisor: Dr. N. Shuto)
- b) Graduate student thesis project
- c) Completed
- d) Buoyant plume discharged vertically upward from a point source into the water where waves exist are bent-over and folded by wave motion. As a result, the total length of the plume from the outlet to the free surface becomes longer, and the plume becomes much diluted. The sectional shape of the bent-over plume is not circular but of the "horse shoe" shape. Near its central portion, upward motion is induced giving big entrainment. These effects were investigated both theoretically and experimentally. The dilution rate at the free surface is given, in terms of wave characteristics and initial conditions of the plume, by

$$\frac{\Delta\rho}{\Delta\rho} = \frac{1}{1.274} \frac{1}{a^2} \frac{w_p}{g} \frac{L}{H} \frac{(h)^{-2}}{D_o}$$

in which the entrainment coefficient

$$a = 1.72 F_{ru}^{-3/2} \quad \text{for } 1 < F_{ru} \leq 3$$
$$= 0.33 \quad \text{for } 3 \leq F_{ru} < 10$$

- e) Thesis No. 536, AIT, 1973.
- 2177 EFFECTS OF FREE AND FIXED BOUNDARIES ON FORCES INDUCED BY AN OSCILLATORY FLOW
- Eugene Ching Liu (Supervisor: Dr. N. Shuto)
  - Graduate student thesis project
  - Completed
  - When a sphere is oscillating in the water, two forces, drag and inertia, act on the sphere. Major cause of the drag force is the form drag, if the sphere is placed deep enough below the free surface not to produce waves there. Approaching the free surface, the wave drag is added, and the drag coefficient  $C_D$  is found to change as a function of the depth of submergence of the sphere. Another factor affecting  $C_D$  is the ratio of the maximum velocity of the sphere to the wave velocity. According to this ratio, expressed in terms of Froude number, wave pattern in the neighbourhood of the sphere changes, thus producing change in the magnitude of  $C_D$ .  
Streamlines around a sphere near the fixed boundary are different from those in the unbounded water. This causes the increase of the inertia coefficient. Theoretical value of this effect was found smaller than experimental results.
- e) Thesis No. 538, AIT, 1973.
- 2179 EXPERIMENTAL STUDY OF HYDRAULIC JUMP IN AN EXPANDING CHANNEL
- Abdul Samad Qureshi (Supervisor: Dr. Anat Arbhahirama)
  - Graduate student thesis project
  - Completed
  - An experimental study of the hydraulic jumps occurring in various locations of a gradually expanding channel is presented. Equations describing the various characteristics of the expanding channel jump were tested experimentally. Classification of various types of jumps forming in expanding channels was attempted.
- e) Thesis No. 540, AIT, 1973.
- 2180 AIR ENTRAINED VORTEX FLOW
- Sacha Sethaputra (Supervisor: Dr. N.L. Ackermann)
  - Graduate student thesis project
  - Completed
  - The conditions required to produce entrainment of air by vortex flows near a pump intake were investigated. Small quantities of air entering the intake side of a pump can produce large decreases in pumping efficiency. Design criteria presently used to prevent air entraining vortex flows were found not to be adequate. Hydraulic modeling of such flow conditions requires simultaneous duplication of both Reynolds and Froude numbers.
- e) Thesis No. 541, AIT, 1973.
- 2188 STUDY OF MINIMIZING DRAW-DOWN CURVES UPSTREAM OF A WATER-DROP USING VARIOUS TYPES OF CONSTRICTIONS
- Lai-Chen Ou (Supervisor: Professor B.Z. Kinori)
  - Graduate student thesis project
  - Completed
  - The purpose of this research was to eliminate – or at least to minimize – the erosion caused by the gradually increasing flow-velocity along the draw-down upstream of a water drop. The specific energy line was raised, just at the edge of the drop, to the elevation of the energy level at normal flow, by using 5 different types of constrictions. The effect of these constrictions was studied, regarding the velocity and its distribution on the upstream side. The choice of the best type for various discharges was recommended together with recommendations for further research.

- e) Thesis No. 570, AIT, 1973.

**2189 OPERATING PROCEDURE FOR RESERVOIR TO OPTIMIZE POWER PRODUCTION**

- a) Reazuddin Ahmed (Supervisor: Dr. Norbert L. Ackermann)  
b) Graduate student thesis project  
c) Completed

- d) The purpose of this study was to determine an operating procedure to optimize benefit from power production by using the method of linear programming. Non-linear economic return from power was linearized by piece-wise linearization.

The power generating function was written as

$$P(t) = K[Q_a H_a + Q_a h(t) + H_a q(t) + q(t)h(t)]; K = \text{constant}$$

where  $Q_a$  and  $H_a$  were average values and  $q(t)$  and  $h(t)$  were fluctuating values of discharge and reservoir head respectively. The assumption was made that the relative value of the fourth term on the right hand side of the above equation is small and was eliminated. The resulting equation is linear and was used for the LP solution.

The error term  $Kq(t)h(t)$  was brought within few percent of the total value of power produced by varying average reservoir head  $H_a$  and the optimum solution was obtained. The operating procedure was based on this optimum solution.

- e) Thesis No. 644, AIT, 1974.

**2194 LOSSES IN JUNCTION BOXES OF STORM DRAINS**

- a) Hwa-Nin Lee (Supervisor: Dr. Subin Pinkayan)  
b) Graduate student thesis project  
c) Completed

- d) This is a study of the hydraulic power losses in junction boxes of storm drains, emphasizing the effect of the lateral spacing. The investigation was done in the laboratory.

The experimental model of the study had the same configurations as that of Lorah, a previous investigator, who studied the power losses in a single junction box.

The investigation was confined to the steady, uniform, subcritical, combining flow of clean water. The angle of intersection between the lateral and the main conduit was 90 degrees. Two positions of inlet condition of the lateral flow into the junction box were tested, i.e. the upper inlet and the lower inlet. There were three junction boxes in the model system. The spacings of the junction boxes were changed from 1 meter to 2 meters, 4 meters, 6 meters, and 8 meters. The rates of the lateral flow into each junction box were kept the same.

The effect of the spacing of lateral inflow on the power losses in junction boxes is identical. The results of the investigation were expressed in terms of some dimensionless power loss parameters and were presented in the forms of graphical relations with respect to those parameters as well as in the forms of functional relations.

The results of the investigation were compared with the results obtained by Lorah. The agreements were reasonably close.

- e) Thesis No. 649, AIT, 1974.

**2207 HYDRAULIC MODELING AT DISCHARGE STRUCTURES**

- a) Chun-Yu Tsai (Supervisor: Dr. Norbert L. Ackermann)  
b) Graduate student thesis project  
c) Completed

- d) The behaviour of flow in the vicinity of a sluice gate placed downstream of a straight rectangular channel has been found to exhibit complex secondary currents. A wave front extending across the channel was found to exist upstream from the sluice gate.

In the present investigation, laboratory model tests have been performed to analyse these phenomena and to locate the position of this wave front from the gate.

Several experimental runs for different discharges, amounts of gate opening and channel slopes were conducted in a 40-foot long, 1-foot wide tilting flume. A plot of the elevation of water surface showed that in each case the locations of the wave front observed from the experiment and computed from a simple mathematical model are very close.

- e) Thesis No. 663, AIT, 1974.

- 2210 **USE OF INVERTED FILTER FOR AVOIDING TAIL EROSION AT THE DOWN-STREAM END OF VERTICAL DROP STRUCTURE**
- a) Ramani Kumar Barman (Supervisor: Professor B.Z. Kinori)
  - b) Graduate student thesis project
  - c) Completed
  - d) Water falling over a vertical drop structure, has excess of kinetic energy. As a result, a scour hole is developed behind the structure itself. A common method of dealing with this problem is to construct concrete apron or stilling basins behind the structure.  
If sand and stone of suitable size and quality are available near a construction site, a scour hole excavated to a calculated depth and covered with inverted filter would provide the same safety as concrete structure, with much lower expense.  
Model tests, using inverted filter as a protective measure against scouring, had been carried out in a model channel of 6 m long, 0.3 m wide and 1.0 m deep and the results of the experiments suggest the suitability of this method as a substitute for concrete structures.
  - e) Thesis No. 667, AIT, 1974.
- 2211 **EFFECTS OF FREE SURFACE ON CHARACTERISTICS OF FINITE UNIFORM FLOW FIELD PASSING A SUBMERGED AND PARTIALLY SUBMERGED CYLINDER**
- a) Pongsakdi Sermatanasvusdi (Supervisor: Dr. Anat Arbhahirama)
  - b) Graduate student thesis project
  - c) Completed
  - d) Characteristics of the finite uniform flow field passing submerged and partially submerged bodies were experimentally investigated. The characteristics under consideration were pressure drag coefficient, pressure distribution around the cylinder, free surface profile in vicinity above the cylinder. The Reynolds number was kept to be sufficiently high,  $4.8 \times 10^4 - 1.5 \times 10^5$  so that the friction drag was small in comparison with pressure and wave drags. The results showed how free surface effects influence the characteristics of the flow for various submergences and Froude number, which was kept to be in the range of 0.2 to 0.5
  - e) Thesis No. 673, AIT, 1974.
- 2212 **PREVENTION OF PIPING AT BOTTOM CORNERS OF A TRAPEZOIDAL DRAINAGE DITCH**
- a) Devindar Singh (Supervisor: Prof. B.Z. Kinori)
  - b) Graduate student thesis project
  - c) Completed
  - d) The problem of high exit gradient that causes piping at the bottom corners of a trapezoidal drainage ditch was investigated. A drainage system of parallel and equidistant open ditches, situated at the same level in a homogeneous and isotropic soil resting on a horizontal impervious stratum, was considered. A steady state condition whereby infiltration caused by rainfall or irrigation water is equal to the discharge of drain ditches was assumed. A general approach to the solution was theoretically developed. With the help of a conductive sheet electric analogue model, different alternative methods for reducing the exit gradient at the corners were investigated. It was found that two sheetpiles through each corner, one perpendicular to the bottom of the ditch and the other perpendicular to the side of the ditch, give best results. When the angle between a ditch boundary and the sheetpile was more than  $\pi/2$ , the exit gradient at the intersection of sheetpile and ditch boundary approached infinity. On the other hand if the angle is less than  $\pi/2$ , the exit gradient at the corner reduced considerably but increased farther away from the corner.  
A 30 cm length of sheetpiles was found satisfactory. It was observed that provision of sheetpiles had no effect on the water table.
  - e) Thesis No. 674, AIT, 1974.
- 2215 **FLOOD PLAIN MODELLING**
- a) Tawatchai Tingsanchali (Supervisor: Dr. Norbert L. Ackermann)
  - b) Doctoral dissertation
  - c) Completed

- d) When overbank flows in a river spread out over a flood plain, an accurate hydrodynamic description is difficult. An analysis or understanding of overbank flows is important for at least the following reasons:
- i) prediction of effects of extreme floods
  - ii) effects of flood plain modification.
- Two simple models of flood plain are presented and shown to enable flood plain modifications and effects of extreme floods to be determined. The models were checked by comparing them to a flood plain that consisted of channels and ponds that were precisely described. The hydrodynamic description of the flow in this channel and pond system was determined through a mathematical model which can completely describe the river flood plain flow. A portion of this description is described by the hydrodynamics of flow in the main channel. When the river geometry is complicated, assumptions regarding flow conditions have previously been made which neglect some of the dynamic characteristics that are important. A derivation of the complete hydrodynamical relationship, including complications formed by variations in geometry, is developed.
- The simple models were then subjected to the same inputs and their responses were obtained from those simple models.
- e) Dissertation No. D11, AIT, 1974.
- 2216 EFFECTS OF FLOOD CONTROL DIKES ON THE HYDRAULICS OF THE MEKONG RIVER ADJACENT TO AND DOWNSTREAM OF VIENTIANE, LAOS AND NONGKHA I, THAILAND.
- a) Faculty, Division of Water Science and Engineering
  - b) Sponsored research
  - c) Completed
  - d) This is an extension of a previous study (*Research Report No. 21*). Whereas the previous study was concerned with the effects on the hydraulics of the Mekong River of continuous flood protection dikes constructed in close proximity to the river bank, the present study considered a system of smaller dikes located farther inland from the main river channel.
- In the event of the recurrence of the design flood, seven dikes protecting Laos flood plain and dikes protecting the cities of Vientiane and Nongkhai would produce water levels in excess of the 1966 maximum values by approximately 49 and 31 cm at Vientiane and Nongkhai, respectively.
- e) ACKERMANN, N.L., PINKAYAN, Subin, THIMAKORN, Prida, and ARBHABHIRAMA, Anat (1973), Effects of Flood Control on the Hydraulics of the Mekong River Adjacent to and Downstream of Vientiane, Laos and Nongkhai, Thailand, *AIT Research Report No. 30*.
- 2219 FIELD CALIBRATION OF WEIRS USING UNSTEADY FLOW TECHNIQUES
- a) Patricio E. Silvestre (Supervisor: Dr. Norbert L. Ackermann)
  - b) Graduate student thesis project
  - c) Completed
  - d) A theoretical study on the effect of transitory waves on unsteady flow weir calibration was undertaken in an attempt to develop a criteria for the use of unsteady flow or falling head weir calibration.
- The transitory negative waves which occur during the calibration were assumed to be steep-fronted in an effort to simplify the solution. This assumption, however, was found out to give results which are not accurate enough for the establishment of the criteria.
- e) Thesis No. 659, AIT, 1974.
- 2220 PREDICTED WATER LEVELS IN THE MEKONG DOWNSTREAM OF VIENTIANE UNDER CONDITIONS OF FULL CONFINEMENT OF FLOOD FLOWS IN MAIN CHANNEL DUE TO DIKING
- a) Faculty, Division of Water Resources Engineering
  - b) Sponsored research
  - c) Completed

- d) The study made use of the mathematical models developed in AIT Research Reports Nos. 21 and 30 to predict peak water levels in the Mekong River's reach between Vientiane and Nongkhai in the event of occurrence of a 10-year and a 25-year flood. Full diking systems along both sides of the river were investigated.
- e) No publication.

2221 THRESHOLD VELOCITY AS A FUNCTION OF GRAIN SIZE DISTRIBUTION IN SAND-BED CHANNELS

- a) Mohammad Arshad (Supervisor: Professor B.Z. Kinori)
- b) Graduate student thesis project
- c) Completed
- d) The primary purpose of this study was to investigate the effect of the grain size distribution on threshold velocity. For this purpose a theoretical study was first made and a functional relationship was developed. The three main variables were related as

$$V_t = f(d_{50}, \sigma_g)$$

Here  $V_t$  and  $d_{50}$  are the threshold velocity and the median diameter respectively, whereas  $\sigma_g$  denotes a measure of gradation. This relationship was then studied experimentally. A series of flume runs were conducted, using various sands, natural as well as "synthesised". Multiple regression analysis was performed on the experimental data, to determine the relationship among the dimensionless groups. An equation giving the relationship of the threshold velocity, the measure of gradation, median diameter and the depth of flow is proposed.

- e) Thesis No. 666, AIT, 1974.

2222 DIVISION AND CONTROL OF SEDIMENTS IN BRANCH CHANNELS

- a) Mirbahar Moula Bux (Supervisor: Professor B.Z. Kinori)
- b) Graduate student thesis project
- c) Completed
- d) Diversion from alluvial streams is the oldest and most important problem in hydraulic engineering. The withdrawal of large quantities of sediments by branch channels necessitates the proper design of intake structures of branch channels. The intake structure of a branch channel must be designed to maintain balance in sediment division between the main channel and the branch channel.

The purpose of present study was to study the division of sediments in a branch channel and recommend a suitable control structure, whose function should be to maintain proper division of sediments between branch channel and main channel extension according to flow distribution.

In this study a model was built comprising a main channel and a branch channel with rectangular X-section. The width of branch channel was half the width of main channel. The angle of diversion was kept  $60^\circ$ . The discharge was kept constant in the main channel upstream from junction. The flow regime was subcritical in both main channel and in the branch channel. A natural sand having median diameter 0.47 mm and geometric standard deviation 2.23 mm was used as sediment material. The sand in dry state was introduced throughout whole width of the main channel and moved as bed load in the main channel upstream from channel junction.

It is observed that the sediment ratio in the branch channel is not in proportion of the discharge distribution but it is nearly twice the discharge ratio in branch channel. This indicates high quantity of sediment entry in branch channel. The sediment ratio is found to depend on the bed load concentration in the main channel upstream from junction. For control over large quantities of sediments in branch channel, different control structures were tested. The control structure was simulated by a rectangular plate, placed on the downstream side of the inlet of branch channel, at  $90^\circ$  to main channel wall. The control structure having width 5.0 cm is found to be most effective when it is placed in the main channel at downstream end of branch channel inlet. For this control structure the sediment ratio in branch channel is in proportion of the discharge distribution.

- e) Thesis No. 668, AIT, 1974.

- 2224 **A SYSTEM DYNAMIC SIMULATION MODEL OF THE WATER RESOURCES SECTOR OF THE BICOL RIVER BASIN IN THE PHILIPPINES**
- a) Yolanda Babanto Ladan (Supervisor: Dr. Norbert L. Ackermann)
  - b) Graduate student thesis project
  - c) Completed
  - d) **Built** within the system dynamic simulation concept, this research deals with the formulation and structuring of a water-resource model. Within the context of regional growth, this model constitutes the "software" of the overall water-resource development of the Bicol River Basin.  
 Skilled planning and careful management are essential to attain the level of efficiency in water use which will be required now and in the future. However, these efforts are broader in scope, influenced by economic, social and political considerations as well as basic engineering facts. Planning is a complex operation, subject to both economic, social and physical constraints. A water resource planner, however, cannot shirk the planning task if he wishes to satisfy human needs. Thus, this study will serve as a management tool in sensing the responsive behavioral patterns of the dynamic society.  
 This water-resource model comprises five sectors, namely: river flow, water supply, irrigation, flood control and hydropower sectors. Each is modelled separately and its complementarities and interrelationships are identified and lumped together to form the overall water model. The mathematical and logical relationships are expressed in systems semantics with its correspondence in DYNAMO language.
  - e) Thesis No. 670, AIT, 1974.
- 2232 **DESIGN DEVELOPMENT OF THE PATTANI DAM SPILLWAY, PATTANI RIVER PROJECT**
- a) Faculty, Division of Water Resources Engineering
  - b) Sponsored research
  - c) Completed
  - d) A hydraulic model investigation was made to determine the flow characteristics of the service spillway of the Pattani Dam, Pattani River Project, South of Thailand.  
 The service spillway was planned to discharge the maximum flood of 4,000 CMS and regulate the flow in connection with the reservoir operation regarding the irrigation supply, power generation and flood control.  
 A 1:60 scale model of the spillway, a portion of the dam and the reservoir and a short reach of the Pattani River downstream of the dam was constructed. The spillway discharges corresponding to the critical conditions for the flood stage and normal spillway release were investigated for the development of the spillway geometry, river stabilization and spillway operation. Structural modifications to the proposed spillway design were recommended to obtain the most stable flow conditions in the spillway and its appurtenances. The discharge rating of the spillway as determined from the model was recommended to be used as information pertinent to the spillway operation.
  - e) THIMAKORN, Prida, ARBHABHIRAMA, Anat and CHATURAPITAPOL, Suchart, Design Development of the Pattani Dam Spillway, Pattani River Project (1975), *AIT Research Report No. 49*.
- 2235 **AUTOMATIC AND SEMI-AUTOMATIC STRUCTURES FOR DIVISION OF IRRIGATION WATER INTO IRRIGATION CHANNELS**
- a) Benedicto V. Boiser (Supervisor: Prof. B.Z. Kinori)
  - b) Special study
  - c) Completed
  - d) For every irrigation project it is highly important that the proper quantity of water will be allotted at the proper time to every field. The division of water from one main supply channel to the various irrigation channels is normally carried out by means of weirs, sluice gates or orifices. Ways of controlling the discharge of water into irrigation channels, irrespective of the discharge of the main feeder channel, were studied utilizing devices such floats, counterweights etc.
  - e) Special Study No. 37, AIT, 1974.

**2244 MASS CHANGING OSCILLATION SYSTEM**

- a) Ching Dann Juang (Supervisor: Dr. H. Shi-igai)
- b) Graduate student thesis project
- c) Completed
- d) A new type of mass changing oscillation system was investigated, where the mass is a function of space. Namely, if a mass is oscillated in the water in the vicinity of a boundary, the virtual mass must change with respect to the distance between the mass and the boundary. As a system, a sphere with a leaf spring oscillating in the neighborhood of a wall was chosen, which is considered as a simplified ocean structure system.  
Experimental results showed that the frequency of the oscillation changes with respect to time if there is a wall. The change is greater with increasing proximity to the wall and also, for a given distance from the wall, with a reduction in density. Solutions obtained from numerical and perturbation methods gave a good agreement with the experimental results except in the initial stage of the oscillation. Phase-plane analysis showed that the solution is stable and periodic.
- e) Thesis No. 743, AIT, 1974.

**2258 FLOOD CONTROL AND SALINITY INTRUSION STUDY OF THE BICOL RIVER BASIN**

- a) Faculty, Division of Water Resources Engineering
- b) Sponsored research
- c) In progress
- d) This study is an extension of a previous investigation (*AIT Research Report No. 48*) which had identified flood control measures that can significantly reduce inundation in the flood plain areas of the Bicol Basin. The objective is to provide information, for the Bicol River Basin, on changes in river depths, discharges and salinity which would result from implementing various recommended river basin modifications. These information are required to enable planners to select an economically optimum combination of approaches which will reduce or eliminate flooding, provide a reliable supply of water and to reduce problems of salt water intrusion in the Bicol estuary.

**HYDROLOGY**

**2171 ESTIMATION ERRORS FROM SHORT PERIOD OF PARTIAL FLOOD SERIES**

- a) Chaidhavaj Deeswasmongkol (Supervisor: Dr. Subin Pinkayan)
- b) Graduate student thesis project
- c) Completed
- d) The estimation error of the return period based on frequency analysis using short record of partial flood series is lower than the error obtained by using the annual flood series for the same return period. The relationship between the estimation errors obtained from partial flood series and annual flood series can be related in terms of the return period. For a return period of more than 50 years, the estimation error from partial flood series is about one half that of the annual flood series and increases when the return period decreases. For an allowable estimation error, a shorter period of record is required if using partial flood series than that using annual flood series.
- e) Thesis No. 533, AIT, 1973.

**2173 MAXIMUM FLOOD FLOWS FOR SMALL WATERSHEDS**

- a) Kee An Hong (Supervisor: Professor N.W. Hudson)
- b) Graduate student thesis project
- c) Completed
- d) A theoretical equation was derived for prediction of floods on small agricultural watersheds. The equation is based on the maximum point rainfall intensity with a duration of one hour occurring once in 25 years, the watershed area, and a theoretically based factor  $W$ , expressing the relationship between topography, vegetation, soil texture, length and slope of the main stream on the watershed, and the frequency of rainfall. A nomograph was constructed for determination of  $W$ .

The equation was tested against flood peaks calculated from frequency analysis of streamflow data for eleven watersheds and against 50 flood peaks observed on 28 watersheds in U.S.A.

It was found that the derived equation estimates the same recurrence distribution as does the frequency analysis of streamflow data. As compared to the observed flood frequency the equation was found to give a slightly high, but still satisfactory, estimate. The highest accuracy was found for watersheds smaller than 5.5 square miles.

- e) Thesis No. 534, AIT, 1973.
- 2174 RAINFALL INTENSITY FOR VERY SHORT DURATIONS IN BANGKOK
- a) Tin Ketratanaborvorn (Supervisor: Dr. Subin Pinkayan)
  - b) Graduate student thesis project
  - c) Completed
  - d) This study deals with the problem of estimating rainfall intensities for very short duration in Bangkok. Rainfall intensities for short durations,  $I_s$ , of less than 5 minutes were estimated from longer duration,  $I_l$ , by the relationship,  $I_s = a I_l^b$ , where a and b are empirical constants. The rainfall intensity for a 5 minute duration is used as the base value for estimating rainfall intensities for durations of less than a minute. The Fergusson type of weighing raingage at the Asian Institute of Technology meteorological station was used to obtain data on storm intensity for very short duration ranging from 1 minute to 5 minutes by expanding the time scale. The relationship between rainfall intensity, duration and frequency curves were obtained from the maximum annual rainfall depths for 5 minutes to 24 hours. The rainfall intensities for durations of less than 5 minutes were estimated by the extrapolation of these rainfall intensity-duration-frequency curves. The rainfall intensities for durations of 1 min., 2 min., 3 min., and 4 min. obtained from the extrapolation of the rainfall intensity-duration-frequency curves are lower than the observed rainfall intensity for the same durations.
  - e) Thesis No. 535, AIT, 1973.
- 2178 EFFECT OF SAMPLE SIZES OF DAILY RUNOFF RECORDS ON SERIAL CORRELATION COEFFICIENTS
- a) Kittinaparakawong (Supervisor: Dr. Subin Pinkayan)
  - b) Graduate student thesis project
  - c) Completed
  - d) The purpose of this research is to study the effect of sample size of daily runoff records on serial correlation coefficients. The river flow model is composed of three components, namely, trend, periodic and stochastic component. The trend component was eliminated by adding irrigation diversion to measure flow and thereby obtaining the reconstructed virgin flow. The virgin flow series was then made stationary by removing periodicity from the series after fitting a 365-day period and its significant harmonics. The stationary stochastic series was found to fit well with a linear autoregressive scheme of the third order. It was found that the primary variable is not an essential part of the synthetic stream flow generation. The values of the expected value of the first, second and the third serial correlation coefficient were under estimated when the recorded length was small and their maximum error, based on 50 years of record, is within the limit of  $\pm 1\%$  when the sample length is equal to or greater than 20 years.
  - e) Thesis No. 539, AIT, 1973.
- 2181 NONLINEAR REGRESSION ANALYSIS OF SEDIMENT DISCHARGE, RUNOFF, RAINFALL, AND RAINFALL INTENSITY
- a) Vivat Thammaphornphilas (Supervisor: Dr. Subin Pinkayan)
  - b) Graduate student thesis project
  - c) Completed
  - d) The stepwise multiple regression technique was used in the study to find the relationship between sediment discharge, rainfall characteristics and runoff. The relationship has a nonlinearity contributed by the second degree terms and the cross product terms. The data for this study was obtained from twelve experimental plots at Kog-Ma watershed, Chiangmai, Thailand. Two different types of model, namely the additive function and the multilog function, were tested. The additive function gives better results than the multilog function, since the nonlinearity contributed by the cross product terms in the

additive model made a great improvement. The effect of each variable to the process of soil erosion and its contribution to soil loss were also studied.

- e) Thesis No. 542, AIT, 1973.
- 2187 **AREAL-TIME DISTRIBUTION OF TROPICAL DAILY RAINFALL**
- a) Prasert Patramai (Supervisor: Dr. Subin Pinkayan)
- b) Doctoral dissertation
- c) Completed
- d) This study deals with the areal and time distribution of tropical daily rainfall using a probabilistic approach. Records of daily rainfall over an area in the central part of Thailand were analyzed. The rainy season is divided into three periods and it is assumed that the rainfall characteristics are stationary within each period. The marginal distribution of daily rainfall at a station was found to be a mixed variate Gamma distribution. The conditional distributions of rainfall at a distance from a control station, given the rainfall at the control station, also follow the mixed variate Gamma distribution. The relation of the parameters of the conditional distribution to distance and the given rainfall at the control station were determined to describe the areal distribution of daily rainfall. The degree of dependence of rainfall at two stations decreases as the distance between them increases. The sequences of occurrence and non-occurrence of daily rainfall were assumed to follow the simple Markov chain. The distribution function of total rainfall days was obtained from the distribution function of rainfall in one rainy day. The conditional distribution functions of total rainfall in N day were analyzed and compared with the observed data. It was found that the probability of rainy days to follow a non-rainy day is higher than the probability of rainy days to follow a non-rainy day. It is also found that the probability is higher of having a heavy rainfall in N days if it is given that the preceding day is a rainy day rather than a non-rainy day.
- e) Dissertation No. D6, AIT, 1973.

- 2190 **SYNTHETIC UNIT HYDROGRAPHS FOR REGIONS WITH INADEQUATE HYDROLOGIC DATA**
- a) Tissa H. Illangasekare (Supervisor: Dr. Subin Pinkayan)
- b) Graduate student thesis project
- c) Completed
- d) The applicability of rainfall data collected from the closest rain gauge station to derive unit hydrographs in small watersheds was tested. Average unit hydrographs from thirteen sample watersheds in the range of 18 to 235 square kilometers from Northern, North Eastern, Central and Southern Thailand were derived. Runoff records from forty two typical storms were analyzed. A new approach of deriving unit hydrographs without using rainfall data was tested. After studying the special characteristics of the derived unit hydrographs, a simple four parameter double triangle model was fitted. The hydrograph parameters were expressed in the form

$$P = KP_1^a P_2^b P_3^c P_4^d$$

by four measurable watershed characteristics using multiple regression analysis.

- e) Thesis No. 645, AIT, 1974.
- 2200 **HYDROGRAPH SEPARATION BY COMPUTER**
- a) Leopoldo A. Polintan (Supervisor: Dr. Subin Pinkayan)
- b) Graduate student thesis project
- c) Completed
- d) The method and procedure for the separation of a complex hydrograph into its main components, namely, baseflow or groundwater flow, interflow or subsurface flow and surface flow or overland flow through the IBM 1130 digital computer, was presented. The separation was carried out by means of the use of the composite recession curve which is a composite of all individual recession for a given water year period. The derivation of the composite recession curve through the IBM 1130 digital computer was successful. Occurrence of the maximum amount of groundwater flow directly below the inflection point of the daily mean river discharge hydrograph was predicted by the use of the inter-

relationship of the rate of change in flow among the three types of flow; baseflow, interflow and surface flow. The prediction was done by use of an iteration procedure on the IBM 1130 digital computer.

A mathematical equation for recession was derived and the relationship between a certain type of flow and its rate of change 24 hours later was also derived by the aid of the recession curve with the known recession equation. Also the inter-relationship of the rate of change in flow among the three types of flow was formulated from the composite recession curve.

The separation of the direct runoff hydrograph into interflow and surface flow was treated by similar procedure employed in the separation of the daily mean river discharge hydrograph into baseflow and direct runoff.

The completed separation process into baseflow, interflow and surface flow led to 7 Fortran-IV source programs and 18 different subroutines.

- e) Thesis No. 655, AIT, 1974.

#### 2203 FLOOD DAMAGE EVALUATION OF A RIVER BASIN

- a) Rolando Gozum Roque (Supervisor: Dr. Subin Pinkayan)
- b) Graduate student thesis project
- c) Completed

- d) This study deals with the methodology for a more comprehensive way of evaluating flood damage. Since damage varies according to height of inundation and its duration, the river stage-probability curves of floods of different durations are important tools in understanding the character of flooding of the area considered. Using these curves, the areas inundated by each flood were identified on the map, and the different economic activities in these areas were investigated to estimate the damage.

Flood damage was divided into three categories; agricultural losses, urban losses, and social suffering. Agricultural losses were determined by mainly considering the type of vegetation, the phase of growth, the depth of submergence and the duration of flooding. Urban losses were mainly due to height of inundation. Residential losses, commercial losses, industrial losses, road losses, emergency losses, relief costs, are all types of urban losses. Sampling and statistics considerations and also field investigations are significantly needed in the proper estimate of flood losses especially for the case of urban losses. Social sufferings indicate the people affected by floods; these forms of losses are intangibles.

The construction of a damage-probability curve gave an area bounded by the curve itself which in reality was the mathematical expectation of annual flood damage. To achieve non-dimensionality, every element included in damage axis in the damage-probability curve was divided by the damage occurring at the expected annual average river stage without flood mitigation structures. Thus, modular coefficients of damages were developed. The area under the flood modular coefficient-probability curve is the dimensionless flood damage index.

Considering flood mitigation measures aimed at lowering the river stage, the degree of protection is defined for this purpose as the percent of reduction of the untouched expected annual average river stage. Therefore, for specified flood mitigation structures the residual damage can be obtained by multiplying the damage at expected annual average river stage with control structures to the dimensionless flood damage index. In the hypothetical river basin considered, graphical flood damage models were developed considering different degrees of flood protection. The models show the responses of the flood plain to different degrees of protection. With a given degree of protection, the residual damage, the relieved people and the affected people are all revealed in the models.

- e) Thesis No. 658, AIT, 1974.

#### 2204 OPTIMAL RESERVOIR OPERATION RULE DERIVED BY PROBABILISTIC APPROACH

- a) Somchat Sottimai (Supervisor: Dr. Subin Pinkayan)
- b) Graduate student thesis project
- c) Completed

- d) This study is to find the reservoir operation rule of Bhumibol reservoir, month by month throughout the year. This operation rule is shown in the form of the discharge at any reservoir elevation in the given month. To find the discharges, the constraints of multi-purposes are used.

Based on the assumption that the inflow of each calendar month has its own probabili-

ty distribution, the dynamic programming technique is used to optimize all benefit functions. One hundred years of generated data of monthly rainfall and runoff are used in this study.

The simulation of the reservoir operation is done by using the derived operation rules and the generated hydrologic time series. The monthly reservoir elevations from the simulation are classified for each calendar month to be a frequency distribution. The probability density functions of 'log-normal' type are fitted to the distribution of monthly elevation.

- e) Thesis No. 660, AIT, 1974.

2206 RELATIONSHIP BETWEEN POINT AND AREAL MEAN RAINFALL IN SMALL CATCHMENT AREA

- a) Uldarico H. Trawon (Supervisor: Dr. Subin Pinkayan)  
 b) Graduate student thesis project  
 c) Completed  
 d) Storm data collected on Bangkok raingage network having an area of approximately 300 sq.km. have been used to determine the areal representativeness of point rainfall measurements.

Rainfalls of 5-min., 10-min., 30-min., 1-hr., 2-hr., 6-hr., and 24-hr. duration were read at the autographic stations. Respective short duration rainfalls at the nonautographic stations were interpolated from the ratios of the short duration to daily rainfall records at the autographic stations, weighted by the "Reciprocal-Distance Method". Areal mean rainfall for each short duration were calculated by computer, based on the concept used in finite element analysis techniques. Per cent of areal mean to point rainfall, measured at the station nearest to the center of mass of the fallen precipitation was then determined for each short duration on areas of various sizes. Empirical relation for per cent of areal mean to point rainfall was developed from a model of the form

$$\log(\text{per cent}) = a + b \log(\text{area}).$$

Throughout the study, efforts have been made to analyze from the standpoint of practicality. Results of the study are considered representative of other areas having similar climatic conditions and topography.

- e) Thesis No. 662, AIT, 1974.

2217 APPLICATIONS OF STOCHASTIC METHODS IN HYDROLOGY

- a) Dr. Subin Pinkayan  
 b) Faculty research  
 c) In progress  
 d) The purpose of this research is to apply research results on stochastic hydrology to practical problems. This also includes the study of regional problems on inadequate data and data subject to errors.  
 e) (i) PINKAYAN, Subin (1972), State of the Research of Application of Stochastic Methods in Hydrology in Thailand, Prepared for the *Int. Ass. Hydrol. Sci. Working Group Stochastic Methods in Hydrology*.  
 (ii) PINKAYAN, Subin (1972), Effect of Length of Records of Monthly Flows on the First Serial Correlation Coefficient, *Int. Symp. Uncertainties in Hydrol. and Water Resources Systems*, Tucson, Arizona, U.S.A.  
 (iii) JARASWATHANA, Damrong and PINKAYAN, Subin (1973), Practice of Design Flood Frequency for Small Watersheds in Thailand, *Int. Symp. Design of Water Resources Project with Inadequate Data*, Madrid, Spain.

2218 HYDROLOGIC STUDY OF THE THUNG MA HIU PROJECT, UBOL RAJATHANI, THAILAND

- a) Dr. Subin Pinkayan  
 b) Sponsored research  
 c) Completed  
 d) This hydrologic study deals with the problem of ungaged watersheds. The problems of

hydrology drainage and flood control improvement in the project area were solved by interpolation and extrapolation of the hydrologic data from the nearby watersheds. These include the determination of synthetic monthly streamflows, design floods and inundated areas.

- e) PINKAYAN, Subin and SAHAGUN, V.A. (1973) Hydrologic Study of the Thung Ma Hiu Project, *AIT Research Report No. 42.*

2223 APPLICATION OF RESERVOIR OPERATION WITH STOCHASTIC INFLOWS

- a) Mohammed Monayem Huq (Supervisor: Dr. Subin Pinkayan)
- b) Graduate student thesis project
- c) Completed

- d) The purpose of this study was to find out the best schedule for filling a reservoir in order to meet the requirements for irrigation, power, navigation, and salinity control. This reservoir operation to find out the schedule for filling the reservoir was applied to the Quae Yai No. 1 Project, Thailand, to get the maximum benefit from irrigation and power.

Based on the assumption that the inflow in each calendar month has its own probability distribution, the simulation technique was used to find out the best schedule for filling the reservoir. Simulation of the reservoir operation was carried out for a ten-year period during the time of filling. Fifty such sets of reservoir operation study were carried out by using fifty sets of different ten-year generated data of monthly runoff. Frequency distributions of the annual average values of total time required to fill the reservoir completely, total time to successfully fulfill the downstream requirements, total quantity of water delivered for downstream requirements, net benefit from irrigation, total benefit from irrigation and power, and present worth value of total benefit were drawn for the linear growth of irrigation target output by 5, 10, 15 and 20 years respectively. All the elements for which frequency distributions were drawn were found to be more when the time of linear growth of irrigation target output was less. So it was found that maximum benefit would occur when the linear growth of irrigation target output was 5 years.

- e) Thesis No. 669, AIT, 1974.

2225 EFFECT OF LENGTH OF STREAMFLOW RECORD ON WATER RESOURCES PLANNING

- a) Le Ngo Huu Thien Tam (Supervisor: Dr. Norbert L. Ackermann and Dr. M. Okamoto)
- b) Graduate student thesis project
- c) Completed

- d) A planning decision made on the basis of sample information is, in general, not optimal for the population from which the sample is drawn. The resulting loss in net benefits due to imperfect information is a function of sample size. The present research is mainly involved with the analysis of sampling errors as a result of limited length of record. This objective is attained in a pragmatic fashion by analysing the historical streamflows of a river having a good period of record and comparing the result with those obtained when it is assumed that only a part of the historical record was available. The problem is solved by using simulation techniques. Two models of streamflow generation are also introduced to cope with the problem of inadequate hydrologic data. Their results are compared with the historical streamflows on the basis of their statistical characteristics to determine the limitation of application.

- e) Thesis No. 671, AIT, 1974.

2229 HYDROLOGICAL INVESTIGATION FOR THE HETAUDA--NARAYANGARH ROAD PROJECT, NEPAL

- a) Faculty, Division of Water Resources Engineering
- b) Sponsored research
- c) Completed

- d) The Hetauda--Narayangarh road project is an 80 km section of the proposed east--west highway of Nepal. The proposed road passes through rugged hills and plains and crosses river where hydrologic data are scarce. The required design information such as peak runoff and flood hydrographs for each drainage and bridge structure were obtained by regional analysis. The expected water levels at the major bridge sites for several design floods were also computed.

- e) PINKAYAN, Subin, ACKERMANN, N.L., SAHAGUN, V.A., TINGSANCHALI, Tawatchai and ILLANGASEKARE, T.H., Hydrological Investigation for the Hetauda–Narayangarh Road Project, Nepal (1974), *AIT Research Report No. 46.*
- 2231 BICOL RIVER BASIN FLOOD CONTROL INVESTIGATION
- a) Faculty, Division of Water Resources Engineering
- b) Sponsored research
- c) Completed
- d) A mathematical model of the river system in the Bicol basin was developed that enabled the effects of various flood control measures to be investigated. Verification of the accuracy of the model was established by its excellent reproduction of flooding events that occurred in the Bicol basin as a result of typhoon Sening in October 1970. The mathematical model requires inputs of a time series of daily basin rainfall and a continuous record of water surface elevation in San Miguel Bay and Ragay Gulf. Historical data consisting of basin rainfall and characteristics of storms enabled the model inputs to be determined which are believed to represent events having 13 and 50 year return periods. The effectiveness of the various flood control measures were studied with regard to their ability to mitigate basin flooding in the event of these storms. Of the individual flood control measures investigated the most effective along the Bicol River was the Bicol–Ragay Diversion, while the Sipocot–San Miguel Diversion effected the greatest reduction of flood levels along the Sipocot River.
- At locations of their maximum effectiveness, these flood control measures reduced flood levels by as much as approximately 1 meter.
- e) ACKERMANN, N.L., PINKAYAN, Subin, SHI–IGAI, H., TINGSANCHALI, Tawatchai and SAHAGUN, V.A., Bicol River Basin Flood Control Investigation (1975), *AIT Research Report No. 48. Vols. I and II.*

## IRRIGATION & DRAINAGE

- 2166 AN INVESTIGATION OF DROP SIZE DISTRIBUTION OF RAINFALL IN THAILAND
- a) Promode Chandra Baruah (Supervisor: Mr N.W. Hudson)
- b) Graduate student thesis project
- c) Completed
- d) An investigation of the drop size distribution of rainfall at various intensities was made by the flour pelleting technique. Using a machine, especially designed for automatic rain sampling near the ground at any pre-determined intensity, samples at intensities varying from 1 in/hr to 5 in/hr were taken for analysis. Any variation in intensity during the sampling period was recorded on a specially designed rain-intensity switch.
- It was found that the modal value of drop diameter increases with increasing intensity up to a value in the interval 2.5 in/hr 3.5 in/hr, after which it starts to decrease. Similarly, the median volume drop diameter increases with increasing intensity up to approximately 4 in/hr, after which the trend is reversed.
- e) Thesis No. 528, AIT, 1973.
- 2170 AN INVESTIGATION OF FRICTION LOSSES IN SPRINKLER IRRIGATION EQUIPMENT AND THE EFFECT OF LOSSES ON SYSTEM DESIGN
- a) Abdul Hafeez Qaiser Choudry (Supervisor: Professor B.Z. Kinori)
- b) Graduate student thesis project
- c) Completed
- d) The purpose of this research was to study the distribution of the discharges and the head-losses in sprinklers located in equal distances along an irrigation lateral pipe. Though the problem was studied in the past by other researchers, the head-losses caused by joints and other fittings were not considered. The present research intended to find a solution, both for the discharges as well as the hydraulic head, considering all the losses, longitudinal and local ones as well.
- e) Thesis No. 544, AIT, 1973.

- 2183 A STUDY OF THE ERODIBILITY OF SOME TROPICAL SOIL**
- a) Muhammad Rafiq Choudry (Supervisors: Mr N.W. Hudson and Mr L. Petersen)
  - b) Graduate student thesis project
  - c) Completed
  - d) The validity of the equation given by WISHMETER, JOHNSON and CROSS (J. Soil Water Conservation 26 (1971): 189-192) for prediction of the erodibility of a soil from its particle size distribution, organic matter content, permeability and structure was tested for 10 soils from Thailand and Malaysia. Air-dried, disturbed soil samples were placed in iron containers and subjected to simulated rainstorms of fixed intensity from a rainfall simulator. The amount of soil washed off the pans was compared with the calculated erodibility. No close relationship was found between the two variables. It was best described by an exponential equation but deviations were considerable. The relationship was improved by changing the particle size fractions employed in the equation mentioned above. The erodibility was found to decrease with increasing sand content and increase with increasing silt content. There was an indication that the erodibility of latosolic soils was considerably lower than that of other soils with similar particle size distribution and organic matter content.
  - e) Thesis No. 568, AIT, 1973.
- 2185 RECLAIMING SODIC SOILS BY HIGH-SALT-WATER DILUTION METHOD**
- a) Ramchand N. Oad (Supervisors: Mr N.W. Hudson and Mr L. Petersen)
  - b) Graduate student thesis project
  - c) Completed
  - d) The possibility of reclaiming alkali soils by leaching with successive dilutions of salt solutions (sea-water) was investigated. Portions of a strongly saline soil having 32% exchangeable sodium were placed in especially designed PVC-cylinders and leached with different solutions and their dilutions. The ratio of sodium concentration to the concentration of divalent ions remained constant in all leaching solutions. The divalent cations were calcium alone, magnesium alone, or a mixture of both in the ratio found in sea-water. Control leachings were made with a solution saturated with gypsum, and with distilled water. A reduction in exchangeable sodium percentage to approximately 10 was obtained in all the columns leached with the salt solutions, while a substantially smaller reduction in exchangeable sodium percentage was obtained by leaching with the saturated gypsum solution for a comparable period of time. It was found that the cation exchange taking place during each leaching could be satisfactorily predicted from the equation given in Agriculture Handbook No. 60, USDA. The hydraulic conductivity as estimated from the rate of liquid flow through the soil columns was found to depend on the total salt concentration of the leaching solutions, the exchangeable sodium percentage and the dilution rate. Some, partly unexplained, differences were observed between solutions containing different kinds and proportions of the divalent cations.
  - e) Thesis No. 527, AIT, 1973.
- 2186 MATHEMATICAL MODEL OF AN IRRIGATION CANAL SYSTEM**
- a) Sandat Richiravanich (Supervisor: Dr. Anat Arbhabhirama)
  - b) Graduate student thesis project
  - c) Completed
  - d) A simulation approach using formulated mathematical models to determine the hydraulic characteristics of the main distribution system of an irrigation canal was introduced to regulate the control structures of the system. The system is composed of a conveyance canal which is divided into reaches by several control structures. Discharges and water levels in the canal are controlled by a system of canal regulators. The system was simulated by calibrating the roughness coefficients of the reaches and the system discharge coefficient using the water surface profiles observed during steady conditions. The system discharge coefficients were shown as functions of the reach characteristics and the ratio between height of gate opening and head approaching the control structure. The roughness coefficients and the corresponding relationships of system discharge coefficient were used to determine the gate openings and to predict the water levels at various stations along the canal for a given discharge through each regulator and the retention levels upstream of the regulators.
  - e) Thesis No. 571, AIT, 1973.

2196 **ECONOMICAL DESIGN OF CHANNELS WITH SPATIALLY INCREASING DISCHARGE**

- a) Ying-Chun Lee (Supervisor: Professor B.Z. Kinori)
- b) Graduate student thesis project
- c) Completed
- d) The former studies of solving the water profile of a channel with spatially increasing discharge are based on the conditions that the channel cross-section and bed slope are given and prismatic. Instead of a given prismatic channel, some of the prescribed flow restrictions, such as constant ratio of bottom width and water depth, constant water surface slope, constant tractive force, constant mean velocity, etc., are involved to solve the momentum flow equation in order to find a more economical channel size for every section.
- e) Thesis No. 651, AIT, 1974.

2197 **THE DESIGN OF IRRIGATION BORDERS WITH UNIFORM WETTING OF THE ROOTING ZONE**

- a) Arturo Alejos Mactal (Supervisor: Professor B. Z. Kinori)
- b) Graduate student thesis project
- c) Completed
- d) A mathematical model to achieve uniformity of wetting the root zone during border irrigation was derived. The theory of the model which is called reduction irrigation provides a manner in which the inflow of water in the border must be reduced so as to keep the deep percolation losses at the head of the border to the minimum and runoff losses at the tail end minimum, if not completely eliminated.  
Experimental tests of the theory yield satisfactory results for the conditions studied, specifically for a soil which is described by infiltration characteristic equation,  
 $Y = 1.49t^{0.70}$ .  
Further laboratory and field tests of the theory derived on different types of soils will be of significant contribution to the knowledge of surface irrigation hydraulics.
- e) Thesis No. 652, AIT, 1974.

2213 **A MATHEMATICAL MODEL OF THE SUPHAN RIVER IRRIGATION SYSTEM**

- a) Chukiat Sapphaisal (Supervisor: Dr. Anat Arbhabhirama)
- b) Graduate student thesis project
- c) Completed
- d) A mathematical simulation technique was developed and applied to determine the hydraulic characteristics of a natural river which is used as a main irrigation distributor limited by several unknown parameters such as cross-sectional area of a river, type of river materials and discharge characteristic of the regulating structure. The simulated hydraulic condition obtained from the study has limited application. It was possible to determine the so-called simulated operation of the canal and the regulators such that the required discharge through the system could be obtained. The predicted water level at control reach was found to be within the acceptable accuracy when checked with existing record of similar operation.
- e) Thesis No. 675, AIT, 1974.

**POROUS MEDIA**

2167 **EFFECT OF PORE SIZE DISTRIBUTION INDEX ON PERMEABILITY**

- a) Ching-Chung Chen (Supervisor: Dr. Anat Arbhabhirama)
- b) Graduate student thesis project
- c) Completed
- d) The investigation considered a coefficient describing the pore size distribution of a medium and its effect on permeability. An equation was developed relating the permeability with porosity, characteristic grain size diameter and a constant which is a function of the pore size distribution index of the medium. Experiments were conducted to determine the functional relationship of the constant and the pore size distribution index.

- e) Thesis No. 529, AIT, 1973.
- 2172 **EXPERIMENTAL STUDY OF FRICTION FACTOR AND REYNOLDS NUMBER IN POROUS MEDIA**
- a) Ashim Das Gupta (Supervisor: Dr. Anat Arbhabhirama)
- b) Graduate student thesis project
- c) Completed
- d) Flow characteristics of water through porous media of wide ranges of grain sizes were studied experimentally. The relationship between friction factor and Reynolds number for uniform porous media developed by a previous investigator was verified with experimental data. This relationship for uniform porous media was presented with a third parameter equal to the ratio of particle mean diameter to the square root for permeability representing the roughness coefficient of the porous medium.
- A limited study was conducted with non-uniform porous media. Three non-uniform media of 0.5 and one non-uniform medium of 1.0 coefficient of variance of grain diameter was used. It was observed that for the same coefficient of variance of grain diameter different porous media had different relationships between the friction factor and Reynolds number.
- e) Thesis No. 532, AIT, 1973.
- 2182 **CHARACTERISTICS OF FLOW THROUGH POROUS MEDIA ABOVE AN INCLINED IMPERVIOUS BOUNDARY**
- a) Thai Weiengding (Supervisor: Dr. Anat Arbhabhirama)
- b) Graduate student thesis project
- c) Completed
- d) The purpose of this research is to present a theory which describes how partially saturated flow will affect saturated flow through two different portions of porous media above an inclined impervious boundary. In this study Pavlovsky's and Childs' solutions for the free surface profile and the quantity of flow were compared with a solution taking into account partially saturated flow above the free surface. The comparison of the solutions was made for three different cases: (1) an aquifer which is so thick that it can be considered to have infinite thickness; (2) an aquifer whose thickness is treated as finite with uniform flow in the upstream medium only and constant water depth at the bottom end of the downstream medium; (3) an aquifer whose thickness is treated as finite, with uniform flow in both media.
- A generalized computer program was developed, based on the method of successive approximations, for the three cases.
- The results of this study indicated that if the flow in the region above the water table is neglected considerable error may be involved in predicting the quantity of flow and the free surface profile.
- e) Thesis No. 543, AIT, 1973.
- 2193 **EXPERIMENTAL STUDY OF TURBULENT FLOW THROUGH POROUS MEDIA**
- a) Fukiat Jongfeungprinya (Supervisor: Dr. Anat Arbhabhirama)
- b) Graduate student thesis project
- c) Completed
- d) Research was undertaken into flow characteristics of water through non-uniform media, of wide ranges of coefficient of variance of grain diameter. Experiments were conducted to obtain the friction factor and Reynolds number relationship. The investigation of the twenty-four non-uniform porous media of various coefficients of variance of grain diameter led to the conclusion that empirical relationship  $f_k = 1/R_k + C$  can fit for different porous media having differences of variance of grain diameter. However, the value of roughness coefficient and coefficient of variance of grain diameter could not give a sufficiently strong correlation with the porous media constant. For the same roughness coefficient, the porous media constant in non-uniform media was higher than in uniform media, and it was shown that the turbulent flow in non-uniform media would occur more rapidly than in uniform media.
- e) Thesis No. 648, AIT, 1974.

- 2201 **THE EFFECT OF KINDS AND PROPORTIONS OF ADSORBED CATIONS ON THE HYDRAULIC CONDUCTIVITY OF SOIL**
- a) Mohammad Asghar Rana (Supervisor: Mr J.L. Petersen)
  - b) Graduate student thesis project
  - c) Completed
  - d) The research was conducted to see the effect of kinds and proportions of adsorbed cations on the hydraulic conductivity of soil.  
Seventeen soil columns were prepared in the laboratory by leaching with laboratory prepared salt solutions of electrolyte concentration of 300 meq/lit. The salt solutions were made from chlorides of calcium and magnesium in different ratios. After soil preparation the leaching was conducted with salt solutions containing 5 meq/lit to find the hydraulic conductivity of these soil columns.  
Experimental results indicate that calcium improves the soil hydraulic conductivity by improving aggregation. Adsorbed sodium has great detrimental effect on the soil hydraulic conductivity. The effect of magnesium alone is between sodium and calcium, closer to calcium than to sodium results. Adsorbed magnesium has detrimental effect on the soil hydraulic conductivity in the presence of sodium. It has been found that in the presence of 11 to 14% adsorbed sodium in four soil columns, the hydraulic conductivity decreases linearly with the increasing percentage of adsorbed magnesium.
  - e) Thesis No. 656, AIT, 1974.
- 2202 **HYDRAULIC CONDUCTIVITY OF RICE SOILS**
- a) Muhammad Rashid (Supervisor: Mr J.L. Petersen)
  - b) Graduate student thesis project
  - c) Completed
  - d) Two different soils, a loam and a silty clay, from the plains of Thailand were studied to investigate the effect of puddling on the hydraulic conductivity and related soil parameters.  
Results showed a drastic decrease in the hydraulic conductivity of plow layer (0–15 cm), a smaller decrease in the second layer (15–45 cm) and little change in the third layer (45–75 cm) of both soils.  
Among the soil parameters studied, aggregate stability index showed a decrease consistent with that in hydraulic conductivity due to puddling. A decrease in bulk density and an increase in porosity and void ratio with puddling of plow layer showed that the effect of puddling was not in accordance with the common belief that puddling causes a reduction in the apparent specific volume of soil.
  - e) Thesis No. 657, AIT, 1974.
- 2209 **SOIL MOISTURE CHARACTERISTIC CURVES OF RICE SOILS**
- a) Curban Ali Awan (Supervisor: Mr J.L. Petersen)
  - b) Graduate student thesis project
  - c) Completed
  - d) Two different soils, a loam and a silty clay from the central plain of Thailand, were studied to investigate the effects of puddling on the soil moisture characteristic curves and related soil parameters.  
Results showed a drastic change in the shape of the soil moisture characteristic curves in the plow layer (0–15 cms) with an increase in the total pore volume; and a little change in the second layer (15–45 cms) with a decrease in the total pore volume. There was no effect in the third year (45–75 cms).  
Among the soil parameters, a decrease in the bulk density in the plow layer and an increase in the second layer showed consistency with that in soil moisture characteristic curves due to puddling.  
As regards the parameters of hydraulic properties, an increase in the pore size distribution index and the bubbling pressure was observed in the upper layers (0–45 cms), which showed a decrease in the hydraulic conductivity on puddling.
  - e) Thesis No. 665, AIT, 1974.
- 2226 **SOIL MOISTURE POTENTIALS IN SUBMERGED RICE SOILS**
- a) Naseer Mohammad Qazi (Supervisor: Mr J.L. Petersen)
  - b) Graduate student thesis project

- c) Completed
- d) The soil moisture potentials at depths 15, 30, 45, 60 and 90 centimeters in three submerged rice soils in the Central Plain of Thailand have been recorded during the growing of a dry-season rice crop. Earlier studies have indicated that the soil below the puddled layer may be highly unsaturated and show negative soil water potentials. However, in this study all soils were found to be fully saturated to the depths investigated, and, accordingly, positive potentials were found in all layers throughout the entire period.  
The variation pattern of the hydraulic gradient indicated that a considerable lateral flow occurred in two of the three soils investigated. This complicated flow pattern made a comparison of the hydraulic conductivities of the single soil layers difficult. However, it could be evaluated from some of the measurements that the hydraulic conductivity of the puddled layer was substantially lower than that of the underlying layers. In two of the three soils investigated, a close relationship was found between the soil moisture potential and the volumetric water content. A small increase in the potential caused a large increase in the volumetric water content. This was normally most pronounced for the upper layers.
- e) Thesis No. 672, AIT, 1974.

### THESIS RESEARCH TOPICS FOR 1974-75

1. River siltation due to tin mining
2. Sediment movement of Bassac River
3. Determination of porous media hydraulic properties using unsteady flow
4. Predicting prototype stilling basin revetment from flip bucket impact modelling
5. Analysis and synthesis of the Mekong River monthly flow
6. Prediction of salt water concentration at Chao Phya estuaries
7. Hydraulic model for steady non-uniform flow in straight channel
8. Evapotranspiration due to water hyacinth
9. Interaction of irrigation, power and flood control sector in multi-purpose project
10. The characteristics of wave transformation in Danang bay
11. Long shore sand drift at Chumporn estuary
12. Developing an economic formula or graphs for the design of open channels with or without lining
13. Free surface effects on the drag of circular cylinders in finite uniform flow field
14. Equation for sediment transport in Chao Phya River below Chainat dam
15. Characteristics of flow and sedimentation in Pak Phanang estuary
16. Dynamic characteristics of nine southern rivers of Thailand
17. Synthesis of hydrologic data from independently insufficient information
18. Sediment budgets on a partially sheltered bay subjected to low wave energy in south east Thailand coast
19. Interaction between irrigation and power sectors of multiple purpose project
20. Discharge coefficient of broad crested weir with various degree of side contractions
21. Cyclonic rainfall over tropical area
22. Calibration of hydrodynamic models

## PROJECTS COMPLETED BETWEEN JANUARY 1969 AND JANUARY 1973

(Projects completed prior to January 1969 are found in the Research Summary for January 1973)

No.	Title	Research Worker	Publications
2062	Characteristics of Radial Wall Jet Bounded by Circular Jump	Wei-Chun Wan	Thesis No. 284, 1970
2064	Energy Dissipation in Open Channels by Large Semi-Circular Disk Roughness Elements	Der-Ruenn Charng	Thesis No. 232, 1969
2071	Theoretical Study of Fluctuation Characteristics of Water Tables in Circular and Strip Islands Due to Ocean Tides	Suphat Vongvises-somjai	Thesis No. 233, 1969
2072	The Forces Exerted by Flow Through a Flared Entrance of a Submerged Conduit	Yaw-Huei Jiang	Thesis No. 259, 1969
2073	Equilibrium Shapes of Coastline in Plan	Narongsak Vichetpan	Thesis No. 280, 1969
2074	Pattern Forming Forces in Deltas	Catalino del Rosario de la Cruz	Thesis No. 275, 1969
2075	Forces of Submerged Jets on Rigid Rigid Circular Disks	Rodolfo Undan	Thesis No. 265, 1969 <i>J. Hydraul. Div., ASCE</i> 1970, Vol. 96, Hy 11, pp. 2231-2240
2076	Flow of Fresh Water to Drains in a Coastal Aquifer	Hung-Tao Shen	Thesis No. 248, 1969 <i>Proc. 13th Congr., IAHR,</i> 1969, Vol. 4, pp. 67-75
2077	A Tidal Mathematical Model of the Chao Phraya River	Padoong Torranin	Thesis No. 247, 1969 <i>2nd Ann. Comp. Applic. Symp., Bangkok, 1970</i> Tech. Note No. 33
2078	A Study of Class "A" Pan and Piche Evaporation	Eliodoro J. Ravalo	Thesis No. 245, 1969
2079	Surface Disturbances Produced by Flow from Submerged Jets	Suvit Siriyong	Thesis No. 277, 1969 <i>J. Hydraul. Div., ASCE</i> 1969, Hy 7, pp. 937-948
2080	Water Balance in Northern Thailand	Aolad Hossain	Thesis No. 262, 1969
2081	Flood Hydrographs from Small Watersheds	Chumporn Komsartra	Thesis No. 278, 1969
2082	Free Streamline Analysis of a Two-Dimensional Jet	Anat Arbhahirama	<i>J. Hydraul. Div., ASCE</i> 1969, Vol. 95, Hy 4, pp. 1139-1148
2084	Characteristics of Flow Past a Circular Disk Placed Near the End of a Circular Pipe	Teliang Kung	Thesis No. 249, 1969
2085	Effects of the Fluctuation of Water Level in a Reservoir on Seepage Gain or Loss	Sudham Chatvalvong	Thesis No. 270, 1969
2086	Hydraulic Jump within a Gradually Expanding Channel	Alejandro U. Abella	Thesis No. 276, 1969 <i>J. Hydraul. Div., ASCE</i> 1971, Vol. 97, Hy 1, pp. 7831-7842
2087	A Study of the Base Flow Characteristics of the Chao Phraya River	Vatana Meevasana	Thesis No. 283, 1969
2088	Sediment Motion in a Gravity Convected Flow	Syed M. Mansur	Thesis No. 268, 1969
2089	River Bed Degradation	A.T.M. Sadequr Rahman	Thesis No. 266, 1969
2090	Optimization of Benefit from Lam Dom Noi River Development	Chamlong Uchukomol	Thesis No. 334, 1970

No.	Title	Research Worker	Publications
2091	Capillary Tube Theory and the Effect of the Pore-Size Distribution Index for drainage in Porous Media	Macra D. Alfajardo	Thesis No. 279, 1969
2092	Scour Under Offshore Mobile Jack-Up Rig Legs	J.M. Barradell-Smith	Thesis No. 324, 1970
2093	Modified Du Boy's Bed Load Equation with the Emphasis on the Critical Shear Stress	Jaw—John Chang	Thesis No. 312, 1970
2094	Salt Water-Fresh Water Interface During Groundwater Pumping and Equivalent Single Phase Flow System	Yuang-Yan Chang	Thesis No. 311, 1970 <i>J. Hydraul. Div., ASCE</i> 1971, Vol. 97, pp. 223–232
2095	Sewage Disposal into Sea	Zafar Iqbal Chaudry	Thesis No. 310, 1970
2096	Probability Distributions of Short Duration Annual Rain-falls in Thailand	Cengiz Ertuna	Thesis No. 307, 1970 <i>Symp. Results Res. Representative and Exp. Basins,</i> <i>Int. Ass. Scient. Hydrol.,</i> Wellington, 1970, pp. 4.28–4.40
2098	Pore-Size Distribution of a Porous Medium and its Application	Ying-Yeung Ho	Thesis No. 306, 1970
2099	Stochastic Models of Monthly Flows at Bhumiphol Dam	Raziuddin Khaleel	Thesis No. 309, 1970 <i>Proc. Water Resources Symp.,</i> Indian Inst. of Sci., Bangalore, 1971 <i>Proc. Math. Models in Hydrol.,</i> Int. Ass. Scient. Hydrol., Warsaw, 1971, pp. D7–1–D7–12
2100	Turbulent Flow of Gas Through Porous Media	Ah Chiew Kok	Thesis No. 330, 1970
2101	Cooling Water Intake	Han-Kien Nhan	Thesis No. 313, 1970
2102	Effect of Sample Sizes of Monthly Runoff Records on the First-Order Serial Correlation Coefficient	Chalermchai Ratnarak	Thesis No. 333, 1970
2103	Economic Planning for Staged Development in Water Resource Systems	Virgilio A. Sahagun	Thesis No. 335, 1970 <i>Proc. 2nd A. Comp. Applic. Symp.,</i> Bangkok, 1970
2104	Forces on Pipe Entrance	Amnuay Sai-ngern	Thesis No. 326, 1970
2105	Gravitational Convection	Tawatchai Tingsanchali	Thesis No. 336, 1970
2106	Characteristics of the Jet of a Two Dimensional Orifice Past a Rectangular Plate	Tang-huei Wang	Thesis No. 308, 1970
2107	Force from Submerged Jets	Soor Gul Wardak	Thesis No. 320, 1970
2108	Routing of Flows from Peak Load Generation Through River Channel	Surapong Winyawonk	Thesis No. 329, 1970 <i>Proc. Water Resources Symp.,</i> Indian Inst. of Sci., Banga- lore, 1971, pp. B17–1–B17– 19
2110	A Case Study of Distorted River Models	Roberto Moreno Antonio	Thesis No. 372, 1971
2111	Channel Networks	Chien—Kee Chang	Thesis No. 362, 1971
2112	Wind Force on a Body at Water Surface	Huan-Tsong Chang	Thesis No. 370, 1971
2113	Air Entrainment	Ruengsak Chantaraj	Thesis No. 390, 1971
2114	Friction Factor and Reynolds Number Relationship in Flow Through Porous Media	Antonio A. Dinoy	Thesis No. 371, 1971
2114A	Application of Pore-Size Dis-	Zahir Uddin Ahmad	Thesis No. 389, 1971

No.	Title	Research Worker	Publications
	tribution in Partially Saturated Flow Through Porous Media		
2115	Crenulate Shaped Bays	Siew-Koon Ho	Thesis No. 346, 1971
2116	Study on Wave Overtopping	Rong-Chung Hsu	Thesis No. 360, 1971
2117	Accelerated Motion of a Sphere in Water	Teh-Shin Huang	Thesis No. 315, 1971
2118	Areal Distribution of Short Durations Rainfall over Bangkok	Md. Sirajul Islam	Thesis No. 318, 1971
2119	Analysis of Runoff Data Subject to Errors	Md. Nazmul Karim	Thesis No. 347, 1971
2120	Effect of Some Measurable Soil Parameters on Bubbling Pressure	Ton-Tai Lin	Thesis No. 345, 1971
2121	Unsteady Flow Weir Calibration	Thai Huu Nguyen	Thesis No. 391, 1971
2122	Use of Mixing Tube on Marine Sewage Disposal	Mana Patarapanich	Thesis No. 361, 1971
2123	Probability Models of Wet and Dry Days	Prasert Patramai	Thesis No. 392, 1971
2124	Multiple Time Series Analysis of Hydrologic Data	Precha Sekhararidhi	Thesis No. 374, 1971
2126	Extended Study of the Modified Du Boy's Bed Load Equation with the Emphasis on the Critical Shear Stress	Md. Karimul Haque Talukdar	Thesis No. 373, 1971
2127	Three Dimensional Ground Water Flows	Tee Wian	Thesis No. 393, 1971
2134	Wave Force on Submerged Structure	Suphat Vongvises-somjai	Dissertation No. D3, 1972
2135	Storm Surge	R. Silvester	<i>Proc. 12th Conf. Coastal Engng.</i> , Washington, 1970, pp. 1995-2010
2136	Wave Amplification	R. Silvester	<i>Proc. 13th Congr. Int. Ass. Hydraul. Res.</i> 3, 1969, pp. 113-121
2137	Beach Processes	R. Silvester	<i>La Houille Blanche</i> 24, 1969, pp. 615-621
2138	Jet Pumps for Dredging	R. Silvester	<i>Proc. 3rd World Dredging Conf.</i> , Singapore, 1970
2139	Longshore Sediment Transport	R. Silvester	<i>Trans. Inst. Engrs. Aust. CE12</i> , 1970, pp. 63-71 <i>Proc. 12th Conf. Coastal Engng.</i> , Washington, 1970
2140	Coastal Defense	R. Silvester	<i>Proc. Instn. Civil Engrs.</i> 45, 1970, pp. 677-682
2141	Wave Generation	R. Silvester	<i>J. Hydraul. Res.</i> 8, 1970, pp. 493-521 <i>Proc. Instn. Civ. Engrs.</i> 1971, pp. 259
2143	Modelling of Sediment Motion Offshore	R. Silvester	<i>J. Hydraul. Res.</i> 8, 1970, pp. 229-259
2144	Hydraulic Model Investigation of Sam Lae Pumping Station	Faculty, Division of Water Resources Engineering	Research Report No. 17, 1971
2145	Navigation Channel Improvement of the Mekong River at Keng Kabao	Faculty, Division of Water Resources Engineering	Research Report No. 15, 1971
2146	Effect of Dikes on Flood Flows of the Mekong River Near Vientiane	Faculty, Division of Water Resources Engineering	Research Report No. 21, 1972
2147	Effect of Sample Sizes of Daily Runoff Records on Some Statistics	Rogelio R. Altamera	Thesis No. 452, 1972
2148	Unsteady Weir Flow	Abhu Ahmed Samsul Haque Barbhuiya	Thesis No. 453, 1972

No.	Title	Research Worker	Publications
2149	Impact of Breaking Waves	Chun Chou	Thesis No. 454, 1972
2150	Overland Flow	Shy-Ru Chou	Special Studies Report No. 12, 1972
2151	Effect of Gradation on the Critical Shear Stress	Arsad Hossain	Thesis No. 455, 1972
2152	Diffraction of Waves in a Basin of Nonuniform Depth	Jesada Jiraporn	Thesis No. 456, 1972
2153	The Effect of Wake on Virtual Mass	Erdal Ozhan	Special Studies Report No. 14, 1972
2154	Estimation Errors from Short Period of Flood Record	Peerawat Premchun	Thesis No. 457, 1972
2155	Modeling of Channel Geometry	Md. Fazlur Rahman	Thesis No. 448, 1972
2156	Effect of Concentration on Sediment Motion	Md. Shamsur Rahman	Thesis No. 449, 1972
2157	Prediction of Flood Flow from Rainfall Data by Regression Analysis	Rolando D. San Pedro	Thesis No. 451, 1972
2158	Analysis of 'Black Box' Relation- ship Between Sediment Discharge, Rainfall and Runoff	Prahalad Prabhu Shirahatti	Thesis No. 458, 1972
2159	Wind Profile and Wind Wave Generation	Shu-Sheng Siah	Thesis No. 459, 1972
2161	Application of Linear Model in Natural Channel	Veera Sripunvoraskul	Thesis No. 460, 1972
2162	Mathematical Model of Flood Flows from Small Watersheds	Viraphol Taesombut	Thesis No. 461, 1972
2163	Wave Forces Acting on a Fixed Flat Plate	Yau-Tang Tsay	Thesis No. 450, 1972
2164	Circulation Currents Produced by Air Entrainment	Pairaj Visvakul	Thesis No. 462, 1972
2165	Vortex Formation	Wen-Yue Wang	Thesis No. 463, 1972

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## RESEARCH IN STRUCTURAL ENGINEERING AND MATERIALS

The infrastructure development now taking place in Asia poses a tremendous challenge to structural engineers. This gave rise to more complex structures in concrete and steel being constructed and hence the need to investigate more complicated structures. Rapid population growth and limited resources necessitate proper planning and design, choice of materials and building techniques. Providing adequate housing for an increasing population of which the great majority is in the low-income group is another challenge to structural and materials engineers. The research in the Division of Structural Engineering and Materials is directed towards the solution of some of these problems. The Division also devotes a considerable amount of effort in the utilization of construction materials indigenous in the region.

Both experimental and analytical investigations are carried out in connection with student theses at the Master's and Doctoral levels. The Structural Engineering Laboratory is divided into several specialized areas. The largest of these is the strong floor which covers an area of 521 sq.m. and is provided with anchorage slots spaced 1 m. apart and cluster points with a capacity of 100 tons per cluster. The arrangement provides versatility in the mounting of experiments and full-size members or models of complete structures can be loaded to destruction. Compression and tension machines with capacities ranging from 3 to 300 tons as well as torsion testing apparatus are available. A 100-ton anchorage bed for prestressing of concrete members provides ample capabilities for the study of prestressed concrete structures. Recording instruments are available for the measurements of loads and strains, including a 100-channel data logger. Another floor area of 288 sq.m. is devoted to concrete technology. It has facilities for the testing of cement and the curing of large size concrete specimens, as well as insulated rooms with temperature and humidity control. The structural models laboratory is equipped with, among other standard equipment, a photo-elasticity apparatus. The structural dynamics laboratory is equipped with vibration simulators and dynamic recording instruments. A separate structural materials laboratory is devoted to the study of low-cost construction materials.

The diversity of past and current research work in the Division is reflected in the research summaries on the following pages.

**DIVISION OF STRUCTURAL ENGINEERING AND MATERIALS  
FACULTY AND SENIOR RESEARCH STAFF**

**Chairman : Dr Pisidhi Karasudhi**

**Professor**

***Seng-Lip Lee\**** B.S.C.E., Mapua Institute of Technology; M.S.E., Michigan; Ph.D., California; former Division Chairman until May 1975. (*Structural Engineering and Mechanics*)

**Associate Professors**

***Tongchat Hongladaromp*** B.Eng., Chulalongkorn; M.Eng., SEATO Graduate School of Engineering; Ph.D., Northwestern. (*Structural Engineering*)

***Pisidhi Karasudhi*** B.Eng., Chulalongkorn; M.Eng., SEATO Graduate School of Engineering; Ph.D., Northwestern. (*Structural Engineering and Mechanics*)

***Fumio Nishino*** B.Eng., M.Eng., Tokyo; Ph.D., Lehigh. (*Structural Engineering and Mechanics*)

***Ricardo P. Pama*** B.S.C.E., Mapua Institute of Technology; M.Eng., SEATO Graduate School of Engineering; Ph.D., St Andrews; Associate Chairman of the Division. (*Structural Engineering*)

***David J. Cook*** B.E. (Hons) Western Australia; M.Sc., Ph.D., Calgary. (*Structural Engineering and Materials*)

**Assistant Professors**

***Khus Chiev*** B.S.E.E., M.S., Ph.D., New Mexico State. (*Applied Mathematics*)

***Shosuke Morino*** B.S., M.S., Kyoto University; Ph.D., Lehigh University. (*Structural Engineering*)

***Hirokazu Takemiya*** B.S.C.E., M.S.C.E., D.Eng., Kyoto University. (*Structural Engineering and Mechanics*)

**Associated Faculty**

***Vithool Jearkjirm*** B.Eng., Chulalongkorn; M.S., Ph.D., Purdue. (*Structural Engineering and Construction*)

**Research-Laboratory Supervisor**

***Pichai Nimityongskul*** B.Eng., Chulalongkorn; M.Eng., D.Eng., Asian Institute of Technology.

**Reserach Associate**

***Anant R. Kukreti \**** B.E., Roorkee; M.Eng., AIT.

\* This list includes all faculty and staff holding appointment in the period since January 1973. Those who no longer hold appointment are indicated by an asterisk.

**RESEARCH PROJECTS COMPLETED OR IN PROGRESS SINCE  
JANUARY 1973**

- 4149 **INFLUENCE OF INTERMEDIATE DIAPHRAGMS ON THE LOAD DISTRIBUTION IN BOX GIRDER BRIDGES**
- a) Pichai Nimityongskul (Supervisors: Dr. S.L. Lee and Dr. R.P. Pama)
  - b) Doctoral dissertation
  - c) Completed
  - d) The static behavior of simply supported box girder bridges with or without intermediate diaphragms subjected to concentrated joint loads is investigated. The elements in the box section are treated as rectangular plates subjected to lateral and in-plane boundary forces. The end diaphragms are assumed to be infinitely rigid in and flexible normal to their planes. The intermediate diaphragm is assumed to act in such a way that it exerts only concentrated vertical and horizontal reactions on the joints of the box section without introducing resisting moments against joint rotations. The values of these reactive forces are determined from the conditions that the rigid body displacements of the intermediate diaphragm are compatible with the joint displacements under the simultaneous effect of the applied loads and the reactive forces, and that the reactive forces on the diaphragm are in self equilibrium. Continuous spans over intermediate supports are also treated in a similar manner.

Numerical results for a simply supported double cell box girder bridge subjected to unit loads applied separately at the middle and side joints are initially obtained for the case without intermediate diaphragms. These results are then used as influence coefficients in developing the solutions for cases with one intermediate diaphragm at the midspan and three intermediate diaphragms at the quarter points. Numerical solutions for a two-span continuous box girder bridge with and without intermediate diaphragms are also obtained by setting the rigid body displacements at the joints of the diaphragm at the intermediate support equal to zero.

The displacements, transverse bending moments, normal forces and membrane shear forces for cases without intermediate diaphragms, with one intermediate diaphragm and three intermediate diaphragms due to unit loads applied at different positions along the span are plotted together and compared in order to visualize the influence of the intermediate diaphragms.

The results show that the distortion of the cross section of a box girder without intermediate diaphragm is more prominent when loaded along the side joints. With one intermediate diaphragm, the distortion at the loaded section remains practically the same when the diaphragm is sufficiently far from the applied loads, but is considerably reduced when the diaphragm is located near the loads. The use of intermediate diaphragms decreases effectively this cross sectional distortion throughout the span and the associated transverse bending moments, increases the overall stiffness of the bridge and redistributes the longitudinal normal forces. For the set of parameters investigated, the use of three intermediate diaphragms at quarter spans seems sufficient to practically eliminate the cross sectional distortion even when the loads are applied midway between two diaphragms.

The proposed method of analysis with unit antisymmetrical joint loads is an accurate and efficient means for analysing the behavior of multi-cell box girder bridges with or without intermediate diaphragms and supports. With the availability of computers nowadays, the proposed solution can be readily used to obtain the design of box girder bridges with optimum numbers of intermediate diaphragms.
  - e) (i) Dissertation No. D7, AIT, 1973.  
(ii) NIMITYONGSKUL, P. PAMA, R.P. and LEE, S.L. (1973), Influence of Intermediate Diaphragms on Load Distribution on Box Girder Bridges, *Proc. 4th Australasian Conference on Mechanics of Structures and Materials*, Brisbane, Australia, pp. 208-216.
- 4177 **FORCE AT A POINT IN THE INTERIOR OF A TWO-LAYER ELASTIC HALF SPACE**
- a) Kin-Seng Chan (Supervisors: Dr. S.L. Lee and Dr. Pisidhi Karasudhi)
  - b) Doctoral dissertation
  - c) Completed
  - d) This study formulates, by the technique of integral transforms, the solution of a two-layer

half space subjected to a concentrated force which may act either vertically or horizontally in the interior of the system. Accurate approximations of the reciprocals of the common denominators involved in the solution integrals are suggested in such a way that the latter are in standard closed forms and can be identified by two parts. The first part is the singular part of Mindlin's solution which is singular at the point of application of the force, and the second is non-singular. The solutions for plane problems are also obtained in closed forms by performing appropriate integrations of the solutions for the corresponding three dimensional cases.

Although the proposed solution for the two-layer half space is approximate, it yields, as limiting cases, the exact solutions of Mindlin and Melan as well as of the half space fixed on the surface, the latter a limiting case of Rongvéd's solution.

- e) Dissertation No. D5, AIT, 1973.

4178 **INELASTIC LATERAL STABILITY OF WIDE FLANGE BEAMS UNDER BIAXIAL END MOMENTS**

- a) Chesada Kasemset (Supervisors: Dr. S.L. Lee and Dr. F. Nishino)

- b) Doctoral dissertation

- c) Completed

- d) A consistent one dimensional theory of thin-walled members of open section subjected to the action of axial force, biaxial bending and torsional moments is derived based on a set of simple assumptions and the virtual work principle. The strain-displacement relations are obtained by reducing the three dimensional finite strain-displacement relations in view of the assumptions and subsequently used in the virtual work equation to yield the equilibrium equations and the associated boundary conditions. In view of the strain-displacement relations, the force-displacement relations are obtained by the definition of stress resultants. The latter are linearized and substituted in the equilibrium equations which lead to the governing differential equations in terms of displacements. These non-homogeneous governing equations are derived in terms of general loading functions and reduce, for the homogeneous case when linearized, to those obtained by Timoshenko and, with slight difference, to those derived by Vlasov. The solutions to the nonlinear equations for simple loading conditions are obtained and compared with those obtained from the linearized equations.

In the second phase of the study, a numerical integration scheme is proposed to symmetrical biaxial end moments. Taking advantage of symmetry, the problem is treated as cantilever beams subjected to biaxial end moments at the free end. Instead of dealing with the equilibrium equations derived at the load level which contain the derivatives of the products of stress resultants and displacements, the second order moment equilibrium equations used in the proposed numerical integration scheme involve the products of the stress resultants and the derivatives of the displacements. The latter allow the numerical integration to be carried out without iteration between consecutive stations. The ultimate load carrying capacity of the member is obtained with the aid of an extension of Horne's criterion for in-plane problems. The latter is formulated as a nonlinear programming problem which is transformed by the penalty function method presented by Fiacco and McCormick to an unconstrained maximization problem. The optimizing scheme suggested by Fletcher and Powell is used to obtain the numerical solutions. The solutions for several wide flange sections are obtained and the ultimate moments and corresponding displacements are plotted against an argument,  $\lambda$ , which is a function of length, sectional dimensions and yield stress. The eigen value solutions obtained for beams subjected to in-plane symmetrical end moments are also presented for comparison.

- e) (i) Dissertation No. D8, AIT, 1973

- (ii) KASEMUT, C., NISHINO, F. and LEE, S.L. (1974), Inelastic Stability of Beams under Biaxial Bending, *Proc. ASCE, Journal of Engineering Mechanics Division*, 100, EMS, pp. 965-989.

4179 **INELASTIC STABILITY OF STEEL BUILDING FRAMES**

- a) Chitti Vijakkhana (Supervisors: Dr. S.L. Lee and Dr. F. Nishino)

- b) Doctoral dissertation

- c) Completed

- d) Assuming elastic-perfectly plastic moment-curvature relation, a method for determining the ultimate load of steel frames is proposed. In terms of generalized stress resultant and gen-

eralized strain, i.e., moment stress resultant and curvature, strain reversal is taken into account, i.e., the unloading of plastic hinges is considered. The effect of the axial force on the moment capacity of a section is taken into consideration. The stiffness matrix is so derived that it is applicable to any piecewise elastic regime in the elastic-plastic deformation of a member, the effect of the axial force on the stiffness being taken into account by means of approximate stability function. Delta functions defining the formation as well as the unloading of plastic hinges are employed in the formulation. The numerical computation for the smallest critical load can be rapidly carried out by following the standard matrix procedure for calculating eigenvalues.

Linear extrapolation schemes for predicting the load parameter at which a plastic hinge forms before and beyond the stability limit are used. The method of analysis facilitates the study of not only the stability limit but also those states beyond and remote from this point. The failure of the frame is signified by either the loss of stability due to the formation of plastic hinges and secondary moments caused by axial force acting on the laterally displaced frame members, or by the formation of a beam mechanism. The formation of a sway mechanism coincides with the stability limit unless the latter occurs prior to the former.

It is shown that, provided no unloading of plastic hinges occur, the value of the critical load parameter  $\lambda_c$ , hence the overall stiffness of the frame, is reduced at the formation of each plastic hinge. The overall stiffness of the frame can be effectively increased if the value of  $\lambda_c$  is increased. This enables the designer to effect possible material savings through the revision of the capacity of frame members which are more effective in raising the ultimate load of the frame.

The results of this study show that the proposed method of analysis can be conveniently applied to the practical design of unbraced steel building frames. A design procedure for multi-story frames is presented and demonstrated in detail by means of simple numerical examples. A comparison of the result with that obtained by means of exact stability functions is made and found to be in good agreement. The influence of unloaded plastic hinges on the frame behavior is illustrated. The post-buckling behavior of the frame are traced up to the formation of a sway mechanism.

- e) (i) Dissertation No. D9, AIT, 1973.
- (ii) NISHINO, F., VIJAKKAHANA, Chitti and LEE, S.L. (1974), Stability Considerations in Design of Unbraced Tall Buildings, *Proc. ASCE-IABSE Regional Conference on Tall Buildings*, Bangkok, pp. 163-176.

#### 4180 FURTHER EXPERIMENTAL STUDY OF TAPERED STEEL COLUMNS

- a) Gregoria Santos Garcia (Supervisor: Dr. F. Nishino)
- b) Graduate student thesis project
- c) Completed
- d) This research presents further experimental investigation of tapered steel columns. Tests were performed on six columns of welded box-sections. The primary variables are slenderness ratio, taper slope, and the ratio of the eccentricities at the column ends.  
The larger section of the column is 4" x 4" and the smaller section varies with the taper slope. The columns were fabricated from steel plates, the flanges being cut from 1/2" and the web from 3/16" plates respectively. The effective length of the longest column was 7' - 6 1/2" and the shortest was 6' - 3/16". All columns were tested under simple supports and were loaded up to failure.  
The experimental results were compared with the analytically predicted loads based on the theoretical analysis presented by Lin, Rossow and Lee. Good correlation exists between the experimental and the theoretical analysis.
- e) Thesis No. 546, AIT, 1973.

#### 4181 STIFFNESSES OF INFILLED FRAMES

- a) Dumrong Hormdee (Supervisor: Dr. Tongchat Hongladtomp)
- b) Graduate student thesis project
- c) Completed
- d) The problem of infilled frames subjected to lateral force is investigated by the finite element method. A rectangular element with assumed simple form of displacement is used to formulate the system stiffness matrix. A reinforced concrete frame with brick, mortar and plywood wall panel is studied for the distribution of stresses in the infilled panels and their influences upon the stiffness of the infilled frame. Separation between the frame and the

infilled panel was taken into account in the analysis and it was found that the separation, though it has considerable effect on the stress distribution, has only slight influence upon the stiffness of the infilled frame.

From the study of infilled frame interaction, it was found that the stiffness of infilled frame is far greater than that of the frame or the wall alone, and the results obtained reveal that the use of equivalent diagonal struts may lead to underestimation of infilled frame. Stiffness curves for infilled concrete frame with brick, plywood and mortar wall panel are presented to be used as a guide in estimating stiffnesses of such infilled frame structures.

e) Thesis No. 547, AIT, 1973.

#### 4182 PRECAST WOOD-CONCRETE COMPOSITE BEAMS

a) Ku-I Hsiung (Supervisor: Dr. Pisidhi Karasudhi)

b) Graduate student thesis project

c) Completed

d) The purpose of this research is to study the flexural behavior and load carrying capacity of a precast wood-concrete composite beam with a double T section, with a concrete flange and two Yang wood webs. The flange is bonded to the webs by an epoxy glue. Tests are conducted on three full size simply supported beams subjected to a static third-point loading. The cost and the weight of the composite beams are compared with the ordinary reinforced concrete beams to study the feasibility of formers for residential buildings. It is concluded that the use of the composite beams is feasible from both the engineering and the economic standpoints.

e) Thesis No. 548, AIT, 1973.

#### 4183 STABILITY OF FLEXURE CRACKS IN REINFORCED CONCRETE BEAMS

a) Jiunn-Shyong Juang (Supervisor: Dr. R.P. Pama)

b) Graduate student thesis project

c) Completed

d) This investigation deals with the study of the stability of flexural cracks in singly and doubly-reinforced concrete beams. The analysis is based on assumed stress-strain curves for the concrete and steel. Tests were conducted on six rectangular reinforced concrete beams subjected to two point loads. The span and cross-sectional dimensions of the beams were kept constant. For singly-reinforced beams, the tensile reinforcements were varied and for the doubly-reinforced beams the compression reinforcements were kept constant while the tensile reinforcements were varied. All specimens were tested to destruction. It was observed that the stability of flexural cracks in reinforced concrete beams is a function of the tensile strength of concrete and the amount of tension reinforcement. The influence of compression reinforcement in stabilizing the propagation of cracks is not very significant. The experimental results obtained compared favorably with theoretically predicted values.

e) Thesis No. 549, AIT, 1973.

#### 4184 ANALYSIS AND DESIGN OF CONICAL RICE BINS

a) Worsak Kanoknukulchai (Supervisor: Dr. Pisidhi Karasudhi)

b) Graduate student thesis project

c) Completed

d) The main purpose of this study is to analyse and design a ferro-cement rice bin which consists of two conical shells joined at their outer edges by an ordinary reinforced concrete ring girder. The bottom cone is complete, while the top cone is a conical frustrum. The inner edge of the top cone is stiffened by an ordinary reinforced concrete ring girder which is in turn supporting a circular ferro-cement lid. The ferro-cement is selected for the construction due to its superior crackproof properties and the fact that the materials are available locally.

The bin is subjected to three conditions of loading namely dead load, vertical ring load on the top edge, and water load. Initially, the shell will be treated, under the applied loading, as a membrane. Under such conditions, the statically determinate stress resultants in each cone can be obtained without dependence on their geometric continuities. A consideration is then given to the effects of the statically indeterminate force and couples which must exist at the edges of each cone to preserve the continuity. This can be done by applying the corrective shearing forces and couples in the bending analysis. Finally, by combin-

ing both parts of solution, the total solution of the bin are obtained.

A design example of a bin of a 3.5-ton capacity is presented. It is found that the resultants as a result of the water loading are critical, and they are most severe in the neighborhood of the cone union.

- e) (i) Thesis No. 550, AIT, 1973.
- (ii) KANOKNUKULCHAI, W., KARASUDHI, Pisidhi and LEE, S.L. (1973), Analysis and Design of Conical Rice Bins, *AIT Research Report No. 33*.

**4185 SHEAR DISTORTION IN TORSION OF WIDE FLANGE BEAMS**

- a) Kuang-Tsan Liang (Supervisor: Dr. F. Nishino)
- b) Graduate student thesis project
- c) Completed
- d) The behavior of elastic beams is discussed considering the effect of warping deformation due to the presence of shear distortion. In this study, the elementary torsion theory thin-walled sections in which shear distortion is neglected is modified in such a way that the continuity of warping deformation due to the shear distortion is satisfied. Numerical examples are presented for beams with wide-flange section under simple loading and boundary conditions.
- e) Thesis No. 551, AIT, 1973.

**4186 CONCRETE CANAL LINING WITH FERRO-CEMENT FACINGS**

- a) Hon-Kwong Ng (Supervisor: Dr. S.L. Lee)
- b) Graduate student thesis project
- c) Completed
- d) Concrete canal linings with ferro-cement facings are analysed in the form of isotropic elastic sandwich plates on Winkler type elastic foundation. Based on small deflection theory, a system of differential equations for the bending of the plate is developed by means of a variational theorem. The solutions of the governing differential equations are obtained in terms of Bessel and Hankel functions for the case of a large sandwich plate subjected to a uniformly distributed circular load and a concentrated force. A simple but accurate technique of numerical integration is developed for evaluating the solution functions. The results from parametric studies are presented in the form of graphs for the purpose of analysis and design of such structures and a design example is presented.
- e) (i) Thesis No. 552, AIT, 1973.
- (ii) NG, Hon-Kwong, LEE, S.L. and KARASUDHI, Pisidhi (1973), Concrete Canal Lining with Ferro-Cement Facings, *AIT Research Report No. 34*.

**4187 MECHANICAL PROPERTIES OF CEMENT MORTAR WITH RANDOMLY ORIENTED SHORT STEEL FIBERS**

- a) Bunchu Pakotiprapha (Supervisor: Dr. S.L. Lee)
- b) Graduate student thesis project
- c) Completed
- d) This paper deals with an analytical and experimental investigation of the mechanical properties of cement mortar reinforced with randomly oriented short steel wires. Analytically, the material is treated as a composite and its properties are derived by the laws of mixture. The effect of random orientation of the short wires is taken into consideration by the introduction of dimensionless factors which are derived on the assumption that the geometric centers of the wires are uniformly distributed in space and that any wire has equal probability of being oriented at any angle with the direction of the applied stress. Explicit expressions are given for moduli of elasticity and ultimate strength in tension and compression. In bending and torsion, the composite is idealized as a bi-linear material to describe its behavior in the uncracked and cracked range provided that the volume fraction and length of fibers used exceed certain critical values which are suggested. Experiments were conducted and the results obtained were shown to be in good agreement with theoretically predicted values.
- e) (i) Thesis No. 553, AIT, 1973.
- (ii) PAKOTIPRAPHA, B., PAMA, R.P. and LEE, S.L. (1973), Mechanical Properties of Cement Mortar with Randomly Oriented Short Steel Fibres, *AIT Research Report No. 35*.

4188 **THREE DIMENSIONAL ANALYSIS OF SHEAR WALL-FRAME BUILDINGS**

- a) Pipat Pithayachariyakul (Supervisor: Dr. Tongchat Hongladaromp)
- b) Graduate student thesis project
- c) Completed
- d) A discrete method of three dimensional analysis for multistory buildings under lateral loads is presented. The buildings are considered to consist of stiffening elements which are either frames or shear walls laid in the directions parallel to the axes of the structures. Certain assumptions on the member stiffnesses are made to simplify the problem so that only one joint rotation per floor for each stiffening element is involved. Slope deflection equations are used in the formulation of the equilibrium equations of the stiffening elements in terms of joint rotations and relative lateral deflections. From the equilibrium conditions at the joints, the joint rotations are expressed in terms of relative lateral deflections. The lateral stiffness of each frame or shear wall can then be obtained in terms of the lateral deflections only. Having obtained the lateral stiffnesses of all the elements, the total stiffness of the overall building is then determined by superposition, making use of the three equilibrium conditions at each floor. The latter are solved for the floor translations and floor twisting which subsequently yield the stress resultants in all members.

An example asymmetrical building with known solutions by another method is analysed by the proposed method and the results obtained are found to be in good agreement. Two other buildings are analysed to study the three dimensional behaviors of tall buildings subjected to wind loads. It is found that the exterior frames parallel to the long axis of a long rectangular building normal to the direction of the load have slight effect upon the reduction of the twisting of the building. However, the reduction becomes considerably larger for the case of a highly asymmetrical building square in plan. The results obtained also indicate that, whenever the twisting is small, the shear wall-frame interaction is effective and On the other hand, in case of a highly asymmetrical building where the floor twisting is comparatively large, very little interaction between the shear walls and the frames is evident. In such cases, the two types of stiffening elements act rather independently and hence two-dimensional analysis could lead to erroneous solutions.

- e) (i) Thesis No. 554, AIT, 1973.
- (ii) PITHAYACHARIYAKUL, P. HONGLADAROMP, Tongchat and LEE, S.L. (1974), Three Dimensional Analysis of Shear Wall-Frame Buildings, *Proc. ASCE-IABSE Regional Conference on Tall Buildings*, Bangkok, pp. 353-365.

4189 **ANALYSIS OF CIRCULAR PILE CAPS**

- a) Siripong Sholsiripunlert (Supervisor: Dr R.P. Pama)
- b) Graduate student thesis project
- c) Completed
- d) The research described in this paper is an extension of an earlier work done by BERNARDO (4152). The experimental ultimate loads of reinforced concrete pile caps are compared with those predicted by a simple analysis based on truss analogy. Six specimens, consisting of two half-scale models of rectangular two-pile caps and four quarter scale models consisting of two circular six-pile caps and two circular eight-pile caps were constructed and tested to destruction. Test results indicated that good predictions of the ultimate loads of these pile caps can be obtained by truss analogy. The ultimate loads were found to coincide with the yield point stress of the steel.

- e) Thesis No. 555, AIT, 1973.

4190 **SHEAR LAG IN T-BEAMS**

- a) Anang Pal Singh (Supervisor: Dr F. Nishino)
- b) Graduate student thesis project
- c) Completed
- d) The behavior of elastic simply supported T-beams is discussed considering the effect of warping deformation due to the presence of shear deformation. The Navier-Bernoulli hypothesis assumes that plane sections normal to the neutral axis before deformation remain plane after deformation. The elementary beam theory is modified in such a way that the continuity of warping deformation due to the shear strain is satisfied.

Numerical examples are presented for simply supported T-beams under uniformly distributed load and under a patch load spread over a fairly small length at the mid-span.

- e) Thesis No. 556, AIT, 1973.

- 4191 **RESPONSE SPECTRA OF STRAIN HARDENING STRUCTURAL SYSTEMS TO EARTHQUAKE MOTIONS**
- a) David Srimahachota (Supervisor: Dr. Tongchat Hongladaromp)
  - b) Graduate student thesis project
  - c) Completed
  - d) The influence of strain hardening on the response of structures to earthquake motions is investigated by treating a single degree of freedom system. An idealized bilinear resisting force-displacement relation for a shear frame derived from an idealized elastic-strain hardening moment-curvature relation is used in the analysis. Response spectra for El Centro earthquake, May 1940, are generated for various values of strain hardening coefficient and ductility factor. The linear acceleration method is used for numerical integration of the equation of motion.  
The results reveal that the inelastic behavior effectively reduces the response, for the case of no damping, in a similar manner as the effect of damping on the response of the elastic system. The optimum response spectra, the optimum values of the yield displacements at which the corresponding maximum displacement responses are minimum, are also studied.
  - e)
    - (i) Thesis No. 557, AIT, 1973.
    - (ii) HONGLADAROMP, T., SRIMAHACHOTA, David and LEE, S.L. (1973), Response Spectra of Strain Hardening Structural Systems to Earthquake Motions, *Presented at the ASME/DED 4th National Conference on Mechanical Vibration*, Cincinnati, Ohio, 1973.
    - (iii) *Journal of Engineering for Industries*, Transaction ASME, Series B (in press).
- 4192 **FURTHER INVESTIGATION ON THE MECHANICAL PROPERTIES OF FERRO-CEMENT**
- a) Chooyos Sutharatanachaiyaporn (Supervisor: Dr R.P. Pama)
  - b) Graduate student thesis project
  - c) Completed
  - d) This study is an extension of the earlier investigation conducted by *Raisinghani* (4171) to predict the mechanical properties of ferro-cement for use in design. In this investigation ferro-cement is treated as a homogeneous composite material and its properties in bending, torsion, tension and compression are determined from the laws of mixture. In bending and torsion, ferro-cement is idealized as a tri-linear material to describe its behavior in the uncracked, cracked and yield range. Explicit expressions, slightly different from those of *Raisinghani*, are also derived for its moduli and rigidities in bending, torsion and its Poisson's ratio. The ultimate resistance of ferro-cement in bending, torsion, tension and compression are discussed. Further experiments were conducted to supplement the data obtained by *Raisinghani*. Specimens with different layers of wire mesh were tested in torsion and the results obtained were shown to be in good agreement with theoretically predicted values.
  - e)
    - (i) Thesis No. 558, AIT, 1973.
    - (ii) SUTHARATANACHAIYAPORN, C., PAMA, R.P. and LEE, S.L. (1973), Further Investigation on the Mechanical Properties of Ferro-Cement, *AIT Research Report No. 36*.
- 4193 **VIBRATION OF FRAME FOUNDATION WITH BILINEAR HYSTERESIS FOR ROTATING MACHINERY**
- a) Guan Tan (Supervisor: Dr. Pisidhi Karasudhi)
  - b) Graduate student thesis project
  - c) Completed
  - d) The vibration of a single-story frame with bilinear hysteresis supporting a rotating machine is analyzed. The excitation force caused by the rotating unbalanced mass of the machine has a frequency dependent amplitude. The bilinear hysteresis of the resisting force of the frame to the motion is derived from the bilinear moment-curvature relationship of the frame columns. Solving the equation of motion of the system by the method of slowly varying parameters, the system exhibits unbounded resonance when the product of the machine unbalanced mass and its eccentricity exceeds a critical value. For the purpose of design and analysis of this type of structure, the displacement amplitude is plotted against arguments of the frequency for various values of two parameters involved.

- e) (i) Thesis No. 559, AIT, 1973.  
(ii) KARASUDHI, P., TAN, Guan and LEE, S.L. (1973), *Vibration of Frame Foundation with Bilinear Hysteresis for Rotating Machinery, Presented at the ASME/DED 4th National Conference on Mechanical Vibration, Cincinnati, Ohio, 1973.*  
(iii) *Journal of Engineering for Industries*, Transaction ASME, Series B (in press).
- 4194 **CURVED BOX GIRDER BRIDGE UNDER VEHICULAR WHEEL LOADS**
- a) Visit Tansirikongkol (Supervisor: Dr. Pisidhi Karasudhi)  
b) Graduate student thesis project  
c) Completed  
d) In this study, a curved box-girder bridge which is simply supported along the two straight edges, free on the curved edges and subjected to a uniformly distributed load and vehicular wheel loads, is analysed as a segmental annular sandwich plate whose top and bottom facings are assumed to resist the bending and twisting moments while core medium is assumed to resist only the vertical shear. The problem is governed by three partial differential equations obtained upon the separation of the variables are in turn solved by the finite difference method. The numerical results agree very well with those obtained by the technique of curved strips. Since the convergence involved in obtaining results by the proposed technique is relatively fast, it is advantageous over other methods in reducing the computation time.  
The simplified solution based on neglecting the shear deformation associating with the bridge girders leads to a good prediction in deflection, very conservative girder moments and a very poor prediction of other stress resultants.
- e) (i) Thesis No. 560, AIT, 1973.  
(ii) TANSIRIKONGKOL, V., KARASUDHI, P. and LEE, S.L. (1973), *Curved Box Girder Bridge Under Vehicular Wheel Loads, AIT Research Report No. 38.*
- 4195 **ANALYSIS AND DESIGN OF FERRO-CEMENT PIPES**
- a) Nibhondh Theeranartsin (Supervisor: Dr. S.L. Lee)  
b) Graduate student thesis project  
c) Completed  
d) The purpose of this research is to study the analysis and design of ferro-cement pipes subjected to design loads specified by ASTM Designation C76-72. The analysis is carried out by employing cylindrical shell theory with some simplifying assumptions. Various designs for the ferro-cement pipe are considered and compared, in terms of cost and weight, with ordinary reinforced concrete pipes designed for the same load. It was found that ferro-cement pipes with the minimum use of wire mesh, which possess better cracking properties than reinforced concrete pipe, could be designed to yield competitive cost with reinforced concrete pipes of the same diameter.
- e) (i) Thesis No. 561, AIT, 1973.  
(ii) THEERANARTSIN, N., LEE, S.L. and HONGLADAROMP, T. (1973), *Analysis and Design of Ferro-Cement Pipes, AIT Research Report No. 37.*
- 4196 **BENDING ANALYSIS OF HYPERBOLIC PARABOLOID SHELL ROOFS**
- a) Iqbal Ahmed Turk (Supervisor: Dr. R.P. Pama)  
b) Graduate student thesis project  
c) Completed  
d) A bending analysis of hyperbolic paraboloid shell roofs with continuous supports along the edges and subjected to uniformly distributed normal load is presented. The solution is obtained by Kantrovich's method and subsequently improved by Galerkin's procedure. Of particular interest are the adopted boundary conditions which are realistic for such type of structures as constructed. Parametric studies are carried out and the results are presented to facilitate the design of such structures.
- e) Thesis No. 562, AIT, 1973.
- 4197 **SHEAR LAG IN BOX BEAMS**
- a) Chin-Yi Wang (Supervisor: Dr. F. Nishino)  
b) Graduate student thesis project  
c) Completed

- d) **The behavior of the elastic beam is discussed considering the influence of shear deformation. The Navier-Bernoulli hypothesis assumes that plane sections normal to the neutral axis before bending remain plane after deformation and normal to the neutral axis. Timoshenko beam theory is based on the assumption that plane sections normal to the neutral axis before bending remain plane after deformation but no longer normal to the neutral axis.**

In this study, a modification of the elementary beam theory is proposed, taking into consideration the effect of shear deformation. Using iterative technique, the solutions of the elementary beam theory and the Timoshenko beam theory are iterated successively for the discontinuity of longitudinal displacements arising as a result of shear deformation.

Several numerical examples for beams with box section under simple loading cases and boundary conditions are given. For certain range of the parameters, fairly good agreement exists between the results of the proposed theory and those obtained by the more exact folded plate theory.

- e) Thesis No. 563, AIT, 1973.

#### 4198 BEAM VIBRATION WITH SHEAR DISTORTION

- a) Sui Kui Yii (Supervisor: Dr. S.L. Lee)  
 b) Graduate student thesis project  
 c) Completed

- d) **The vibration of elastic beams is discussed and consideration is given to the effect of warping deformation due to the presence of shear stress. The elementary and Timoshenko beam theories assume that plane cross sections remain plane after deformation. In this study, the governing equation of transverse vibration is derived taking into consideration the out-of-plane deformation of cross sections caused by shear distortion. The governing equation of torsional vibration is similarly derived.**

Numerical examples are presented for beams with simply supported boundary condition. Narrow rectangular, thin-walled tube and box sections are used to illustrate transverse vibration; wide flange sections are used to illustrate torsional vibration.

- e) Thesis No. 564, AIT, 1973.

#### 4199 DISCRETIZATION OF SKEW SLABS

- a) Ming-Hong Yu (Supervisor: Dr. Tongchat Hongladaromp)  
 b) Graduate student thesis project  
 c) Completed

- d) **The analysis of equivalent grid framework representing skew slabs in flexure is investigated. An orthogonal grid model with one series of the orthogonal grid members normal to supported edges is used to discretize skew slabs with uniform thickness. The stiffness method of structural analysis is employed to analyse the grid system. Four cases of skew slabs with different boundary conditions are investigated to show how orthogonal discretization can be used for the analysis of the skew slabs and how to simulate the boundary conditions.**

A detailed comparison of deflections, moments and torques predicted by the equivalent grid framework system is given for different types of skew slab. The results obtained from the analysis of equivalent grid framework are found to be in good agreement with those obtained by other methods, notably the finite difference and the finite element methods, except for results obtained along free edges. Proper simulation of boundary conditions and good engineering judgement must be exercised in utilizing this method for the purposes of practical design.

- e) Thesis No. 565, AIT, 1973.

#### 4200 MECHANICAL PROPERTIES OF BAMBOO REINFORCED SLABS

- a) Zahid Ali (Supervisors: Prof. S.L. Lee and Dr. R.P. Pama)  
 b) Graduate student thesis project  
 c) Completed

- d) **The purpose of this investigation is to study bamboo reinforced mortar as a structural material and to predict its mechanical properties for use in design. Bamboo reinforced slab elements with varying layers of bamboo mesh reinforcements were tested in flexure, torsion, axial compression and direct tension. The experimental values obtained from these tests were found to be in good agreement with theoretical values predicted by treating bamboo reinforced slabs as a composite material.**

A variety of bamboo scientifically called *Thyrsostachys Oliveri* Gamble known locally

as *pai ruak* Thailand was used in the investigation because of its high tensile strength. The test results also showed that presoaking of the bamboo fibres before embedment in the cement mortar resulted in better bond strength and help prevent the appearance of swelling cracks in the composite.

e) Thesis No. 676, AIT, 1974.

4201 DYNAMIC ANALYSIS OF A MACHINE TIEDOWN ON AN AIRCRAFT

a) Yanchai Buranasiri (Supervisor: Dr. Pisidhi Karasudhi)

b) Graduate student thesis project

c) Completed

d) A tiedown of a Madsen 20 mm automatic cannon on a C-47 aircraft is analysed in this study as a one-degree-of-freedom system. The excitation force is computed from the characteristics of the cannon, bullet and firing rate. The mass of the system is assumed equal to the mass of the cannon with the tiedown. The calculation of the stiffness of the system is based on zero rotation of the gun and an elastic horizontal deflection of twelve intercostae supporting the gun base. The damping coefficient is assumed equal to one percent of the critical damping coefficient.

The response of the system is found to have a dynamic load factor equal to 0.6589. The maximum shear stress in the fuselage skin is less than three percent. The most critical area is the immediate vicinity of the gun tiedown. However, all stresses are below the allowable limits.

e) Thesis No. 677, AIT, 1974.

4202 THE EFFECT OF RICE HULL ASH IN CEMENT AND CONCRETE MIXES

a) Virgilio G. Columna (Supervisor: Dr. R.P. Pama)

b) Graduate student thesis project

c) Completed

d) The effect of rice hull ash in cement and concrete mixes was investigated. The mechanical properties studied include compression strength, splitting tensile strength, creep, shrinkage, expansion and durability. Two series of tests were conducted and these are referred to as Series A and B. In Series A, rice hull ash was used as aggregate with cement. The amount of cement was kept constant while the rice hull ash and water-cement ratio were varied. In Series B, the rice hull ash was used as partial replacement of cement in an ordinary concrete mix. The water-cement ratio in this mix was also varied.

The compressive and splitting tensile strengths in both series were obtained for different mix proportions. Creep and shrinkage properties were obtained from specimens over a 60 day period. The durability of the specimens was measured by repeated wetting and drying process. The effect of rice hull ash on these mechanical properties is discussed.

An economic study for the production of lightweight cement-rice hull ash hollow blocks was conducted and the results showed that these can be produced at a price lower than the cement-sand blocks of the same volume sold locally.

e) Thesis No. 678, AIT, 1974.

4203 INELASTIC BEHAVIOR AND ULTIMATE STRENGTH OF FERROCEMENT PIPES

a) Dradjat Hoedajanto (Supervisors: Prof. S.L. Lee and Dr. Tongchat Hongladaromp)

b) Graduate student thesis project

c) Completed

d) A method for analyzing the post yielding piecewise linear load-deformation behavior of ferrocement pipes is presented. The material is idealized as elastic-perfectly plastic. Following the approach of Lee and Heidebrecht in analyzing elastic-perfectly plastic frames, a separation function  $\Delta_i$  is employed allowing the compatibility and equilibrium conditions to be formulated in general terms which are valid for the piecewise linear regimes. Four ferrocement pipes of two different cross sections were tested in flexure. The results obtained from these tests are found to be in good agreement with theoretical values in the inelastic range but not in the elastic range. To alleviate this difficulty, the construction of a composite load-deflection diagram which predicts the behavior of ferrocement pipes satisfactorily from initial loading to ultimate is proposed.

e) Thesis No. 679, 1974.

- 4204 THICK PLATE ON WINKLER'S FOUNDATION**
- a) Intarachai Hovichitr (Supervisors: Prof. S.L. Lee and Dr. Pisidhi Karasudhi)
  - b) Graduate student thesis project
  - c) Completed
  - d) In this study, the solution of a large thick plate on a Winkler's foundation subjected to a vertical concentrated force which may be applied on the surface or in the interior of the plate is formulated. It is treated as an axisymmetric elasticity problem. Using Hankel transforms, the biharmonic governing equation is changed to an ordinary differential equation, the complete solution of which is obtained by applying the appropriate boundary conditions. The relevant displacement and stress components are then expressed in the form of infinite integrals by means of inverse transforms. Approximations of two functions are proposed to reduce the infinite integrals to the standard forms of integration.  
The proposed solution though approximate is in a closed form and gives accurate results especially in the vicinity of the applied force, since the most dominant component in that vicinity, which is the singular part of Mindlin's solution, is exactly identified. The solution for plane problems of a vertical line force is obtained by an appropriate integration of the proposed solution. Numerical results for the case of concrete plates on grades are presented from which complete solution of displacements and stresses may be computed manually.
  - e) Thesis No. 680, AIT, 1974.
- 4205 VIBRATION OF THIN-WALLED MEMBER WITH OPEN SECTION**
- a) Vijay K. Kejriwal (Supervisors: Prof. S.L. Lee and Dr. Pisidhi Karasudhi)
  - b) Graduate student thesis project
  - c) Completed
  - d) Equations of motion of thin-walled members with open section under the action of time varying axial force, biaxial bending and torsional moments have been derived by means of a variational method. Three equations of motion governing the transverse and torsional vibration of a thin-walled section with no axis of symmetry are coupled hence the section undergoes a triply coupled vibration. For a section with one axis of symmetry, the vibration is doubly coupled since only two equations of motion are coupled. A section, with the shear center coinciding with the centroid undergoes an uncoupled motion due to the fact that its equations of motion are uncoupled.  
Complete solutions for all the three types of free and forced vibrations of simply supported beams are obtained. The natural frequencies and eigenvectors for free vibration have been determined in closed forms. Orthogonal property of natural modes of vibration have been utilised to uncouple the equations of motion for solving the forced vibration. Exact solutions of the displacement functions have been obtained in the form of series. An example is given to illustrate the calculations of relevant geometric properties of a section. The properties of other commonly used structural sections are compiled in a table. Solutions of free and forced vibrations with reference to I-section, channel section, T-section and angle section have been described.
  - e) Thesis No. 681, AIT, 1974.
- 4206 LARGE COMPOSITE ORTHOTROPIC PLATE ON WINKLER'S FOUNDATION**
- a) Fei Keng (Supervisor: Dr. Pisidhi Karasudhi)
  - b) Graduate student thesis project
  - c) Completed
  - d) An approximate method is investigated which provides asimplified treatment of the mechanics of multilayered orthotropic plate on Winkler's foundation. The method is derived on the assumption of plane strain deformation. Behavior of a single layer plate is first investigated. The theory is then extended to the case of a multilayered plate, and the microelastic stress couple is also evaluated for this case.  
Several examples of homogeneous plates are studied. Numerical results are presented in the form of graphs. The comparison of deflections and fiber stresses obtained by the proposed method and the classical plate theory shows that these two solutions are close.
  - d) Thesis No. 682, AIT, 1974.
- 4207 DESIGN AND EVALUATION CRITERIA FOR LOW-COST HOUSING**
- a) Anant R. Kukreti (Supervisors: Dr. Tongchat Hongladaromp and Prof. S.L. Lee )
  - b) Graduate student thesis project

- c) Completed
  - d) This research was aimed at the formulation of design and evaluation criteria for low-cost housing. User needs and functional requirements for low-cost housing are specified and performance concept used to formulate the criteria. The design and evaluation criteria were established for different physical subsystems of the housing system. Several minimum standards suggested in various countries were studied and used as the basis to specify the different criteria.  
An evaluation methodology is suggested consisting of the formulation of an evaluation matrix which represents the relation of the functional requirements of the user to each of the physical subsystems of the dwelling unit. To quantify the evaluation process, the methodology includes the determination of indices which indicate the performance of the individual subsystems and the extent to which individual functional requirements of the user and the housing system as a whole are satisfied. Recommendations for future work in this field are also discussed.
  - e) Thesis No. 683, AIT, 1974.
- 4208 INFLUENCE OF CRACKING ON SHORT-TIME DEFLECTIONS OF REINFORCED CONCRETE BEAMS**
- a) Chiu-Hsiung Lin (Supervisors: Dr. R.P. and Prof. S.L. Lee)
  - b) Graduate student thesis project
  - c) Completed
  - d) This investigation deals with the study of the influence of cracking on the short-time deflections of reinforced concrete beams. The analysis is based on idealized elastic-perfectly plastic stress-strain curves for both the concrete and steel. A bi-linear moment-curvature curve is derived which takes into account the uncrack and crack behavior of the beam. This simplified moment-curvature curve is used in predicting the short-time deflections of reinforced concrete beams in flexure. The theoretical results obtained are compared with previously published experimental values and the comparison was found to be very satisfactory. The proposed expressions are also compared with the existing ACI and CEB recommendations.
  - e) Thesis No. 684, AIT, 1974.
- 4209 ULTIMATE STRENGTH OF PRESTRESSED CONCRETE CIRCULARLY VOIDED COLUMNS**
- a) Chen-Cher Liu (Supervisor: Dr. Tongchat Hongladaromp)
  - b) Graduate student thesis project
  - c) Completed
  - d) The resisting capacities of prestressed concrete hollow columns is investigated. The stress-strain curve for concrete adopted by the European Concrete Committee is used in this analytical study. Parametric study has been made to show the influence of prestressing, eccentricity, slenderness and void upon the ultimate resisting capacity of the column. Some simplified formulae have also been probed and compared with the solution of the more accurate formulae. Sets of non-dimensional bending moment bending moment-axial force interaction curves are presented for design purposes.
  - e) Thesis No. 685, AIT, 1974.
- 4210 DESIGN OF ASBESTOS CEMENT LOW-COST HOUSES**
- a) Seri Pathomkulmai (Supervisors: Prof. S.L. Lee and Dr. Tongchat Hongladaromp)
  - b) Graduate student thesis project
  - c) Completed
  - d) In an attempt to help solve Thailand's low-income housing problems, two experimental low-cost asbestos cement houses have been designed and constructed for use in suburban and rural areas. Attractive, sturdy, and comfortable, these one-story asbestos cement houses are simple to build with the employment of low-skilled labour and prefabricated construction materials. The unit cost of the duplex is about ฿ 500 per square meter. With floor area of about 50 square meters per unit, the total cost is ฿25,000 per unit. The other house is a single detached unit with floor area of about 60 square meters, the total cost being ฿32,000. They are designed to meet the requirements of Thai National Standard Specifications.
  - e) Thesis No. 686, AIT, 1974.

- 4211 MODEL STUDIES OF DOUBLE-CELL BOX GIRDER BRIDGE WITH INTERMEDIATE DIAPHRAGMS**
- a) Daniel Z. Pribadi (Supervisor: Dr. Ricardo.P. Pama)
  - b) Graduate student thesis project
  - c) Completed
  - d) An experimental study on the influence of intermediate cross-bracing diaphragm on the behavior of a simply supported double-cell box girder bridge has been carried out. A model made of perspex was tested under various loading conditions and the test results are compared with theoretical values suggested by NIMITYONGSUL, PAMA and LEE. The experimental and theoretical results for deflections, longitudinal and transverse normal forces for cases without intermediate diaphragm under different positions of loading are plotted or tabulated in order to visualize the influence of these diaphragms on the load distribution characteristics of the bridge girder. The experimental results for deflection and longitudinal normal forces are shown to be in good agreement with the theoretical results. This study showed that the use of intermediate diaphragm decreases effectively the cross-sectional distortion throughout the span, increases the overall stiffness of the bridge and redistributes the longitudinal normal forces.
  - e) Thesis No. 687, AIT, 1974.
- 4212 PREFABRICATION IN HOUSING CONSTRUCTION**
- a) Narong Rerkshanandana (Supervisor: Dr. Tongchat Hongladaromp)
  - b) Graduate student thesis project
  - c) Completed
  - d) This study aims to evaluate the capabilities of local builders in prefabrication and to determine the most suitable system of construction for the local conditions. Capabilities are considered in terms of manpower, equipment and experience.  
The analysis has been carried out in three stages. The first stage is cost analysis, yielding the minimum unit cost for each system of prefabrication. In the second stage of analysis, the results obtained in the first part are used in the comparison of the performance of the systems in terms of cost, construction time, structural safety, and flexibility in design and maintenance. The economics of prefabricated buildings are then studied in the last stage. The economic study emphasizes the determination of shape and sizes of buildings having the minimum cost.  
The study reveals that the shortage of heavy lifting equipment and lack of experience are the main obstacles to prefabricated construction in Thailand, and that the beam-column prefabricated system is the most suitable one at present.
  - e) Thesis No. 688, AIT, 1974.
- 4213 FIELD TEST OF A FERROCEMENT RICE BIN**
- a) Snit Siridanupath (Supervisor: Dr. Pisidhi Karasudhi)
  - b) Graduate student thesis project
  - c) Completed
  - d) The purpose of this investigation is to study the construction techniques and to take field measurements of deflections and strains of a conical ferrocement rice bin. A prototype was constructed at the Asian Institute of Technology. Measurements were carried out using dial gages for deflections and electrical resistance strain gages for strains. Test results showed that the bin underwent very small deformations, but cracks and leakage in the bin occurred due to an inadequate compaction and a big loss of moisture content of mortar during construction. The construction technique with some recommended improvements seems feasible.
  - e) Thesis No. 689, AIT, 1974.
- 4214 LATERAL STIFFNESS OF INFILLED FRAMES**
- a) Benjamin Sugiya (Supervisor: Dr. Tongchat Hongladaromp)
  - b) Graduate student thesis project
  - c) Completed
  - d) Finite element method is used to study the stiffness of rectangular infilled frame. Rectangular element with simple displacement function for plane stress problem is used in the formulation of the stiffness matrix of the structure.

Experiments were carried out to verify the theoretical results and to study the behaviour and effect of the infill. Concrete frames with mortar infill and without infill were tested for the purpose. The stiffness of the infilled frame obtained from the finite element technique is considerably stiffer than those obtained from the experiments.

Parametric study for brick infilled concrete frame was also carried out from which stiffness curves were obtained. A simplified method using these curves is introduced to estimate the lateral deflection of a multistorey infilled frame and its result was compared with those obtained from diagonal strut theory and the frame without infill. From the comparison, diagonal strut theory gives a larger deflection than that obtained by the simplified method which indicated that the equivalent strut method may lead to an underestimation of the stiffness.

e) Thesis No. 690, AIT, 1974.

#### 4215 BENDING OF ELLIPTIC PARABOLOID SHELL

a) Somsak Swaddiwudhipong (Supervisor: Prof. S.L. Lee)

b) Graduate student thesis project

c) Completed

d) The bending analysis of elliptic paraboloid shells continuously supported along the edges by rather stiff edge members and subjected to uniformly distributed vertical load is presented. The governing equations based on the assumptions for thin shallow shells are expressed in terms of displacement components. The adopted boundary conditions are realistic for such type of structures as constructed. The solutions are obtained by two methods and subsequently improved by the Galerkin procedure. Another approach consists of expressing the displacement functions as double series in characteristic functions and determined coefficients by the orthogonality property of the assumed functions. Parametric studies are carried out and the results are presented to facilitate the design of such structures.

e) Thesis No. 691, AIT, 1974.

#### 4216 SHORT-TIME DEFLECTIONS OF BONDED PRESTRESSED CONCRETE BEAMS

a) Kai-Chong Tan (Supervisor: Dr. R.P. Pama)

b) Graduate student thesis project

c) Completed

d) This investigation deals with the flexural behavior and deflection analysis of prestressed concrete beams due to short-time loads. The analysis is based upon assumed stress-strain curves for the concrete and the prestressing steel. It is limited to beams with tension steel only.

Two methods of analysis are presented to calculate the deflection of bonded prestressed concrete beams. The first method utilizes the true moment-curvature curve of the beam while the second method is approximate whereby the moment-deflection curve is assumed to be bi-linear, consisting of a straight line from zero to cracking and another straight line from cracking to ultimate condition. In both methods of analysis the tensile strength of the concrete is considered.

With the moment-curvature known, the deflections of prestressed concrete beams are derived by conjugate beam method. The theoretical results are compared with experimental values reported earlier and the comparison was found to be satisfactory. This study also revealed that short-time deflection of under-reinforced bonded prestressed concrete beams can be predicted quite accurately by the first method of analysis which is based on the true moment-curvature curve whereas over-reinforced beams showed good correlation with the approximate bi-linear moment-deflection curve.

e) Thesis No. 692, AIT, 1974.

#### 4217 FIELD TEST OF FERROCEMENT CANAL LINING

a) Chainan Thumasujarit (Supervisors: Dr. Pisidhi Karasudhi and Prof. S.L. Lee)

b) Graduate student thesis project

c) Completed

d) Various types of canal lining are reviewed with regards to their structural design consideration, failure causes and prevention, loading conditions, and construction and repairing techniques. The most critical factor in design load is the water level in the subgrade causing a hydrostatic pressure, and a swelling pressure if the subgrade is clay. These pressures can be

reduced by means of a proper design of a drainage system consisting of weepholes with filters and, for a clayey subgrade, a previous layer between the lining and the subgrade.

The characteristics of a ferrocement canal lining were studied experimentally concerning its construction procedures and load carrying behaviors. The stress resultants due to concentrated patch loads were compared with an existing theoretical prediction.

The cost of a ferrocement canal lining compared to that of other types of lining is rather high but the load carrying capacity is far superior.

- e) Thesis No. 693, AIT, 1974.

#### 4218 DYNAMICS ANALYSIS OF TALL MULTI-FLUE STACK UNDER WIND LOADS

- a) Ying-Chau Tsai (Supervisor: Dr. Pisidhi Karasudhi)

- b) Graduate student thesis project

- c) Completed

- d) The response of a tall multi-flue stack to wind loads was investigated in this study. Each flue consists of a number of equal lengths supported on bearings. The outer shell mass was idealized into the same number of elements as the flue lengths. The system was therefore represented by a number of masses with associated spring and damping elements. The equation of motion was derived by means of Lagrange equation incorporating the rotational effects of all masses. The stiffness of the outer shell was computed on the assumption that it behaves as a slender cantilever beam. The damping coefficients in the system were assumed to be proportional to masses and stiffnesses.

Two types of wind loads, gust and vortex actions, were considered. The gust load was computed from a simulated hurricane velocity. The critical wind velocity for vortex action was calculated from the fundamental frequency of the system.

Expressing the displacements of each mass in term of modal displacements, the governing equations of the latter become uncoupled, and their solutions for gust load was obtained by means of a numerical integration. For vortex load, the steady state solution is the most relevant for practical purposes.

The stack chosen for illustrating the analysis is 242m high and made of reinforced concrete. The outer shell with a 26m diameter encloses and supports three elliptical reinforced concrete flues. It is found that a dynamic analysis for the response of the structure subjected to wind loads is very important and the vortex action is most critical in the analysis.

The response of this type of structure depends very much upon damping and wind load coefficients. More investigations on these coefficients both by means of a model and a prototype are recommended.

- e) Thesis No. 694, AIT, 1974.

#### 4219 AN EXPERIMENTAL INVESTIGATION ON THE RIGIDITIES OF RIBBED SLABS

- a) Rosalie O. Victoriano (Supervisors: Dr. R.P. Pama and Prof. S.L. Lee)

- b) Graduate student thesis project

- c) Completed

- d) The torsional and flexural rigidities of orthogonally eccentrically stiffened slabs were investigated experimentally and the results are compared with those obtained from various theoretical methods. The parameters involved in this study are the height of ribs, number of transverse ribs and height of longitudinal ribs with no transversals. The desired variations were obtained by milling down the two original asbestos cement models, each about 22.5 in. x 18 in. in dimension. The variations resulted into eight models each of which was subjected to anticlastic corner loads, cylindrical bending and eccentric loading tests. The theoretical values of the flexural rigidities obtained from the different methods of approach considered were found to be in agreement with experimental values. For torsional rigidities, the values suggested by NISHINO, PAMA and LEE give the closest correlation with the experimental results (Nishino, Pama and Lee, *Orthotropic Plates with Eccentric Stiffeners*, Int. Ass. Bridge and Struct. Engng, 34-II).

- e) Thesis No. 695, AIT, 1974.

#### 4220 RESPONSE OF SUBMERGED SPHERICAL STRUCTURES TO EARTHQUAKE MOTIONS

- a) David Srimahachota (Supervisors: Prof. S.L. Lee & Dr. Tongchat Hongladaromp)

- b) Doctoral dissertation

- c) In progress

- d) The dynamic response of single degree of freedom spherical structures submerged in a viscous fluid of infinite extent, initially at rest, is investigated. The equation of motion includes the expression for fluid reaction derived by Basset. The equations are solved numerically by linear acceleration method. Time history responses of a single degree of freedom system and response spectrum curves for the N-S component of the May 1940 El Centro earthquake are generated for different values of structural damping, density ratio and Stokes number.

For the submerged multi-degree of freedom system, the responses are studied in the form of time history curves generated for different parameters. A modal analysis is derived for the case, the only possible case, where all the spheres have the same size and density and the damping coefficient is proportional to the mass. The response spectra generated previously are used to predict the maximum displacements of the multidegree of freedom systems and the results are validated by comparing with those obtained from direct numerical integration.

Finally, the elastic-plastic single degree of freedom system subjected to the El Centro earthquake is studied. The response spectra for the elastic perfectly plastic system are generated for different values of density ratio and ductility factor. The results show that there exists an optimum value of the yield displacement at which the maximum displacement response of the system is a minimum.

For the range of parameters considered in this study for civil engineering purposes, the lateral forces in both the elastic and the elastic-perfectly plastic systems submerged in fluid are in general larger than those acting on the structure vibrating in a vacuum.

#### 4221 TRILINEAR BEHAVIOR OF FERROCEMENT SLABS

- a) Nicanor C. Austriaco (Supervisors: Prof. S.L. Lee and Dr. Ricardo P. Pama)  
b) Doctoral Dissertation  
c) In progress

- d) An experimental program consisting of tests on rectangular slabs under cylindrical bending and on circular slabs under central load applied through a boss was carried out to study the load-deformation behavior of ferrocement slabs. The experimental results showed that a ferrocement slab under transverse loads exhibits the properties of a trilinear material with a limit surface.

The moment-curvature relations of a ferrocement section are derived on the assumption that the wire mesh yields as soon as it is impinged by a crack. These moment-curvature relations led to an idealized trilinear moment-curvature curve which was used in the deflection analysis of ferrocement slabs. A complete solution based on the theory of trilinear materials with a limit surface is obtained for the case of rectangular slabs under cylindrical bending. For the circular slabs under central load applied through a boss, a rigorous solution is presented to predict the deflections up to a certain load level beyond which non-regular progression of stress points occurred. For the range of loading which involves non-regular progression of stress points, the solution entails tedious mathematical calculations and large amounts of computer time. An approximate solution based on the theory of elastic-perfectly plastic material is introduced to predict the deflection of the circular slabs at higher load range.

The comparison of theoretical results and experimentally obtained values are shown to be satisfactory.

#### 4222 ANALYSIS OF NEGATIVE SKIN FRICTION IN END-BEARING PILE DUE TO SURCHARGE LOAD

- a) Ng Hon-Kwong (Supervisors: Dr. Pisidhi Karasudhi and Prof. S.L. Lee)  
b) Doctoral dissertation  
c) In progress

- d) This research investigates the development of negative skin friction along an end-bearing pile due to a surcharge load. The pile is taken as an elastic rod which is embedded in a two-layer elastic half-space, with the end of the rod located at the interface of the layers. The problem is found to be governed by a Fredholm integral equation of the second kind which can be solved by a numerical method. The time effect is incorporated by the assumption that the upper layer is consolidating according to Terzaghi's consolidation theory. Furthermore, the drag force associated with the secondary compression of the soil skeleton is considered with the assumption that the upper layer is a viscoelastic medium. Numerical results will be presented showing the effects of various soil and pile parameters on the magnitude and the rate of development of the negative skin friction with time. Graphs will be given for the purpose of analysis and design of such structures.

4223 **DEVELOPMENT OF LOW-COST FIBER CEMENT BOARDS**

- a) Bunchu Pakotiprapha (Supervisors: Dr. Ricardo P. Pama & Prof. S.L. Lee)
- b) Doctoral dissertation
- c) In progress
- d) The dissertation deals with an analytical and experimental investigation of the mechanical properties of fiber reinforced cement paste. The fiber selected in this study is bamboo, in which the beneficial effects of small and large fibers from bamboo pulp and bamboo chips respectively are identified. Analytically, the material is treated as a composite and its properties are derived by the laws of mixture. The effect of random orientation, shape and the surface texture of the fiber are taken into consideration. Certain assumptions are made concerning the orientation and distribution of the fibers to simplify the analysis. Explicit expressions are given for the mechanical properties of the material in compression, tension, bending and torsion respectively. An optimum mix between bamboo pulp and bamboo chips is determined to meet the required properties. Experiments are conducted to verify the analytical prediction. Tests to show the suitability of the material as roof material and wall panels will be performed.

4224 **INELASTIC BUCKLING OF DIAGONAL BRACES**

- a) Supachai Limpisvasti (Supervisors: Prof. S.L. Lee & Dr. S. Morino)
- b) Doctoral dissertation
- c) In progress
- d) The inelastic buckling of diagonal braces in building frames is investigated theoretically and experimentally. The diagonal brace is idealized as an initially straight bar which is rigidly connected at both ends with an inclination angle to rigid beams of the frame. When the horizontal load is applied on the frame, the diagonal brace is subjected to the combined axial force and bending moment induced by the relative lateral deflection between the upper and lower ends. The elastic-plastic behavior of the diagonal brace under the application of monotonically increasing relative lateral deflection is investigated, based on the general yield condition of the cross section under combined axial thrust and bending. A parametric study on the ultimate strength of the diagonal brace is carried out. The results are compared with experimental results obtained for braces with several different slenderness ratios and inclination angles.

**THESIS RESEARCH TOPICS FOR 1974-75**

Construction Network Compression Programming  
Earthquake Response of a Tall Multi-Flue Stack  
Elastic Lateral Stability of Channel Beams Under Biaxial Uniform Load  
An Efficient Method of Seismic Analysis of Structure-Foundation Systems  
A Study of Bamboo as Reinforcement for Slabs on Grade  
Simulated Wind for Structural Dynamic Analysis in Bangkok  
Shakedown Analysis Including P- $\Delta$  Effect  
Simplified Analysis of Building-Foundation Systems  
Study and Survey of Available Construction Materials, Equipment and Labor in Thailand  
A Survey of Costs and Cost Escalation in Construction Activities in Bangkok  
Design of Low-Cost Houses for Lower-Middle Income Families  
Ultimate Strength of Composite steel Reinforced Concrete Column Subjected to Biaxial Bending  
Evaluation and Redesign of Low-Cost Housing  
Post-Cracking Deflections of Reinforced Concrete Beams under Short-Time Loads  
Buckling of Composite Steel Reinforced Concrete Column  
Mechanical Properties of Wood-Cement Composites  
Dynamic Analysis of Asymmetric Shear Wall-Frame Buildings  
A Design of Low-Cost Rural School Building  
Analysis of Cylindrical Tank on Elastic Foundation  
A Performance Evaluation of a Low-Income Multi-Family Housing  
Theoretical and Photo-Stress Analysis of Cracking and Bond-Slip in Reinforced Concrete Beams  
Evaluation of a Corrugated Asbestos Cement Roof Panel  
Behavior of Bamboo Reinforced Concrete Tied Columns

## PROJECTS COMPLETED BETWEEN JANUARY 1969 AND JANUARY 1973

(Projects completed prior to January 1969 are found in Research Summary for January 1973)

No.	Title	Research Worker(s)	Publications
4096	A Comparative Study of Bent-Up Bars with Other Forms of Secondary Reinforcement In Beams	Kitcha Leksukhum	Thesis No. 273
4097	The Strength of Precast Concrete Girder Flanges Supporting Transverse Members	Javalit Oravenatanakul	Thesis No. 255, 1969
4098	The Effect of Degree of	Chinawood Buranarom	Thsis
4098	The Effect of Degree of Prestressed Concrete Beams	Chinawood Buranarom	Thesis No. 272, 1970
4099	Experimental Investigation of Yield Criteria for Orthotropic Slabs	Boonek Pitugdamrongkija	Thesis No. 258, 1969
4100	The Ultimate Load Capacity of Reinforced Concrete Columns Subjected to Axial Load and Biaxial Bending	Jawed Husian Paliwala	Thesis No. 252, 1969
4101	The Behavior of Slender Upstand Reinforced Concrete Beams in Restrained Torsion	Kitti Areeaksakul	Thesis No. 263, 1969
4102	A Study of a Method for Joining Precast Concrete Members	Rafael F. Erfe	Thesis No. 267, 1969
4103	The Influence of Tie Spacing on the Failure of Reinforced Concrete Columns	Shaiq-Ur Rahman Khan	Thesis No. 253, 1969
4104	Effect of Aggregate Properties on the Elasticity and Creep of Concrete	Pichai Nimityongskul	Thesis No. 271, 1969 <i>Conf. on Problems of Prestressing, Indian Natn. Group, IABSE, Madras, 1969, Sec. IV, pp. 41-52</i> <i>Symp. Design Concr. Struct. Creep, Shrinkage Temp., IABSE, Madrid, 1970, Vol. II, pp. 193-200</i>
4105	The Estimation and Significance of	Kraiwood Kiattikomol	Thesis No. 251, 1969
4105	The Estimation and Significance of the Tensile Strength of Concrete	Kraiwood Kiattikomol	Thesis No. 251, 1969
4106	Ferro-cement Bins for Hermetic storage of rice	R.B.L. Smith, S. Boon-Long	Research Report No. 12, 1970
4107	Long Rectangular Plates Supported by Three Parallel Rows of Equidistant Columns	K.M. Ashraful Alam	Thesis No. 285, 1970 <i>Israel J. of Tech., 1973, Vol. II, pp. 149-156</i>
4108	The Elastic Flexural-Torsional Buckling of Beam-Columns by Discrete Element Techniques	Conrado S. Casem	Thesis No. 295, 1970

No.	Title	Research Worker(s)	Publications
4109	Bending of a Full Circular Plate Supported on Two Rings of Equally Spaced Columns	Chi-Tso Chang	Thesis No. 291, 1970
4110	Bending of Circular Plates	Kasem Chantaramungkorn	Thesis No. 286, 1970
4110	Bending of Circular Plates Supported on Equally Spaced Columns Under an Eccentric Load	Kasem Chantaramungkorn	Thesis No. 286, 1970 <i>J. Struct. Div.</i> , ASCE, 1973, Vol. 99, ST 1, pp. 234-240
4112	Investigations of Bending Torsion Interaction of Reinforced Concrete Members with Application to Grid Structures	Somsakdi Chantra	Thesis No. 301, 1970
4113	Annular Slab Supported on Columns Along Inner Boundary and Fixed at Outer Boundary	Komen Charoensukvanich	Thesis No. 293, 1970
4114	The Effect of Repeated Loading Cycles on Restrained Reinforced Concrete T-Beams	A. B. M. Hossain	Thesis No. 296, 1970
4115	Uniformly Loaded Annular Plates Supported on Columns on the Boundary and Simply Supported on the Other Boundary	Ping Hsu	Thesis No. 287, 1970
4116	The Concentric and Eccentric Shear Strengths of Welded Connections	Worawit Kampanya	Thesis No. 299, 1970
4117	Overhanging Full Circular Plate Supported on Columns	Felix Liu	Thesis No. 288, 1970
4118	Concrete Properties as Influenced by Admixtures Using Local Aggregates	Manop Nakasint	Thesis No. 302, 1970
4119	Rotation Capacity of Uniformly Loaded Reinforced Concrete Beams	Wisut Naksorn	Thesis No. 305, 1970
4120	The Finite Element Method in Plate Bending Analysis	Pricha Ngaocharoenchitr	Thesis No. 297, 1970
4121	The Effect of Joint Rigidity on Frame Stability	Suphot U'hongkidakarn	Thesis No. 298, 1970
4122	Analytical Studies of Reinforced Concrete Slabs	Elmer B. Ramel	Thesis No. 313, 1970
4123	Vibration of Machine Foundations on Elastic Media	Seung-Yo Son	Thesis No. 289, 1970 <i>J. SE Asian Soc. Soil Engng</i> , 1970, Vol. I, No. 2, pp. 103-122
4124	The Finite Element Method in Plate Bending Analysis: Triangular Elements with Assumed Stress Distributions	Terng-Fen Song	Thesis No. 294, 1970
4125	Uniformly Loaded Annular Slabs Supported on Equally Spaced Columns Between the Edges	Suthum Suriyamongkol	Thesis No. 292, 1970

No.	Title	Research Worker(s)	Publications
4126	Lateral Instability of Slender Reinforced Concrete Columns Under Combined Bending Moment and Axial Force	Pramoth Tharasak	Thesis No. 304, 1970
4127	Inelastic Lateral Buckling of Cantilever Steel I-Beams	Kunodom Tharmmaphornphilas	Thesis No. 300, 1970
4128	Uniformly Loaded Orthotropic Rectangular Plate Supported at the Corners	Mohammed Zakeria	Thesis No. 290, 1970
4129	Application of Orthotropic Plate Theory to the Analysis of Folded Plate Structures	Shahbaz Ahmad	Thesis No. 348, 1971
4131	Curved Girder Bridges Under Concentrated Load	Kin-Seng Chan	Thesis No. 349, 1971 Research Report No. 22, 1972
4132	Harmonic Response of Long Multiple-Story Buildings on Flexible Foundation Media	Jin-Ching Chern	Thesis No. 350, 1971
4135	Grid Analysis of Orthotropic Plates	Chung-Tien Ho	Thesis No. 351, 1971
4137	Finite Element Analysis of Plates on Elastic Foundation Considering Separation of Contact Surface	Chesada Kasemset	Thesis No. 352, 1971
4138	Annular Plates on Elastic Foundation Supporting a Concentric Ring of Equally Spaced Columns	Parthasarathi Mukhopadhyay	Thesis No. 353, 1971
4141	Stability of Pipe Columns with Initial Curvature	Thirawat Srichatrapimuk	Thesis No. 354, 1971
4142	Corner Supported Equilateral Triangular Plates	Chitti Vijakkhana	Thesis No. 355, 1971 <i>Int. J. Mech. Sci.</i> , 1973, 15 pp. 123-128
4143	Vibration of Machine Frame Foundations	Suthipoul Viwathanatapa	Thesis No. 356, 1971 <i>Proc. 3rd SE Asian Cont. Soil Engng.</i> , Hong Kong, 1972
4144	Separation of Contact Surface in Bending of Slabs on Grade	Charnon Valantagul	Thesis No. 357, 1971 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn. Engng.</i> , Thailand, 1971, Vol. 1, pp. 87-94
4145	Approximate Analysis of Laterally Loaded Building Frames	Yun-Cheng Wang	Thesis No. 358, 1971 <i>Proc. Reg. Conf. Planning Design Tall Buildings</i> , Warsaw, Poland, 1972 (in press)
4148	Curved Box Girder Bridges with Intermediate Diaphragms and Supports	K.M. Ashraful Alam	Dissertation No. DI, 1972 <i>Proc. Int. Ass. Bridge Struct. Engng.</i> , 1973, Vol. 33-II
4150	Axially Loaded Rigid Cylindrical Body Embedded in an Elastic Half-Space	Suthum Suriyamongkol	Dissertation No. D2, 1972 <i>Proc. 4th Canadian Congr. of Appl. Mech.</i> , May 1973, pp.79-80

No.	Title	Research Worker(s)	Publications
			<i>Proc. 13th Midwestern Mech. Conf., Pitt., August 1973, pp. 333-347</i>
4151	Torsional Rigidities of Prestressed Ribbed Slabs	Imtiaz Gilani	Special Studies Report No. 1, 1971
4152	On Truss Analogy for Analyzing Pile Caps	Juanchito D. Bernardo	Thesis No. 412, 1972
4153	An Approximate Analysis of Shear Wall-Frame Buildings	Roberto P. Bernardo	Thesis No. 413, 1972
4154	Steel Bridge Deck with Torsionally Stiff Eccentric Stiffeners	Jaime F. Cancio	Thesis No. 414, 1972 Research Report No.24, 1972
4155	Load Distribution in Rectangular Footings on Piles	Nan-Jim Chen	Thesis No. 415, 1972 <i>J. SE Asian Soc. Soil Engng</i> , June 1973 (in press)
4156	Shear Deformations in Beams	Shan-Teng Chung	Thesis No. 416, 1972
4157	An Experimental Investigation of Reinforced Concrete Ribbed Slabs	Basudev Dey	Thesis No. 417, 1972 Research Report No. 23, 1972
4158	Composite Timber-Concrete Structural Elements	Edgardo B. Dionisio	Thesis No. 418, 1972
4159	Response Spectra of Ruby Tower Earthquake	Eliseo I. Evangelista	Special Studies Report No. 3, 1972
4160	Elastic Rigidities of Circularly Voided Slabs	Sayan Imsom-Somboon	Thesis No. 419, 1972 Research Report No. 25, 1972
4161	Curved Box Girder Bridges as Segmental Annular Sandwich Plates	Torng-Shen Jou	Thesis No. 420, 1972
4162	Ultimate Strength of Wide-Flange and Box Columns	Tokul Kanchanalai	Thesis No. 421, 1972 Research Report No. 29 1972 <i>Proc.IABSE Colloquim Column Strength</i> , Paris, France, 1972
4163	Optimization of Single Storey Single Bay Rigid Frame	Vichit Kuratong	Special Studies Report No. 4, 1972
4164	Design of Steel Members for Fatigue in Highway Bridges	Siang-Teh Lu	Special Studies Report No. 5, 1972
4165	Torsion of Steel Sections	Yung-Tuane Ni	Special Studies Report No. 6, 1972
4166	Load Distribution in Skew Slab-Girder Bridge Decks	Praxedes R. Parcero	Thesis No. 423, 1972 Research Report No. 26, 1972
4167	Probabilistic Analysis of Load Factor Using Sample Data	Ramasubbu Perumalswamy	Special Studies Report No. 7, 1972
4168	Wind Load on Structures in Bangkok Metropolitan Area	Nopadol Prapaitrakul	Special Studies Report No. 8, 1972 <i>J. Engng Inst.</i> , Thailand, 1972, Vol. 5, pp. 23-35
4169	Rotation Capacity of Uniformly Loaded Reinforced Concrete Beams	Tariq M. Qureshi	Special Studies Report No. 9, 1972
4170	Three-Way Reinforcement in Reinforced Concrete Slabs	Md. Shofiqur Rahman	Thesis No. 424, 1972

No.	Title	Research Worker(s)	Publications
4171	Mechanical Properties of Ferro Cement	Murlidhar Raisinghani	Thesis No. 425, 1972 Research Report No.27, 1972 <i>FAO Semin. Design Constr. Ferro-Cement Fishing Vessels</i> , Wellington, New Zealand, 1972, pp. 1-20
4172	Experimental Study of Tapered Steel Columns	Dominador F. Soriano	Thesis No.426, 1972
4173	Nonsymmetrical Buckling of Pipe Columns with Initial Curvature	Somchet Taeracoop	Thesis No.428, 1972 <i>Proc. Jap. Soc. Civ. Engrs</i> , 1972, Vol.208, pp. 149-156
4174	Analysis and Design of Long-Span Prestressed Concrete Beams	Carlito P. Talaboc	Special Studies Report No.10, 1972
4175	Axisymmetric Deformation of Floating Ice Sheets	Thiti Thananuwatna	Thesis No.429, 1972
4176	Composite Action Between Flanges and Webs of T-Beams	Mana Vongpivat	Special Studies Report No. 11 1972

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## RESEARCH IN ENVIRONMENTAL ENGINEERING

Environmental quality control and management are receiving much attention around the world and developing countries are becoming increasingly aware of the need to invest in projects which overcome the adverse effects of urbanization and industrialization. At the same time the large majority of the population in these countries remains in rural areas and has to cope with the more basic economic and public health problems of water supply and sanitation. The tropical environment, together with the conditions of a developing economy, present unusual constraints and stimulants which provide challenging problems for research. The Institute is in a unique position to provide the region with a research service on environmental problems.

Providing a safe and adequate water supply to rural communities at a reasonable cost is still the most urgent problem of developing countries and it is appropriate that the Environmental Engineering Division is involved in research in this field. The costs and benefits of providing community water supplies in Thailand are being analyzed with a view to improving the type and reliability of service and directing investment in the future. New techniques for treating surface water supplies using local materials are being investigated for their effectiveness, cost, and simplicity of operation in the rural context.

Pollution control through waste treatment is a particularly strong area of research in Environmental Engineering. Rational design criteria for anaerobic, facultative and high-rate aerobic oxidation ponds in tropical countries have been developed for use by industry and municipalities. Research grants have supported work on sewage treatment and the harvesting of algal protein as a waste treatment by-product. Local industry is financing research on air quality in Bangkok and its relation to traffic density.

Research interests in environmental engineering are extending into urban environment planning, air pollution and solid wastes management. Improved techniques for planning and decision making in the management of the Asian urban environment are being investigated.

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\* This list includes all faculty and staff holding appointment in the period since January 1973. Those who no longer hold appointment are indicated by an asterisk.

**RESEARCH PROJECTS IN PROGRESS OR COMPLETED SINCE  
JANUARY 1973**

**5012A ANTHRACITE-SAND FILTRATION STUDIES AT THE SAMSEN WATERWORKS OF  
THE BANGKOK METROPOLITAN WATER WORKS AUTHORITY**

- a) Prof. M.B. Pescod
- b) Sponsored research
- c) Completed
- d) An investigation was conducted to obtain design and operational information for the future Bang Khen Filter Plant of the Bangkok Metropolitan Waterworks. Four anthracite coal-sand dual-media filters were studied by utilizing the coagulated and settled water from the existing Samsen Waterworks as influent water for filtration. These were tested at two filtration rates (12.7 and 20.0 m<sup>3</sup>/m<sup>2</sup> hr) over a wide range of influent turbidity conditions. The addition of anionic polyelectrolyte to improve filtration efficiency was evaluated over dosage levels of 0.05 to 0.2 mg/l.

It was observed that the more uniformly sized anthracite and sand combination had advantages over other sizings, particularly in terms of reduced backwash water requirements. The filtration rate of 20 m<sup>3</sup>/m<sup>2</sup>-hr using these media was technically feasible. Four test runs at this rate were operated for an average period of 35 hours before a head loss of 2.5 m was reached, although turbidities exceeding 5 JTU were reached after 25 hours of operation. The average backwash water requirement was as low as 1.02 percent for the pilot run. Further scaled-up tests are required to substantiate these results. Polyelectrolyte addition resulted in improved effluent turbidities but considerably reduced filtration run lengths and thereby increased backwash water requirements.

- e) PESCOD, M.B. and KAROT, T. (1973), Anthracite-Sand Filtration Studies at the Samsen Waterworks of the Bangkok Metropolitan Waterworks Authority, *AIT Research Report*, Bangkok.

**5032A AN EVALUATION OF THE EFFECTIVENESS OF THE COMMUNITY POTABLE  
WATER PROJECT IN NORTHEAST THAILAND**

- a) Dr. R.J. Frankel
- b) Sponsored research
- c) Completed
- d) The study verified the problem of introducing innovations to the rural village, especially when these innovations resulted in increased costs or charges without the individual fully appreciating the value of what was received. Decreased disease risk, better sanitation, improved aesthetics, etc. are not immediately apparent in the strict material gain sense and hence it will take time and education before villagers fully realize the benefits and importance of a safe and reliable water supply.

In general, the water supply installations evaluated successfully distributed a water of "acceptable" quality and treatment plant operational and maintenance problems did not cause unacceptable plant shutdowns for rural communities. Actual water use was monitored and found on average to be less than half the criterion used in design and this resulted in most plants operating intermittently for 4 to 5 hours per day only. Simpler designs and more easily operated systems were found to be needed and elevated water storage tanks were considered uneconomic for the short duration of distribution accepted as adequate each day. Plants were poorly operated and the dependence of pump and engine operation on imported spare parts caused considerable difficulties and significant plant shutdowns. The level of operator training was insufficient to ensure proper use of chemicals and sensible operation of rapid gravity filters. Lack of motivation and concern for providing responsible service was apparent on the part of most plant operators and this was in part due to insufficient salary and irregular payments.

Although from the points of view of convenience of the supply and availability of water during the dry season the water systems were successful, it was found that some 40 percent of the villagers were not participating in the projects. This caused the water costs to villagers to be relatively high, at 10 Baht (U.S. 50 cents) per family per month on average, and this was often more than some participating villagers were willing to pay, resulting in even higher monthly charges. Budgeting procedures for rural water supply programs need careful thought and planning if projects are to be introduced and operated successfully.

- e) FRANKEL, R.J. (1973), Evaluation of Effectiveness of Community Water Supply in Northeast Thailand, *AIT Research Report*, Bangkok.

**5034A OPERATIONAL TESTING OF A TWO-STAGE WATER TREATMENT FILTER**

- a) Low Peng Peow (Supervisor: Dr. R.J. Frankel)
- b) Graduate student thesis project
- c) Completed
- d) A pilot scale two-stage water filtration unit using coconut husk fiber as roughing material and followed by burnt rice husk as polishing medium was found to be able to treat turbid surface water to meet WHO drinking water standards.

Tests were conducted at a filtration rate of 1.25 m<sup>3</sup>/m<sup>2</sup> per hour. The thickness of roughing and polishing media were 80 cm and 60 cm, respectively. This type of treatment plant appears practicable and acceptable for rural water supply.

- e) Thesis No. 591, AIT, 1973

**5034B OPERATIONAL EXPERIENCE OF TWO-STAGE WATER FILTERS IN THAILAND**

- a) Fan, Soo-Thin (Supervisor: Dr. Nguyen Cong Thanh)
- b) Graduate student thesis project
- c) Completed
- d) A technically simple and economically attractive system of water treatment is necessary for developing countries. The two-stage filter system using local materials is an appropriate and technologically attractive water treatment process. A field study of pilot-scale two-stage water filters using washed and reused coconut husk as roughing filter medium and burnt rice husk as polishing filter medium was conducted. Though alkalinity, chlorides, conductivity, hardness and total solids removals were negligible, the finished water met the recommended WHO International Standards for Drinking Water in terms of turbidity, colour, taste and odour, but not from the point of view of the coliform count (MPN). Though 90 percent or more of the coliforms were removed, slight chlorination would be required to ensure complete disinfection.

An economic study of two-stage filters indicated that they were economically viable, having fixed and running costs less than alternative conventional systems.

- e) Thesis No. 634, AIT, 1974.

**5034C EVALUATION OF PILOT WATER TREATMENT UNITS USING INEXPENSIVE LOCAL MATERIALS AS FILTER MEDIA FOR SUPPLYING DRINKING WATER TO RURAL COMMUNITIES IN THE LOWER MEKONG BASIN COUNTRIES**

- a) Dr. R.J. Frankel
- b) Sponsored research
- c) Completed
- d) Successful testing of different sizes and designs of two-stage filter units for treatment of surface waters was carried out in the Lower Mekong riparian countries. These units served populations from a few hundred up to five thousand and the finished water was always acceptable for drinking and cooking by the communities.

Normally, two-stage filtration alone produced a treated water with turbidity less than 5 JTU from the turbid raw water but surface waters with abnormally high colloidal turbidities required small dosages of coagulant. In general, treated waters met WHO International Standards for Drinking Water in terms of clarity, color, taste and odour. Coliform (MPN) removal was generally 90 percent or more and the treated water was considered to be suitable for supply without chlorination given the sanitation conditions and water use habits typical of villagers.

The length of filter runs was 4 to 5 months without change of the coconut fibre or burnt rice husk filter media. Gasoline pump breakdown was the only significant operational problem. It was concluded that this type of simple filter system had the potential to provide villages in Southeast Asia with an acceptable and relatively-safe treated water at lower cost than alternative systems for treatment of surface waters.

- e) FRANKEL, R.J. (1974), Evaluation of Low Cost Water Filters in Rural Communities of the Lower Mekong Basin, *AIT Research Report*, Bangkok.

**5034D DEVELOPMENT OF A WATER TREATMENT CANISTER AND SERIES FILTRATION UNIT FOR SUPPLYING DRINKING WATER TO INDIVIDUAL SOLDIERS AND SMALL UNITS IN THE FIELD**

- a) Dr. R.J. Frankel
- b) Sponsored research
- c) Completed
- d) A water treatment filter capable of supplying drinking water to small units in the field was developed and successfully tested over a limited range of field conditions in Thailand. The filter unit contained shredded coconut fiber and burnt rice husks as filter media, two readily available and inexpensive materials found throughout most of Southeast Asia. The clarity of the treated water was generally less than 5 units of turbidity (JTU) and color free. Disinfection with 1 mg/l. chlorine or less is necessary to insure USPHS Drinking Water Standards. A water treatment canister, designed for the individual soldier in the field and using the same filter media, was built and tested in the laboratory. Using the canister intermittently wet-dry-wet-dry appears to be workable and produces a satisfactory water quality. Further testing is needed however, but final design and operating criteria can be recommended.
- e) FRANKEL, R.J. (1973), Development of a Water Treatment Canister and Series Filtration Unit for Supplying Drinking Water to Individual Soldiers and Small Units in the Field, *AIT Research Report*, Bangkok.

**5039B A CONTINUOUS FLOW STUDY OF POTABLE WATER RECLAMATION FROM WASTEWATER OXIDATION PONDS**

- a) Lee Thim Loy (Supervisor: Dr. M.G. McGarry)
- b) Graduate student thesis project
- c) Completed
- d) A study was conducted to evaluate the efficiencies of two renovation processes in treating the effluent from high-rate waste water treatment oxidation ponds, to the extent that the resulting effluent could be used as potable water, meeting WHO International Standards for Drinking Water.

The first unit process series consisted of high rate oxidation ponds, dissolved-air flotation, powdered activated carbon adsorption, upflow sedimentation, dual media filtration and chlorination. The second unit process series consisted of the same units except that powdered activated carbon adsorption, upflow sedimentation, and dual media filtration were replaced by semi-rapid filtration.

The experiments indicated that the stripping pond was capable of removing ammonia nitrogen by as much as 80 percent to a value of 6 mg/l. Filtered water had a turbidity less than 0.8 and 3 JTU for dual-media and semi-rapid filters, respectively. Residual ammonia nitrogen present was completely destroyed by chlorination, at a chlorine rate about ten times that of the ammonia nitrogen concentration.

- e) Thesis No. 588, AIT, 1973.

**5039C NITROGEN REMOVAL BY SECONDARY STRIPPING PONDS IN THE RECLAMATION OF POTABLE WATER FROM WASTEWATER**

- a) Cheung Pak-Shing (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project
- c) Completed
- d) In this research, pilot scale secondary oxidation ponds were investigated for the removal of nitrogen in the reclamation of potable water from wastewater. The parameters studied were pond depth, detention time and level of nutrient supplementation (iron and phosphorus). These parameters were optimized with respect to nitrogen removal efficiency, and the following optimum conditions were obtained: 25-cm pond depth, 2-day detention time, 5 mg/l. of phosphorus and 2 mg/l of iron supplementation. The average effluent total-N and ammonia-N were found to be 5.9 mg/l and 3.45 mg/l respectively, corresponding to average removal efficiencies of 73.3% and 83.1%.

Equations correlating the influent and effluent  $\text{NH}_3\text{-N}$ , Org-N and total-N as well as influent  $\text{NH}_3\text{-N}$  and algal-N produced were also formulated by regression equations. A kinetic model for  $\text{NH}_3\text{-N}$  uptake was developed for the system.

- e) Thesis No. 633, AIT, 1974.

5039D THE RECLAMATION OF DRINKING WATER FROM SEWAGE

- a) Dr. M.G. McGarry
- b) Sponsored research
- c) Completed
- d) Indirect reuse of wastewaters in drinking water supplies is common practice in industrialized states today. A river's waters may be treated, used and returned to the river several times before reaching the sea. Purposeful reuse, where wastewater is reclaimed specifically for direct reuse, is less common. However, technologies are becoming available which can supply a potable water in this fashion thereby responding to the ever increasing needs of several urban cities in arid or water short zones. The investigations reported upon herein have been directed towards improvements upon existing techniques more applicable to the tropical and savanna developing country.

High costs and technical difficulties have been encountered in the removal of nitrogen and low level organics. These are normally removed by activated sludge/lime stripping and granular activated carbon adsorption. In this study, investigations have been conducted into nitrogen stripping by photosynthetic algal growth, using the nitrogen as a nutrient with subsequent algae harvest from ponds, and low level organics reduction by (a) powdered activated carbon treatment and (b) semi-rapid filtration.

Several processes including high rate treatment oxidation ponds, dissolved air flotation, roughing filtration, photosynthetic nitrogen stripping ponds, powdered activated carbon adsorption, dual-media filtration and chlorination were developed and specifically applied to domestic wastewater reclamation for drinking water. These were incorporated into two process streams, one using activated carbon for low level organics removal and the other semi-rapid filtration. Both integrated processes were successful in providing a water capable of meeting WHO International Drinking Water Standards in terms of physical, chemical and bacteriological components.

- e) McGARRY, M. G. (1974), The Reclamation of Drinking Water from Sewage, *AIT Research Report*, Bangkok.

5041B DEVELOPMENT OF TROPICAL DESIGN CRITERIA FOR BIOLOGICAL DISC FILTRATION

- a) Chen Chung Sian (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project
- c) Completed
- d) The effects of disc areal loading and influent COD concentration on the performance of biological disc filter units incorporating an upper aerobic compartment (serving as primary & secondary settlement tank as well as aerobic treatment unit) and a lower anaerobic chamber (acting as a sludge digestion chamber) were studied for the treatment of high COD concentration wastewater from a soft drink bottling plant.

The results indicated that for disc areal loadings in the range of 5 to 80 g/m<sup>2</sup> - day and influent COD concentrations in the range of 300 to 4,000 mg/l, with detention times from 30 minutes to 77 hours, the disc areal loading had a more significant effect than influent COD concentration on total COD and nitrogen removal efficiencies. However, the effects of disc areal loading on suspended solids removal efficiency was insignificant.

A 60% to 85% COD reduction was obtained by the system, with disc areal loadings ranging from 30 g/m<sup>2</sup>-day to 15 g/m<sup>2</sup>-day and COD ranging from 300 mg/l. to 4,000 mg/l.

- e) Thesis No. 590, AIT, 1973.

5041C CARBON AND NITROGEN CONVERSIONS IN ROTATING BIOLOGICAL FILTERS WITH ANAEROBIC DIGESTION

- a) Ouano, E.A.R. (Supervisor: Prof. M.B. Pescod)
- b) Doctoral dissertation
- c) Completed
- d) Studies were conducted on a rotating biological filter unit constructed like an Imhoff tank with rotating contact media incorporated in the sedimentation chamber, in this case called the aerobic chamber. The research formulated basic kinetic equations for substrate degradation and nutrient conversion, oxygen mass transfer and consumption, and mass balance of materials entering and leaving the different parts of the system. With these fundamental

equations, the design of a rotating biological filter unit was approached rationally after kinetic constants and mass transfer coefficients had been determined. The optimal operating conditions for a particular situation were readily estimated mathematically using these fundamental equations.

The oxygen transfer efficiencies for three types of substrates, soft-drink bottling plant wastewater, domestic sewage from AIT campus and synthetic sewage, were determined by running the unit without any slime on the contact media. The values were graphed for various ranges of substrate concentration and for disc, rod and packed-cage forms of rotating media. The weights of oxygen required to remove unit weight of COD for the different wastewaters used were determined by a respirometric study. It was noticed that the limiting stages of the oxygen mass transfer were the transfer of oxygen into the liquid bulk and into the slime from the atmosphere, whereas the transfer of oxygen from the liquid bulk to the slime layer was found to be fast enough, that is non-rate limiting. Although substrate degradation takes place in the slime layer, dissolved oxygen in the liquid bulk exerts a great influence in supplying the required oxygen.

The kinetic equations for substrate and nitrogen conversion in the aerobic chamber of rotating biological filters were verified using a total of 26 sets of experimental data. It was found that except for 3 sets, the magnitude of the values predicted by the kinetic equations were very close to experimental values. The substrate degradation equation applying to the aerobic chamber was optimized using geometric programming and it was found that for optimum conditions, the product of the areal loading and the detention time must be equal at each stage. The number of stages is recommended to be at least four to prevent short circuiting, although this could be lowered to two or three if the required percentage removal of substrate is lower than 90%.

Experiments were carried out to determine the ammonia nitrogen and substrate conversions and gas production in the anaerobic compartment of the rotating biological filter unit located underneath the aerobic compartment. It was found that in the absence of any mixing, most of the volatile solids were raised into the scum layer after three days, which gave a low rate of gas production. The total nitrogen to COD ratio in the anaerobic liquor was found to be 50 percent higher than in the aerobic chamber. The recycle of nitrogen into the aerobic chamber is controlled by displacement of anaerobic liquor due to sludge produced in the aerobic chamber.

- e) Doctoral Dissertation No. D10, AIT, 1974.

#### 5042A INVESTIGATION OF RATIONAL EFFLUENT AND STREAM STANDARDS FOR TROPICAL COUNTRIES

- a) Prof. M.B. Pescod
- b) Sponsored research
- c) Completed
- d) Water quality standards were reviewed and tentative stream standards proposed for use in developing countries of Southeast Asia on the basis of legitimate water uses and adaptation of available data to local conditions. A survey of stream standards and water uses applied in the Southeast Asian region indicated that few countries had adopted standards and practically no attempt had been made to adjust to suit local conditions. Experimental studies suggested that oxidation pond effluent would have a beneficial effect on the oxygen balance of a stream under tropical conditions provided that the algal concentration was not more than  $1 \times 10^5$  cells/ml after dilution in stream. Oxidation ponds were assessed as being more attractive than either trickling filter or activated sludge treatment plants for populations less than 175,000 and land rental costs of U.S. \$0.10 per square metre per year or less.
- e) PESCOD, M.B. (1974), Investigation of Rational Effluent and Stream Standards for Tropical Countries, *AIT Research Report* (Interim and Final), Bangkok.

#### 5044 PLANNING FOR WATER SUPPLY, LIQUID AND SOLID WASTES HANDLING IN ASIAN TOWNS

- a) Ling Hong Chie (Supervisor: Dr. R.J. Frankel)
- b) Graduate student thesis project
- c) Completed

- d) The study evaluated the various alternatives to economically and effectively administer and operate water supply and liquid and solid wastes handling systems in an Asian environment.

For water supply, slow sand filters were found to be preferable, then ground water (if quantity and quality are adequate and suitable) and then rapid sand filters, in order of decreasing attractiveness, especially in economic terms.

For solid waste handling, sanitary landfill was found to be the most attractive alternative for disposal. Separate collection and feeding of food wastes to swine appeared attractive if administrative difficulties could be overcome.

For wastewater collection, the combined system was found to be the most advantageous, while using nightsoil as fertilizer was not found to be an economic alternative.

- e) Thesis No. 592, AIT, 1973.

5045 HOUSEHOLD WATER SUPPLY, HYGIENE AND DIARRHEAL DISEASE IN CENTRAL THAI VILLAGES

- a) M. Krishnaswamy (Supervisor: Dr. R.J. Frankel)  
b) Graduate student thesis project  
c) Completed  
d) Three communities each using river water and klong (canal) water for drinking and household uses were studied to determine the quality of drinking water, hygiene, sanitary practices, nutritional status and the incidence of diarrhoea.

The relationship between water quality, as measured by the MPN coliform index, and the incidence of diarrheal cases showed that an increase in the latter was accompanied by an increase in MPN values. However, the limitations of the MPN index as a measure of water quality were exposed when relatively small changes in quality occurred, by comparison with the ranges represented by a particular MPN value.

In both communities malnutrition in children under five years old was an existing problem and the number of diarrheal cases progressed with the degree of malnutrition.

- e) Thesis No. 580, AIT, 1973.

5046 NIGHTSOIL USE IN AGRICULTURE

- a) J.L. Tabago (Supervisor: Dr. M.G. McGarry)  
b) Graduate student thesis project  
c) Completed  
d) A model of nightsoil conveyance through tank truck collection, heat treatment, and utilization of treated nightsoil in crop production was investigated.

The nightsoil was heat treated for pasteurization so that it could be rendered free of the heat resistant helminth ascariasis. *Ascaris* eggs, which are commonly found in human excreta and are the most resistant intestinal parasite of its kind, were completely destroyed by subjecting them to moist heat conditions at 52, 54, 56, and 60 degrees Centigrade with exposure times of 3 hours, 2 hours, 1 hour, 25 minutes, and 5 minutes. Treatment below 50°C was found to be impracticable because of the long exposure time required for effective treatment. Treatment at 60°C and exposure time of 10 minutes was found sufficient to destroy all parasites and render the nightsoil safe for handling.

The preliminary investigation of nightsoil collection and treatment was favorable in terms of unit costs. For a 50,000 population, the unit cost of collection and treatment was estimated to be about ₱ 12 and ₱ 9 per capita per year, respectively, or a total cost of ₱ 21 per capita per year.

- e) Thesis No. 586, AIT, 1973.

5047 WATER RESOURCES AND QUALITY CONTROL IN BANGKOK-THONBURI

- a) Chay Shiu Chang (Supervisor: Prof. M.B. Pescod)  
b) Graduate student thesis project  
c) Completed  
d) Frequency analysis was used to analyze the daily freshwater flow records of the Chao Phya River. A 28 m<sup>3</sup>/sec overall design flow for the pollution modelling was determined.

Finite difference models for BOD and DO distributions in the Chao Phya River Estuary were developed with the objective of managing water quality in the Estuary. The dissolved oxygen standard for estuary water quality was recommended as 2.0 mg/l. The developed model was applied in the consideration of alternative wastewater treatment schemes, and a fifty percent BOD removal was suggested so as to achieve the DO standard recommended for the Estuary. Annual cost comparisons for several alternative wastewater treatments to meet the required fifty percent BOD removal were also made.

- e) Thesis No. 593, AIT, 1973.

**5048 CHARACTERISTICS OF INDUSTRIAL WASTEWATERS IN TROPICAL DEVELOPING COUNTRIES**

- a) Luo Muh Huo (Supervisor: Dr. M.G. McGarry)
- b) Graduate student thesis project
- c) Completed
- d) Eight categories of industries were selected to evaluate pollutants discharged. These were: pulp & paper, canning, distilling, sugar, tapioca, rubber, abattoir and noodle processing industries. Information regarding manufacturing processes, water supply, wastewater treatment, etc. were obtained. Wastewater flows were also measured and analysed.

Although a number of the industries surveyed had modern manufacturing techniques, their waste discharges were high because of poorly operated waste reuse, recovery and treatment systems.

- e) Thesis No. 589, AIT, 1973.

**5048A COASTAL WATER POLLUTION SURVEY OF CHONBURI PROVINCE**

- a) Dr. M.G. McGarry and Dr. Nubuo Shuto
- b) Sponsored research
- c) Completed
- d) Wastewater surveys of domestic and industrial sources along the coast of Chonburi Province were conducted. Municipal and sanitary district practices of refuse collection and disposal were also ascertained. The beach resorts of Bang Saen and Pattaya were surveyed for sea water contamination by enteric organisms and for practices of sewage disposal by the hotels and businesses operating along the beaches. A preliminary study was made of the inland Huai Khlong Yai/Khlong Phan Thong river system to assess the severity of inland water pollution.

It was estimated that six million kilograms of suspended solids and thirteen million kilograms of biochemical oxygen demand reach the upper Gulf of Thailand each year from Chonburi's coast-line. Nearly all (over 97%) of this waste load is derived from the tapioca starch producing industry, with over fifty starch refineries being located within two kilometres of the coast. These discharges have caused anaerobic benthic conditions in the marine environment which are intolerable for most of the normal littoral flora and fauna of Chonburi's coast.

Severe contamination of faecal origin was also observed in the oyster bed growing area north east of Ban Ang Sila and off the popular beach resorts of Bang Saen and Pattaya. Illegal rubbish dumps and inadvertent littering have resulted in a major problem of refuse being scattered along the beaches and clogging urban storm-water drains.

The study concluded that Chonburi had not yet reached the stage at which immense costs must be incurred to achieve a desirable level of environmental quality through pollution control programs. Environmental planning and implementation through land use control is urgently needed as Chonburi is now entering its most rapid stage of development.

- e) MCGARRY, M.G., SHUTO, N., WHITAKER, T. and CHAVANICH, L. (1972), Coastal Water Pollution Survey, *AIT Research Report*, Bangkok.

**5048B AN EVALUATION OF INDUSTRIAL WASTE WATERS IN THAILAND, WITH SPECIAL REFERENCE TO INORGANIC AND HEAVY METAL WASTE WATERS**

- a) Chen Jyi-Hong (Supervisor: Dr. Maung Nay Htun)
- b) Graduate student thesis project
- c) Completed

- d) Wastewaters from steel, electroplating, battery, petroleum and pharmaceutical factories in Bangkok were quantitatively and qualitatively evaluated together with their manufacturing process and water use.

It was found that heavy metals, especially lead, iron, copper and chromium, in the effluents were discharged at levels exceeding those normally considered acceptable. The study also recommended methods for reducing water use and suggested possible wastewater treatment processes for each of the factories surveyed.

- e) Thesis No. 631, AIT, 1974.

#### 5049 YEAST RECOVERY FROM TAPIOCA WASTE

- a) Ng Jo Shong (Supervisor: Dr. M.G. McGarry)  
b) Graduate student thesis project  
c) Completed

- d) The use of yeast to biodegrade the sugar content in tapioca wastewaters was studied, to determine i) biochemical oxygen demand reduction, and ii) production of yeast for livestock feed protein concentrate and to offset the burden of wastewater treatment. Studies were also conducted to explore the possibility of treating the solid waste (pulp) by acid hydrolysis to provide additional inexpensive sugar for growing yeast, as carbon sources were found to be limiting to the wastewater treatment system.

Two yeast species *Torula* 720802 and 730117 and wild yeast (y-10) 720802 and 730117 were maintained as pure cultures. A wide range of pH was found optimal for *Torula* (4.5-5.5) whereas the yeast y-10 proliferated in a much narrower range, optimizing at pH 5.5.

No nutrients, apart from oxygen and available carbon, were found to be significantly limiting in the wastewater up to about 8g/l of yeast under aerated conditions. The y-10 species of yeast was found less promising under aerated conditions compared with *Torula*, in view of its lower growth rate.

- e) Thesis No. 587, AIT, 1973.

#### 5049A BIOLOGICAL TREATMENT OF TAPIOCA STARCH WASTEWATERS

- a) Wu Jy-Shing (Supervisor: Dr. Nguyen Cong Thanh)  
b) Graduate student thesis project  
c) Completed

- d) The physical, chemical and biological properties of wastewater from the extraction process of a tapioca starch refinery were assessed, and the biological treatability of the settled separator waste using *Torula* yeast was studied. The applicability of the yeast system was evaluated on the basis of the following criteria: maximum extent to which compounds in the waste were assimilated; and the yield of microbial mass that may be expected in a marketable form.

It was found that *Torula* yeast could grow predominantly in the waste and could be acclimatized to most of the compounds in the waste, with reducing sugars and volatile acids being readily removed. The overall COD reduction was around 73%. The yeast mass contained about 50% protein with a yield of 0.5 kg yeast solids per kg COD removed. The protein content of the yeast was significantly decreased when yeast was growing in the non-enriched waste. The only nutrient needed to be added was nitrogen, and supplemented nitrogen utilization was about 1.0 lb of nitrogen per 50 lbs of COD removed. Supplementation of phosphorus and other trace elements was not critical.

- e) Thesis No. 641, AIT, 1974.

#### 5050 STUDY OF POTENTIAL EFFECTIVENESS OF VARIOUS LOCAL MATERIALS IN FILTERING INDUSTRIAL AND DOMESTIC WASTES

- a) Yen Tzu Chen (Supervisor: Dr. R.J. Frankel)  
b) Graduate student thesis project  
c) Completed  
d) A laboratory-scale series filtration wastewater treatment system using local materials as media was developed and tested for industrial and domestic wastes.

Field experimental studies using shredded coconut husk fibre (50 cm) with burnt rice husks (30 cm) at a filtration rate of  $1.24 \text{ m}^3/\text{m}^2\text{-hr}$  appeared feasible as a tertiary treatment process. The average BOD removal efficiency was about 40 percent from the effluent of the oxidation ponds. Using a single medium of shredded coconut husk fibre at a filtration rate of  $2.5 \text{ m}^3/\text{m}^2\text{-hr}$  and a depth of 80 cm, an average BOD removal efficiency of over 40 percent was achieved. This single medium filter was also found to be suitable as a secondary or tertiary treatment process for the treatment of domestic wastes. While with a dual media filter, using pea gravel (50 cm) with sugar cane bagasse ash (30 cm), at a filtration rate of  $1.25 \text{ m}^3/\text{m}^2\text{-hr}$  as a secondary filter, a BOD removal of 55% was achieved. This two-stage filter system appears to have possibilities of being a primary and self-sufficient wastewater treatment process.

- e) Thesis No. 567, AIT, 1973.

5051 BANGKOK NOISE POLLUTION SURVEY

- a) Saman Thangtongtawi (Supervisor: Dr. Maung Nay Htun)  
 b) Graduate student thesis project  
 c) Completed  
 d) A survey of noise level and noise pollution level,  $L_{NP(A)}$ , caused by different noise sources in different activities and areas in Bangkok was conducted. It was found that daytime  $L_{NP(A)}$  had a range of 58.6 to 88.7, corresponding to private residential areas and heavy traffic road junctions, while the night time  $L_{NP(A)}$  ranged between 56.5 and 84.5. Generally, noise levels in Bangkok commercial, manufacturing and industrial areas exceeded the U.S. Minnesota State standards. In areas designated as residential, the noise level was less than these standards.  
 e) Thesis No. 639, AIT, 1974.

5052 TROPICAL FRESHWATER FISH TOLERANCE AND TOXICITY STUDY

- a) Lim, Siew Yoke (Supervisor: Prof. M.B. Pescod)  
 b) Special studies project  
 c) Completed  
 d) *Cyprinus Carpio*, an economically important fish in the tropics was used to test the toxicity of 4 heavy metals, 4 pesticides and one herbicide. The limiting D.O. for *Cyprinus Carpio* was also investigated. All the experiments were done at a constant temperature of  $30^\circ\text{C}$ .

It was found that  $\text{Cu}^{++}$  is very toxic to carp, the median tolerance limit of 96 hours is as low as 20 ppb.  $\text{TL}_{m96}$  of  $\text{Cd}^{++}$ ,  $\text{Zn}^{++}$  and  $\text{Pb}^{++}$  were 0.16, 1.30, 1.05 mg/l as the metals, respectively. Lethal concentrations for  $\text{Zn}^{++}$  and  $\text{Pb}^{++}$  toxicity, but longer periods of time were needed for  $\text{Cu}^{++}$  and  $\text{Cd}^{++}$  to achieve threshold concentrations.

Endrin, a chlorinated hydrocarbon was the most toxic pesticide to fish among those tested. The threshold concentration for *Cyprinus Carpio* was 0.14 ppb. All the pesticides and herbicides tested (endrin, D.D.T., dieldrin parathion and 2-4 D Na Salt) approached threshold concentrations after one week of exposure. Threshold concentrations of D.D.T., dieldrin, parathion and 2-4 D Na salt were 0.042, 0.02, 0.88 and 455 mg/l as active ingredient, respectively. Chlorinated pesticides were more toxic than organic phosphate pesticides, and herbicides were less toxic than pesticides.

The limiting D.O. for *Cyprinus Carpio* ranged from 0.8 to 1.1 mg/l in an enclosed chamber with final  $\text{CO}_2$  below 30 mg/l and a decreasing rate of D.O. of approximately 0.3 mg/l per hr.

- e) Special Studies Project Report No. 58, AIT 1974.

5053 SOFT DRINK PLANT WASTE HANDLING STUDY

- a) Tsui Tak Sang (Supervisor: Dr. Ping Yi Yang)  
 b) Graduate student thesis project  
 c) Completed  
 d) Three types of activated sludge pilot plant, conventional, contact-stabilization and extended aeration processes, were set up to determine the optimum operational parameters for treating a soft-drink bottling plant wastewater. Operational cost comparisons were made between the actual activated sludge treatment plant (with 18 hr aeration) and the pilot plants, on the basis of equivalent performance.

The results obtained showed that the biodegradability of the waste could be as high as 99%. The sludge volume index of the sludge obtained was always above 150. From the study, it was concluded that the conventional process gave high sludge production, contact-stabilization yielded unsatisfactory effluents, and extended aeration yielded sparkling effluents together with a lower production of sludge.

Investigation into the actual plant performance showed that nutrient supplementation requirements were a little less than those in the equivalent pilot plant study. Cost analyses gave a cheaper operational cost for the system operated at lower F/M ratios, but the reduction of cost was not large.

- e) Thesis No. 640, AIT, 1974.

#### 5053A ACTIVATED SLUDGE HANDLING FOR A SOFT DRINK BOTTLING PLANT WASTE

- a) Frans Mulia Purnama (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project
- c) Completed
- d) This research attempted to analyse the wastewater treatment plant sludge handling system at the Serm.Suk Co., Ltd. Bangkok, a soft-drink bottling plant. An investigation of several unit processes for treating the sludge from the activated sludge process was carried out. Secondary sludge from the plant was subjected to gravity thickening, dissolved air flotation, aerobic and anaerobic and anaerobic digestion and sand bed drying.

The results obtained in treatment of this sludge indicated that flotation was more efficient than gravity thickening even though the cost would be higher. Flotation followed by aerobic digestion and sand bed drying were found to be more efficient than flotation followed by anaerobic digestion and sand bed drying. The anaerobically and aerobically digested sludges had low fertilizer value.

- e) Thesis No. 638, AIT, 1974.

#### 5054 ANAEROBIC AND FACULTATIVE PONDS FOR TROPICAL WASTE TREATMENT

- a) Frans Djaja Purnama (Supervisor: Prof. M.B. Pescod)
- b) Special studies project
- c) Completed
- d) The purpose of the research was to observe and compare two systems of stabilization ponds, the first consisting of a series of small ponds and the second a single-stage pond with equivalent total area to the alternative system. Two systems of pilot-scale ponds were set up outdoors for treatment of AIT sewage.

The results obtained indicated that areal and volumetric COD removal in all ponds increased with the increase in areal and volumetric COD loading at detention times from 0.5 to 4 days. Effluent quality from a series of small ponds was found to be slightly better than that from a single-stage pond with equivalent area and input COD. However, the difference was very small, in this case 7 percent, and a single-stage pond would be more economical in construction.

- e) Special Studies Project Report No. 24, AIT, 1974.

#### 5055 THE ANAEROBIC CONTACT PROCESS FOR TROPICAL WASTE TREATMENT

- a) Julian Centeno, Jr. (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project
- c) Completed
- d) This research was a short-term investigation of the performance, in terms of COD removal, of anaerobic contact processes in treating a dilute organic waste ( $COD_T = 800$  mg/l). The two systems studied were the anaerobic filter and the dispersed anaerobic contact system. An important variable in this study was temperature since the units were allowed to operate at ambient temperatures characteristic of tropical weather conditions.

The results were encouraging, although the total COD removal by the filters was low (<50%) at the loadings employed. What is more important, however, is the fact that the experimental systems were able to tolerate low pH and alkalinity, and high volatile fatty acids concentrations not normally encountered in well-operating anaerobic digesters.

On the whole, a loading of 0.000648 kg COD/l. day produced the highest total COD removal of 47% and a loading of 0.00280 kg COD/l day gave the lowest COD removal of 20% for the anaerobic filters. Similarly, for the dispersed anaerobic contact system, the highest total COD removals (61-100%) were observed at a low loading of 0.000212 kg COD/l day and the lowest (38-64%) were obtained at the highest applied loading of 0.00280 kg COD/l day.

- e) Thesis No. 630, AIT, 1974.

**5056 EFFECTS OF SOME OPERATING VARIABLES ON BIOLOGICAL FILTRATION OF DOMESTIC WASTEWATER IN THE TROPICS**

- a) Irshad Hussain (Supervisor: Prof. M.B. Pescod)  
 b) Graduate student thesis project  
 c) Completed  
 d) Studies were carried out on laboratory and pilot scale trickling filters employing rock and gravel of various sizes as media for treating a weak domestic sewage with BOD averaging 121 mg/l. Tests performed on 4" to 2½" size rock trickling filters, 3 m in depth, revealed that a BOD removal efficiency of 80% to 88% can be achieved at hydraulic loading rates of 1.2 to 4.9 m<sup>3</sup>/m<sup>3</sup> day, corresponding to organic loadings of 125 to 684 g BOD/m<sup>3</sup> day. The BOD<sub>5</sub> removal efficiency increased to 93% with a recirculation ratio of 3.0. BOD<sub>5</sub> removal efficiency increased as a first order relationship with respect to filter depth.

A comparison of cost to arrive at the optimum media with regard to BOD<sub>5</sub> removal efficiency indicated that 4" to 2½" size rock could be employed more economically than other media tested in this study for the treatment of domestic wastewater in tropical regions. It was found that a previous trickling filter performance formulation based on regression analysis of past operating data most closely fitted performance data collected during this study.

- e) Thesis No. 635, AIT, 1974.

**5057 ROLE OF WATER QUALITY ON DIARRHOEAL DISEASES IN SOME VILLAGES OF CENTRAL THAILAND**

- a) Shadab Ahmad (Supervisor: Dr. Ping Yi Yang)  
 b) Graduate student thesis project  
 c) Completed  
 d) Six villages in Bang Pa In District, Central Thailand were studied to determine the bacterial quality of their water supplies and the incidence of diarrhoeal diseases. Two subdistricts were using klong (canal) and river water as the sources of their water supply. Studies on water supply, personal hygiene and nutritional status of children under 5 years of age were also made.

During the 18 weeks period of study, only three cases of diarrhoea were reported in one village using river water as the source of water supply. Water from the river or klong is stored in large earthenware jars, and alum is added for partial treatment. The storage time varies from 1-3 weeks and this treatment reduces the number of coliforms in the raw water to one hundredth of the original level. Rain water collected during the wet season is preferentially used for domestic purposes and usually has better bacterial quality than river or klong water.

General sanitation conditions in the two subdistricts are not good, but good eating habits and personal cleanliness helped in the control of diarrhoeal cases. Children were found to be undernourished if weight is considered as a parameter of malnutrition.

- e) Thesis No. 628, AIT, 1974.

**5058 DESIGN PARAMETERS FOR OXIDATION DITCHES IN THE TROPICS**

- a) Yau Chap Hoi (Supervisor: Prof. M.B. Pescod)  
 b) Graduate student thesis project  
 c) Completed  
 d) A pilot scale oxidation ditch was built to evaluate whether design parameters used in Europe could be improved under tropical conditions. While nutrients and dissolved oxygen concentrations were maintained at non-limiting levels, eight different organic loadings, ranging from F/M = 0.07 to 0.78, were studied in treatment of a soft-drink bottling plant wastewater at a common detention time of 48 hours. Results showed that the effluent COD in-

creased with increasing loading but the COD removal efficiency remained above 96% throughout the whole organic loading range. The ash content of the sludge was about 24% at loadings below  $F/M = 0.2$ , but decreased to 13% at higher organic loadings.

Keeping the organic loading at  $F/M$  about 0.38, the results of three tests with different detention times showed that the change of hydraulic retention time from 48 hours to 17.5 hours did not change the COD removal rate, nor the ash content of the sludge. However, at the same organic loading, a low influent COD lowered effluent COD and SVI.

In a separate test, laboratory scale aeration units were set up to find out which chemicals could restore the settling properties of a bulking sludge, once it occurred in an oxidation ditch, by changing its microbial composition. It was found that addition of calcium acetate at a concentration of 0.6 g per litre of bulked sludge with  $\text{NaNO}_3$  at a concentration of 0.5 g per litre of bulked sludge, suppressed the growth of *Sphaerotilus*, and selectively promoted the growth of other desirable bacteria so that the bulking problem was completely eliminated in a period of 8 days.

- e) Thesis No. 643, AIT, 1974.

5059 HEAVY METAL CONTAMINATION OF THE QUAE YAI RESERVOIR

- a) Chongrak Polprasert (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project
- c) Completed
- d) An ecological reconnaissance of the proposed Hydro-electric Dam scheme on the Quae Yai River had indicated potential heavy metal contamination of the reservoir from the operation of lead mining and processing within the reservoir basin. This might result in bio-concentration of such metals as lead and cadmium in the biota.

Heavy metal pollution surveys of water, soils, and biological samples within the Quae Yai basin and elsewhere in Thailand (to obtain background data) were conducted between April 1973 and February 1974. Samples were analysed for lead, cadmium, copper and zinc. An ecological survey was carried out along Huai Khitti, a tributary of the Quae Yai River, which is the first stream to receive the tailings effluent from the mine's flotation concentration plant. A study of the effects of lead and cadmium on people was also carried out at the Bo Ngam mine and in the slag washing area. A laboratory investigation of methods for heavy metal removal from the tailings effluent and water was conducted.

It was concluded that man, fish and other aquatic biota in the Quae Yai basin do not suffer excessive harmful effects from heavy metal pollution. However, the subclinical effects of chronic intake and exposure to current heavy metal levels in the water and soil are unknown. The need to reduce heavy metals reaching the Quae Yai river is discussed with relevance to case studies of Huai Khitti and the Bo Ngam slag washing area. Laboratory results suggest that settling ponds can be adopted for the treatment of effluents.

- e) Thesis No. 637, AIT, 1974.

McGARRY, M.G., POLPRASERT, C. WHITAKER, T., and LUO, M.H. (1974). Heavy Metal Pollution and Development of the Quae Yai River, Thailand, *Proceedings Minerals and the Environment Symposium*, Institution of Mining and Metallurgy, London.

5059A ECOLOGICAL RECONNAISSANCE OF THE QUAE YAI HYDROELECTRIC SCHEME

- a) Dr. M.G. McGarry and others
- b) Sponsored research
- c) Completed
- d) An ecological reconnaissance relative to the Hydroelectric Development Scheme proposed for the Quae Yai River Basin of Western Thailand was conducted for the Electricity Generating Authority of Thailand. Potential problems caused by dam construction and operation were identified and actions by which these might be overcome or satisfactorily minimized were recommended. Further investigations were advised in areas where data and information were found insufficient.

Health and welfare aspects of approximately eight thousand Thai and Karen inhabitants whose homes would be inundated by the reservoir were investigated. Consideration was given to their possible relocation and consequent changes in occupations, life-styles and physical and social surroundings. Recommendations were made in relation to these and other inhabitants of the river basin.

The biotic communities of the reservoir area were considered and the value of forestry stands in the area to be inundated were assessed. As aquatic plants are commonly a problem with irrigation projects and reservoir management in Thailand, the potential for aquatic plant growth in the Quae Yai valley was evaluated and counter measures recommended. Other aspects included in the reconnaissance were the possibility of incompatibility of the dam's operation as a hydroelectric scheme with other resource needs of the region, changes in the aesthetic quality of the area, down-stream scour, watershed erosion and the impact of dam operation on ground water levels and physico-chemical changes in agricultural soils of irrigation areas.

Recommendations were made for further archaeological surveys in the river basin (as the Quae Yai basin is viewed as being of prehistoric and historic archaeological value).

Apart from those consequences requiring further investigation, and provided that the several recommendations made in the report were instituted, it was considered that adverse ecological consequences of the dam's installation could be avoided or satisfactorily minimized.

- e) McGARRY, M.G. and others (1972), Ecological Reconnaissance of the Quae Yai Hydroelectric Scheme, *AIT Research Report*, Bangkok.

5059B SELECTED ECOLOGICAL SURVEYS OF THE QUAE YAI HYDROELECTRIC SCHEME

- a) Dr. M.G. McGarry, Dr. Santasiri Sornmani & Dr. Chester F. Gorman
- b) Sponsored research
- c) Completed
- d) The ecological reconnaissance of the proposed Quae Yai Hydroelectric Development scheme conducted during 1972 recommended action by which potential problems caused by the Ban Chao Nen Dam's construction could be overcome or satisfactorily minimized. This study included further investigations which were suggested where data and information had been found to be insufficient. These were related to medical and archaeological aspects of the Quae Yai basin, to the impact of heavy metal mining operations within the basin and to the deterioration in the aesthetic quality of the Quae Yai Valley.

Although schistosomiasis, opistorchiasis and paragonimiasis were not found in the basin, several of their intermediate hosts were. Concern is expressed over the likelihood of introduction of these diseases to the area by the in-migrating labourers from the north-east and central Thailand.

Heavy metal pollution of alluvial soils, water and aquatic biota was observed to be a result of lead mining, ore concentration and spent slag washing operations in the basin. The level of contamination is not considered high enough to give rise to concern for human health with the exception of that of the slag washing labourers who live in what appears to be an environment heavily polluted by lead. Amongst others, recommendations are given for wastewater treatment and water quality monitoring programs.

Alternatives to the proposed transmission line routing, rock quarries and soil borrow area sites were investigated. An acceptable alternative transmission line route is suggested as are recommendations for alternative quarry site investigations and the return of the soil borrow areas and quarry sites as far as possible to their original condition.

The existence of several archaeological sites which may be submerged or located adjacent to the reservoir has been demonstrated. These sites, ranging from Hoabinhian rock shelters to historic structures, evidence a long and continuous human occupation of the Quae Yai Valley and underscore the area's archaeological importance. Recommendations are given for further investigations including excavations.

It was concluded that apart from those aspects requiring further investigation, and provided that the several recommendations arising both from this work and the former ecological reconnaissance were implemented – there was no single ecological consequence or combination of consequences which were of sufficient importance to deter or preclude construction of the Ban Chao Nen Dam.

- e) McGARRY, M.G. SORNMANI, S. and GORMAN, C.F. (1974), Selected Ecological Surveys of the Quae Yai Hydroelectric Scheme, *AIT Research Report*, Bangkok.

5060 POLLUTION SURVEY OF THE CHAO PHYA RIVER IN PATHUMTHANI PROVINCE

- a) Artemio Samoy Bernadino (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project

- c) Completed
- d) Factors which determine whether anaerobic conditions will occur in the Chao Phya River in Bangkok or not are the dissolved oxygen and BOD concentrations of the water entering this downstream reach from upstream. The amount of BOD added to the river in Pathumthani Province and the dissolved oxygen level in this reach were the main focus of this research.

The pollutional contributions of industry, klongs (canals), and houses along the river banks were determined. Industry was found to be the major source of pollution accounting for at least 73% of the total. Klongs were found to be relatively unpolluted. Dissolved oxygen in the Chao Phya River in Pathumthani was found to be low relative to the saturation value. A large drop in dissolved oxygen was found to have occurred upstream of Km. 90 from the mouth of the river. The BOD concentration in the river water was found to be very low, indicating that the river was relatively unpolluted in the reach in Pathumthani at the time of the study. The deoxygenation rate constant of the river was found to be much higher than the laboratory rate of deoxygenation constant. Using an oxygen balance, a value of 0.31 per day was found for the deoxygenation rate constant at a river discharge of 500 m<sup>3</sup>/sec. The deoxygenation rate constant increased with discharge.

Pesticide analysis of water samples taken from the river showed that pesticide pollution does not exist in the river at the present time.

- e) Thesis No. 629, AIT, 1974.

5061 AN EVALUATION OF SOME PHYSICO-CHEMICAL PROCESSES FOR TREATING TEXTILE WASTEWATER

- a) Chen Shu Liang (Supervisor: Dr. Maung Nay Htun)
- b) Graduate student thesis project
- c) Completed
- d) Physico-chemical processes such as series filtration using shredded coconut husk fibre and burnt rice husk as filter media, granular and/or powdered activated carbon adsorption, and chemical coagulation were studied for the treatment of high colour and low BOD synthetic textile manufacturing wastewaters.

Both series filtration and carbon adsorption were found ineffective in colour removal and these processes had short operational times. Chemical coagulation, using alum at 200 mg/l and aided with 0.4 mg/l of san polymer A510, was found to be capable of removing 90% of the colour and 50% of the COD at a pH of 6.0.

- e) Thesis No. 632, AIT, 1974.

5062 PERFORMANCE OF TUBE SETTLERS IN CLARIFICATION OF TURBID TROPICAL SURFACE WATERS

- a) Muhammad Amin Mian (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project
- c) Completed
- d) The research was conducted at pilot-plant scale to investigate the performance of tube-settlers and develop design criteria for treatment of tropical turbid surface waters. The evaluation of horizontal tube-settler was carried out using a "Neptune Microfloc" 10 gpm pilot-plant (5-degree tube inclination). The tubes were of 1-in. depth and 2 ft length. An inclined tube settler, with tubes of 2 x 2 in. cross-section, 3 ft length and 60 degrees angle of inclination, was specially designed for this study.

It was found that horizontal tube-settlers were efficient devices in turbidity removal but sludge storage capacity was a limitation on the system. At flow rates of 2.45 m<sup>3</sup>/m<sup>2</sup>-hr (1.0 gpm/ft<sup>2</sup>) and above, and with raw water turbidities of 50-80 Jackson turbidity units (JTU), tubes were filled in about one hour. Flow-rates of 0.98 m<sup>3</sup>/m<sup>2</sup>-hr (0.4 gpm/ft<sup>2</sup>) and 1.96 m<sup>3</sup>/m<sup>2</sup>-hr (0.8 gpm/ft<sup>2</sup>) with average raw turbidities of 60 JTU, gave run lengths of 24 and 8 hours, respectively, for 70-percent removal efficiency. The corresponding detention times were 37.5 and 18.9 minutes. Thus, under these conditions the advantages of short detention times were lost due to the limitation of sludge storage capacity. Dual-media (Anthracite-Sand) filters did not perform satisfactorily when influent turbidities were above 10 JTU.

The inclined tube-settlers performed very well at flow rates as high as 10.0 m<sup>3</sup>/m<sup>2</sup>-hr (4.0 gpm/ft<sup>2</sup>) and detention time of 5.5 minutes, giving about 80 percent turbidity removal.

al operating at influent turbidities of 95 JTU. Thus, the high-rate capabilities of the tube-settling system were clearly demonstrated. The use of tube-settlers in treatment plants will afford substantial savings in space requirements and capital costs.

- e) Thesis No. 636, AIT, 1974.

5063 BANGKOK AIR POLLUTION

- a) Prof. M.B. Pescod  
b) Sponsored research  
c) Completed

- d) A study was carried out to evaluate the air pollution situation in streets of Bangkok and derive mathematical models of pollutant diffusion to be used for air quality management purposes. Yawaraj Road and Rama IV Road were adopted for ambient air monitoring and carbon monoxide was the principal pollutant investigated, although some data were collected for particulates and nitrogen oxides.

The results indicated that undesirable levels of carbon monoxide persisted for most of the daytime in Yawaraj Road during periods of low wind velocity as a result of the narrowness of the street and the high volume and low speed of the traffic. Carbon monoxide concentrations were normally lower in Rama IV Road under similar wind conditions and at similar traffic volumes because the street is wider and average traffic speed is greater. A maximum one-hour average carbon monoxide concentration of 33 ppm was recorded in Yawaraj Road. Pollutant concentration was found to decrease with increase in wind velocity and sampling height in the street. A preliminary survey of the effects of air pollutants on public health and materials in Yawaraj Road proved inconclusive but generally indicated no serious problems and adaptation of the inhabitants to environmental conditions.

A micromodel representing diffusion of pollutants in the street region was developed and verified using ambient data. Input variables were wind velocity, traffic volume and traffic speed but the model was found to have greatest sensitivity to wind velocity. Included as parameters in the model were building height and street width.

The diffusion of pollutants over the city was represented by a macromodel, but insufficient ambient air pollution data for Bangkok precluded verification of this model. Its use was illustrated by calculations for a typical area of Bangkok and it was found that the concentration of pollutant in any square of 500 metre sides was more dependent on the emission rate of the square than on upwind emissions.

The study accentuated the desirability of increasing traffic speeds in Bangkok, particularly in narrow streets, and reducing exhaust emissions by encouraging proper engine maintenance. It also pointed out the need for further monitoring of ambient air pollutants and vehicle exhaust analysis to fully verify use of the micromodel for future vehicle controls and city planning.

- e) PESCOD, M. B. and OUANO, E. A. R. (1973), Bangkok Air Pollution, *AIT Research Report*, Bangkok.

5063 A PRELIMINARY MEASUREMENTS OF EXHAUST EMISSIONS FROM MOTOR VEHICLES IN BANGKOK

- a) Wong Voon Pong (Supervisor: Prof. M.B. Pescod)  
b) Special studies project  
c) Completed

- d) A 7-mode test driving cycle was developed specifically to represent driving conditions in one of the most congested roads in Bangkok.

Exhaust emissions were measured from 35 vehicles (31 gasoline and 4 diesel-powered) run on a chassis dynamometer following the developed driving cycle. Tests were carried out on 9 of the above vehicles to determine the total volume of exhaust gas produced and its relationship with the gross vehicle weight. Both carbon monoxide (CO) and hydrocarbon (HC) mass emissions varied widely, even among similar vehicles, but CO and HC mass emissions increased and decreased, respectively, with increasing gross vehicle weight. The estimated average mass emissions of CO and HC per unit of distance travelled were 135.0 g/Km (5.6%) and 8.2 g/Km (1340 ppm), respectively.

- e) Special Studies Project Report No 56, AIT, 1973.

**5063B VEHICLE EXHAUST EMISSIONS EVALUATION IN BANGKOK**

- a) Tan Cheng Teik (Supervisor: Prof. M.B. Pescod)
- b) Graduate student thesis project
- c) Completed
- d) Increasing concern about air quality stimulated work in this area and the main purpose in this study was to evaluate the total amount of CO and NO<sub>x</sub> emitted by motor vehicles between 7 a.m. and 7 p.m. in a selected area in Bangkok. A traffic pattern survey along the major roads in the region was conducted and exhaust emissions were analyzed when a range of vehicles were tested under a derived Driving Cycle which simulated driving conditions in the study region.

The feasibility of using an empirical equation to represent exhaust emission rates was considered and the equation:  $E = 287S^{-0.75}$  was found to be a good estimate of g-CO per vehicle-km emitted, where S is the average route speed in km/hr.

- e) Thesis No. 642, AIT, 1974.

**5063C A SIMPLIFIED MICROMODEL OF BANGKOK AMBIENT AIR**

- a) Suporn Koottatep (Supervisor: Prof. M.B. Pescod)
- b) Special studies project
- c) Completed
- d) Air pollution in Bangkok is becoming a major problem and the main purpose of this study was to develop a simple micromodel of the Bangkok street situation using a box model which allowed the calculation of carbon monoxide concentrations without the use of computer programming. In addition, the relationships and effects of wind velocity on CO concentration were formulated. The value of CO levels in Bangkok streets was found experimentally to be in the range of 5.5 to 27.2 ppm.
- e) Special Studies Project Report No. 25, AIT, 1974.

**5063D VEHICLE EMISSIONS AND AIR POLLUTION IN BANGKOK STREETS**

- a) Prof. M.B. Pescod, Dr. R.H.B. Laxell and Dr. Maung Nay Htun
- b) Sponsored research
- c) Completed
- d) This project, supported by the Shell Company (Thailand) Ltd., was a continuing study of the levels of air pollutants in Bangkok streets and of the variables which affect those levels.

A standard test driving cycle of duration 163 seconds was developed to represent the typical pattern of driving in a central area of Bangkok. This consisted of acceleration ranges from 0 to 30 km/hr and 30 to 50 km/hr with cruising periods at constant speeds of 30 and 50 km/hr. Deceleration ranges were from 50 to 30 km/hr and 30 to 0 km/hr, without intervening cruise period. Exhaust emissions of a range of vehicle types and sizes were measured and analyzed when the vehicles were driven over the standard cycle on a chassis dynamometer. The average CO concentration in vehicle exhausts, averaging 700 litres in volume over the driving cycle, was found to be 3.7%, and the CO mass emission rate 24.4 g per km. NO<sub>x</sub> concentration averaged 463 ppm, giving an NO<sub>x</sub> mass emission rate of 0.5 g per km (as NO<sub>2</sub>), CO emission was found to increase and NO<sub>x</sub> emission to decrease with increase in cruising speed but no evidence of either being dependent on vehicle age was obtained.

Ambient air was sampled at eight locations on four major Bangkok streets and analyzed for concentrations for CO, NO<sub>x</sub>, particulates (as coefficient of haze, COH), hydrocarbons and organic lead. The highest hourly mean concentration of carbon monoxide in ambient air samples from Bangkok streets was 33 ppm at 9-10 a.m. in Jawaraj Road. At other sites, the mean hourly CO concentration was low in the morning, rose gradually to a peak at 2 to 3 p.m. and fell again in the late afternoon. The level of CO air pollution was positively correlated with traffic density but the effect of wind speed was found to be slight. However, for wind speeds up to 7 km/hr in Bangkok streets enclosed by buildings, the strong correlation between wind speed and traffic volume suggested that the movement of vehicles, and not the general movement of air over the city, was mainly responsible for street level wind speed. CO concentration decreased steadily throughout the night in the street tested, and a minimum of 4 ppm was found to occur at 3-4 a.m. A decrease of CO concentration was obtained with increase in sampling height but no significant difference was found across

the width of a street, even when traffic volume was unevenly distributed on the two sides of a road. Outdoor levels of CO were found to be 10 to 20 percent higher than indoor levels for 85 percent of the time measurements were made. The short duration rain experienced on some days during the study period had no appreciable effect on CO concentrations in the streets. A fair correlation was found to exist between average CO concentration for each hour and the average traffic density divided by the average wind speed. Curves were drawn to be fairly representative of narrow Bangkok streets, 11 to 15 metres wide, and wider streets, 17 to 20 metres wide. Data for NO<sub>x</sub> and particulates concentrations were also collected at each street sampling station and some measurements of organic load concentrations were also made.

- e) PESCOD, M.B., EXELL, R.H.B., CHEN, C.S. and HTUN, N. (1975), Vehicle Emissions and Air Pollution in Bangkok Streets, *AIT Research Report*, Bangkok.

5066 CHEMICAL AND BIOLOGICAL WASTE TREATMENT OF PETROLEUM REFINERY AND PETROCHEMICAL WASTES

- a) Zahid Mahmud (Supervisor: Dr. Nguyen Cong Thanh)  
 b) Graduate student thesis project  
 c) Completed  
 d) Analyses of three petroleum refineries in Thailand were conducted and an extensive study of one of these refineries was then performed. Daily grab wastewater samples were collected, composited and analyzed for physical, chemical and biological characteristics. Diurnal and daily wastewater flow fluctuations were recorded. Existing wastewater generation, collection and treatment systems were studied and wastewater segregation, reuse and effective treatment processes were suggested.

Chemical coagulation-precipitation of refinery effluent after oil separation was investigated using alum and ferric chloride with and without coagulant-aids. This resulted in 30-35 percent total COD reduction and 90-95 percent insoluble COD reduction. Oil removal was 85-90 percent.

Activated sludge units, both batch and continuously-fed systems, were operated using refinery effluent after oil separation and a synthetic petrochemical waste as influents. COD reduction of 40-50 percent, phenol reduction of 80-85 percent, sulfides reduction of 75-80 percent and phosphate reduction of 75-80 percent were achieved. An aerated lagoon was used to polish the effluents from the activated sludge unit. Final effluent COD was 40-45 mg/l; phenols, 0.3-0.5 mg/l; sulfides, 0.2-0.9 mg/l; and phosphates 0.6-1.4 mg/l. Final effluents were found to be non-toxic to fish, based on the results of bioassay tests.

- e) Thesis No. 756, AIT, 1974.

5067 WASTEWATER TREATMENT EVALUATION FOR DAIRY INDUSTRIES

- a) Kalaya Taimmanenate (Supervisor: Dr. Nguyen Cong Thanh)  
 b) Graduate student thesis project  
 c) Completed  
 d) Dairy wastewater containing carbohydrates proteins and fats exerts a high demand for oxygen in receiving streams. The sources of wastewaters in a local dairy industry were investigated. It was found that the waste was highly organic with high COD, most of it soluble and biologically degradable. However, it was found to be deficient in nutrients. Biological treatability studies indicated the feasibility of using biological treatment methods for this waste, and the activated sludge and aerated lagoon processes were chosen for further investigation.

Batch activated sludge process study showed that the oxidation of organic matter was very rapid in the first 4 hours and endogenous respiration took place after 4 hours of aeration. Continuously-fed activated sludge units gave the optimum loading rate of 1.0 g COD/g MLSS - day with a COD removal efficiency of 92 percent. For aerated lagoons, 27-day detention time was considered optimum and this gave an efficiency of 90 percent.

A study of the installed aerated lagoon at a factory was carried out and necessary improvements were suggested.

- e) Thesis No. 758, AIT, 1974.

5068 USE OF LOCAL RAW MATERIALS FOR ABSORBING OIL SPILLS

- a) Snong Tragulsuk (Supervisor: Dr. Maung Nay Htun)
- b) Graduate student thesis project
- c) Completed
- d) Five natural organic sorbents, rice husk, rice straw, coconut husk, coconut fibre sheet, loose coconut fibre and polyurethane foam were evaluated for sorption effectiveness of unweathered diesel, light fuel and crude oils. Coconut husk was found to be the most efficient sorbent with a high oil/water sorption capacity ratio, followed by rice straw and coconut fibre sheet. However, polyurethane foam was a better sorbent than any of the natural materials tested. Coconut husks and polyurethane foam were found to have oil sorption capacities ranging from 5.29 to 5.47 g/g and 28.73 to 32.05 g/g, respectively, after a saturated sorption time of 30 minutes.

The effects of slick thickness, surface area, viscosity and surface tension on sorption efficiency were also evaluated.

- e) Thesis No. 757, AIT, 1974.

5068 A THE STUDY OF TREATMENT OF OIL SPILLS AND WASTES

- a) Dr. Maung Nay Htun
- b) Sponsored research
- c) In progress
- d) This research project, supported by Esso Standard Thailand Limited, is a study of the feasibility and efficiency of oil slicks sorption by rice straws and coconut husks. The parameters to be investigated are: the oil slick's viscosity, density and thickness; the sorbent's mass and shape characteristics; and wave, current and wind conditions. Studies connected with this project will be divided into three phases. The first phase will involve laboratory determination of ideal sorption efficiencies. The second phase will be the scaling up to experiments using a wave basin to simulate and control environmental parameters that would affect sorption efficiencies. Dimensional analysis will be developed and used to group together the parameters for investigation. The third phase will involve testing of oil slick sorption under real conditions and comparing and verifying the dimensionless parameters developed to determine the conditions for maximum oil slick sorption efficiency.

The project will also investigate techniques for practical sorbent application and recovery.

5069 STUDIES ON DESIGN PARAMETERS OF THE COMPLETELY MIXED ACTIVATED SLUDGE PROCESS

- a) Chanika Thijayung (Supervisor: Dr Ping Yi Yang)
- b) Graduate student thesis project
- c) Completed
- d) Lack of appropriate design parameters for biological wastewater treatment processes cause difficulties in the operation of existing plants and in the design of new treatment plants. These difficulties can be eliminated if fundamental design parameters have been evaluated.

The evaluation of design parameters included a comparison of the "MONOD", "ECKENFELDER" and "McKINNEY" theories. Both synthetic (glucose) and industrial (soft drink bottling plant) wastewaters were used in the study. Experiments were conducted at the controlled temperature of 30°C, and batch and continuous-flow cultures (without sludge recycle) were operated.

It was found that the values of  $\mu_m$ ,  $K_s$  and  $Y$  at 30°C were higher than the equivalent parameters evaluated at a temperature of  $25 \pm 2^\circ\text{C}$  for the same synthetic waste. The parameters evaluated for both the synthetic and the industrial waste were compared and it was found that they were the same using the three approaches. However, in using the parameters evaluated for the synthetic waste to predict the effluent quality (e.g. filtrate COD) of the industrial wastewater, it was found that the "MONOD" and "ECKENFELDER" formulae provided a better fit than the "McKINNEY" formula.

- e) Thesis No. 759, AIT, 1974.

5070 A SOLAR ENERGY PROJECT

- a) Dr. Maung Nay Htun

- b) Sponsored research
- c) In progress
- d) This project is sponsored by the John F. Kennedy Foundation and involves the study of solar energy applications in three major areas. The first is in potable water supply and will deal with the testing and operation of various solar still designs when operated under different ambient conditions and fed with different types of water. The second application is in solar driers and will involve the design and testing of practical and efficient units to dry commodity products. The third area of application is the study of the bioconversion of methane from waste products. The major emphasis would be on the development of small scale production units that could be used in villages.

**5078 A PERFORMANCE EVALUATION OF THE BIO-DRUM ROTATING BIOLOGICAL FILTER TREATING TROPICAL ORGANIC WASTEWATERS**

- a) Prof. M. B. Pescod
- b) Sponsored research
- c) In progress
- d) The packed bio-drum developed by the European Plastic Machinery Mfg Co. for treatment of organic wastewaters using the principle of rotating biological filtration has not been tested under tropical conditions. It is the objective of this research to evaluate the performance of a pilot scale bio-drum in treating domestic and industrial wastewaters in Thailand. The unit will be operated at different organic loading levels and the effects on performance determined for each waste. Major dependent variables will be BOD<sub>5</sub>, COD and suspended solids removals and sludge production. Laboratory-scale units will be operated in parallel with the pilot-scale unit to relate the findings to previous results obtained with the smaller units.

**5087 EVALUATION OF CHARACTERISTICS AND TREATMENT OF FACTORY WASTEWATERS**

- a) Prof. M. B. Pescod and Dr. P. Y. Yang
- b) Sponsored research
- c) Completed
- d) Wastewater discharges from a sulphonation plant, a non-soap detergent making (NSD) plant, a soap making and finishing plant, a glycerine plant, a margarine plant and a food production plant, all located at one site, were evaluated. Main stream discharges were monitored for flow and quality variations over 24 hours on different days of the week. Wastewater treatability studies were carried out to test the efficiency of feasible treatment processes so that recommendations could be made on the type of plant required to meet local effluent standards.

Wastewater discharges were found to be highly variable and the danger of basing treatment plant design on only a few days of sampling was confirmed. Flow probabilities were plotted and 90 percentile values recommended for use in design. Quality characteristics of the wastes were also subjected to cumulative relative frequency analysis and 50 percentile values of solids, COD, BOD<sub>5</sub> and grease concentrations recommended for design. Combined waste had 50 percentile values of 9.2 for pH, 1040 mg/l CaCO<sub>3</sub> for alkalinity, 4900 mg/l total solids, 700 mg/l suspended solids, 2140 mg/l COD and 730 mg/l BOD<sub>5</sub> as well as high grease content. Because of flow and quality fluctuations and high wastewater temperatures, flow balancing was recommended.

Chemical and biological treatment studies of the total combined wastewater and of segregated streams were carried out. Three alternative treatment process flow diagrams were suggested as feasible. The first was for the total combined waste and included grease separation, extended aeration activated sludge and final clarification. A second possibility was chemical treatment of the total combined waste with lime followed by grease separation and extended aeration activated sludge treatment, with clarification after both chemical treatment and biological treatment. The last alternative suggested was for chemical treatment and clarification of the combined NSD and sulphonation plant wastewater followed by combination with the other plant wastes for combined treatment in an extended aeration activated sludge process with final clarification. In all cases, sludge dewatering by filter press was recommended.

- e) PESCOD, M. B. and YANG, P. Y. (1974), Evaluation of Characteristics and Treatment of Lever Brother's (Thailand) Ltd. Factory Wastewaters, *AIT Research Report*, Bangkok.

5088 **MODEL DEVELOPMENT FOR ENVIRONMENTAL STRATEGY IN TROPICAL ASIAN METROPOLITAN AREAS**

- a) Soepangat Soemarto (Supervisors: Prof. M. B. Pescod and Dr. Maung Nay Htun)
- b) Doctoral dissertation
- c) In progress
- d) The main objective of this research is to develop a model which can be used to determine a strategy for management of environmental quality in tropical Asian metropolitan areas. A suitable and useful model will be developed, taking into consideration its simplicity, effectiveness, cost and ease of handling. The model can be divided into two main parts, namely the Environmental Strategy Planning Process Model, and supporting Models, particularly the System Dynamics Models which are necessary to supply qualitative information concerning prediction of future conditions and simulations of alternatives to test overall performance.

This research is concerned with tropical Asian metropolitan areas and focuses on pollution caused by oxygen depleting wastes in the water environment, pollution caused by traffic (especially carbon monoxide) in the air, accumulation of uncollected solid wastes and problems of noise pollution. The model will be tested using Jakarta, Indonesia as a case study. Field surveys and investigations are being conducted and data needed for the Model are in the process of being collected.

5089B **STUDY OF BREWERY WASTEWATER CHARACTERISTICS AND TREATMENT**

- a) Prof. M. B. Pescod, Dr. N. C. Thanh and Mrs. Samorn Muttamara
- b) Sponsored research
- c) Completed
- d) The Bangkok Brewery, Bangkok is the largest in Thailand, producing approximately 100,000 hl of beer per annum, and the site on the east bank of the Chao Phya River accommodates a soda-water plant and two brewery plants. It was the major purpose of this study to determine the magnitude of variations in strength and volume of the principal wastewater streams at the brewery and to evaluate the amenability to chemical and/or biological treatment of appropriate combinations of waste flows. Additional objectives were to prevent excessive waste stream flow and reduce pollution load discharged by in-plant evaluation of water use and waste generation.

It was found that a few of the brewery wastewater discharges could be released to the river without treatment while the remainder should be combined together for biological treatment. The wastewater stream from the soda-water plant required separate chemical treatment. Because of flow and quality variations in the brewery wastewater discharges, equalization was recommended and part of the capacity could be used for sedimentation of suspended solids. Mean daily flow rate ( $87 \text{ m}^3/\text{hr}$ ) and median values of wastewater quality parameters ( $450 \text{ mg/l BOD}_5$  and  $590 \text{ mg/l COD}$ ) were recommended for process design of the biological treatment. The ninety percentile level of flow probability ( $350 \text{ m}^3/\text{hr}$ ) was suggested for chemical treatment process design.

Specific ways of reducing the volume of water used and the pollution load in wastewater discharges were recommended after in-plant studies. Proposed brewery expansion plans were reviewed and their impact on wastewater handling considered.

On the basis of laboratory studies, recommendations were made on optimum detention times and chemical dosages for chemical treatment of the soda-water waste in mixing chamber, flocculation chamber and sedimentation tank using acid, alum and polyelectrolyte. Two alternative biological treatment systems for the brewery combined waste were studied in the laboratory. Both the activated sludge process and the high-rate biological filtration process using plastic media were found to be effective methods for treating the waste and the choice would depend on an economic comparison of the two alternatives. Nitrogen and phosphorus supplementation were found to be necessary for both systems. Sludge disposal would also be required for the chemical sludge and either of the biological sludges, but the filter system would produce less secondary sludge. One further possibility was considered; that was the treatment of brewery and soda-water plant waste-waters in combination by neutralization and high-rate biological filtration. This system looked to be marginally cheaper in capital cost and would have operational advantages.

- e) PESCOD, M. B., THANH, N. C. and MUTTAMARA, S. (1975), Study of Brewery Wastewater Characteristics and Treatment, *AIT Research Report*, Bangkok.

5091 ANALYSIS OF THE DYNAMIC RESPONSES OF THE ACTIVATED SLUDGE PROCESS

- a) Trichur H. Venkitachalam (Supervisors: Prof. M.B. Pescod and Dr. Nguyen Cong Thanh)
- b) Doctoral dissertation
- c) In progress
- d) Almost all wastewater treatment plants operate under dynamic conditions, mainly due to temporal variations in the process inputs and environmental factors. Yet, classical approaches to analysis and design of these processes are all based on steady-state considerations and average values of loadings and efficiencies. Research has indicated that the dynamic nature of influent waste characteristics exerts a significant influence on the effluent quality. An understanding of the dynamic responses of wastewater treatment processes to time-varying inputs and changes in environmental factors can lead to the development of more rational design and operating criteria for these processes.

The principal objective of the present work is to investigate the process dynamics of the activated sludge-secondary clarifier system subjected to temporal variations in influent flow rate and organic substrate concentration. A dynamic mathematical model of the overall system is being formulated. Digital computer solutions of the model equations are being developed for unsteady-state system operation. Laboratory and field experimental data will be used to determine the predictive accuracy of the model. The study also includes investigations of system sensitivity to parametric variations as well as parameter estimation.

5095 AN ENVIRONMENTAL BACKGROUND SURVEY OF THE AREA NEAR THE PROPOSED SITE OF THE PETROCHEMICAL COMPLEX IN CHOLBURI PROVINCE

- a) Prof. M.B. Pescod and others
- b) Sponsored research
- c) Completed
- d) A six-month base line study of environmental conditions in the area of the proposed site for a Petrochemical Complex in Cholburi Province, Thailand, was carried out. Included in this background survey were evaluations of freshwater quality and biota, marine water and sediment quality, marine biota, marine currents and sediment deposition, noise levels, air quality and ground vibration.

Principal pollutants in three freshwater streams near the site were organic materials discharged by tapioca starch factories and settlements in the area. High concentrations of hydrocarbons were measured in the freshwater streams at the beginning of the wet season, and this was likely to be due to poor house-keeping at tapioca factories and service stations near the site.

Most physical and chemical quality parameters of the marine water off the site fell within expected ranges but heavy metals concentrations were quite high. By comparison, the heavy metal concentrations in the marine sediment were low and other sediments in the Gulf of Thailand had been found to contain higher levels.

The biomass of benthic organisms during the period of study, from August to December, was usually least in the sandy zone nearest shore. In the intertidal zone, the pismo clams *Donax gouldi* were prevalent and in the sandy zone up to 3 km off-shore, the lancelets *Branchiostoma belcheri* were abundant. Dominant species in the soft mud zone around 3½ km from shore varied but the brittle star and a species of annelid worm were generally found. Samples of sediment taken in November and December showed greater diversification of species than samples taken in the other months.

The volume of zooplankton in the marine study area varied from a low of 636 cm<sup>3</sup>/1000 m<sup>3</sup> of water in September to a high of 42,696 cm<sup>3</sup>/1000 m<sup>3</sup> of water in November. Samples collected in August were found to have the maximum diversity of species composition and December samples to have minimum diversity.

Bottom trawls in the coastal area near the site produced an average of 28 species of fish in the five months of study. Over this period, the average biomass of fish in the area was 310 kg/km<sup>2</sup> with average population density of 39,219/km<sup>2</sup>. The heavy metal concentrations in marine organisms in the coastal area near the site were very low but, with the apparently high values of dissolved and suspended heavy metals in this area, continuous surveillance is recommended. Measurements of marine current movements in the area near the site showed a resultant northward trend at the time of the study, with an average shore current component, of maximum velocity 0.5 knots, and a relatively strong along-shore current. Movement of sand and silt was fairly intense for a month-order period even though the tidal current was not strong.

CO, NO<sub>2</sub>, H<sub>2</sub>S, particulates and organic lead concentrations showed a definite trend of increasing concentration with distance from the centre of the site but SO<sub>2</sub> was an exception. Air pollution levels were, however, less than recorded in suburban areas and much lower than normal urban levels, with concentrations of all gaseous pollutants, apart from CO, less than 10 ppb.

Enviroms the site, low frequency noise (<1000 Hz) dominated during the daytime at all stations and this was caused by traffic on the Sukhumvit Highway. At night, insect noise caused high frequency noise to have a higher amplitude at stations further from the Highway. Average combined noise levels at and near the site were generally lower than in areas with corresponding activities in Bangkok.

Ground vibration at the site is caused by traffic on the Sukhumvit Highway, but only the area very close to the roadway is affected. Vehicle speed (rather than weight) and road roughness appeared to be the dominant influences, and buses and empty trucks at high speeds seemed to yield the highest values of ground motion. Most data fell within the frequency range of 18 to 28 Hz. A peak particle velocity of 3.2 mm/sec was generated on the ground at the edge of the pavement on a bridge approach. At a distance of 20 m from any side of the road, the maximum vibration level just reached the threshold of human perception but was still well below any limit for light damage to structures.

- e) PESCOD, M. B. and others (1975), An Environmental Background Survey of the Area Near the Proposed Site of the Petrochemical Complex in Cholburi Province, *AIT Research Report*, Bangkok.

#### 5097 SIMPLE AND INEXPENSIVE PUMPS FOR VILLAGE WATER TREATMENT SYSTEMS

- a) Dr. Nguyen Cong Thanh and Prof. M. B. Pescod
- b) Sponsored research
- c) In progress
- d) As a part of a research program on rural water treatment systems sponsored by the WHO Community Water Supply and Sanitation Division, research is being conducted into the design and testing of simple and inexpensive pumps directed towards rural water supply needs. Existing systems often use gasoline-powered pumps to raise water from canals, ponds, streams, etc., and although these pumps are commonly available, they do need maintenance and occasionally break down. The proposed study is designed to look into other motive means (double-acting bellow pumps, inertia pumps, solar pumps) for pumping the water so that a truly appropriate village water supply system can be provided at low cost and with simple operation and maintenance.

#### 5098 SLOW SAND FILTRATION IN DEVELOPING COUNTRIES-PHASE I

- a) Dr. Nguyen Cong Thanh and Prof. M. B. Pescod
- b) Sponsored research
- c) In progress
- d) As part of a research program on village water treatment systems sponsored by the WHO International Reference Centre for Community Water Supply (IRC), research is being undertaken into the use of slow sand filtration coupled with pre-filters to treat highly turbid waters in tropical areas. Where the raw water source contains high amounts of turbidity and algae, pre-filters (coconut fibre for example) can be used to remove much of the turbidity and algae before passing through a slow sand filter (or burnt rice husk slow filter) for polishing and removal of the remaining impurities. It is the purpose of this study to conduct: (a) an evaluation of the characteristics of coconut husk fibre as a roughing filter; (b) a comparative study between coconut husk - slow sand filters and coconut husk - burnt rice husk filters; and (c) an investigation of chlorination as an additional process with these filters.

#### 5099 IMPROVEMENT OF TAPIOCA PELLETS PRODUCED IN THAILAND

- a) Dr. Nguyen Cong Thanh, Prof. M. B. Pescod and Mrs. Samorn Muttamara
- b) Sponsored research
- c) In progress
- d) The importance of dry tapioca chips and pellets as a source of biological energy in compound animal feed is increasing rapidly. It is believed that higher quality standards and, in consequence, a greater return to Thai processors and exporters is possible by an attain-

able improvement in tapioca processing technology. This project, which is sponsored by the Canadian International Development Research Centre and has the cooperation of the Thai Tapioca Trade Association and the California Pellet Mill Company, proposes to develop such a technology and to demonstrate the improved technology to those concerned. The objectives of the research are: to develop technologically superior and economically sound processes for the production of tapioca chips and pellets under conditions typical of rural areas in Thailand and similar agro-economic regions of Southeast Asia; to discover and define optimum methods of storage and packaging of chips and pellets; and to make the results available in the form of quality and process control recommendations to Thai and other Asian manufacturers.

### THESIS RESEARCH TOPICS FOR 1974-75

Evaluation and Treatment of Wastes from the Tapioca Industry  
Performance Study and Nutrient Requirements of the Anaerobic Contact Process  
Performance of Oxidation Ditches in Thailand  
Optimization of the Inclined Tube Settler and Anthracite-Sand Filter  
Design and Operation of a Potable Water Solar Still for Village Community Supply  
The Application of Constant Recycle Solids Concentration in the Activated Sludge Process  
Application of Inclined Tube Settlers in Wastewater Treatment  
Renewable Fuels Recovered from Bio-Conversion of Solid Waste  
A New Modified Activated Sludge Process for Treating Carbohydrate Wastes Deficient in Nitrogen  
Water Quality Modelling of the Hsintien River, Taiwan  
Cost-Benefit Effects of Settling Air Quality Standards  
Study on the Stability of Operational Parameters for An Extended Aeration Process with and without Acid Hydrolysis of Recycling Sludge  
Performance of a Rotating Drum Filter in Treatment of Wastewaters in the Tropics  
Treatment of Industrial Wastes by Solar Energy Distillation  
Kinetics of Microbial Growth in the Pure Oxygen System  
Removal of Iron from Groundwater  
Whey as a Culture Medium for Abatement of Water Pollution  
Biological Indices in Water Quality Studies  
High Rate Trickling Filters for Brewery Wastewater Treatment  
Use of Bamboos and Corrugated Asbestos Cement as Local Materials for Tube Settlers  
Evaluation and Treatment of Brewery Wastewaters  
Treatability of Nitrogen-Deficient Carbohydrate Waste by *Azotobacter sp.*  
Role of Activated Carbon in the Biological Treatment of Organic Waste  
Experimental Research Study of the Effects of Raw Water Quality and Media Characteristics on the Effectiveness of Series Filtration and Evaluation of Slow Sand Filter in Developing Countries

## PROJECTS COMPLETED BETWEEN JANUARY 1969 AND JANUARY 1973

(Projects completed prior to January 1969 are found in Research Summary for January 1973)

No.	Title	Research Workers(s)	Publications
5003C	Anaerobic Pond Treatment of Tapioca Starch Waste	Salim M. Uddin	Thesis No. 400, 1969 <i>Proc. 2nd Int. Symp. for Waste Treatment Lagoons</i> , Kansas, 1970, pp. 114-132 Thesis No. 316, 1970
5021	Hardness Removal by Ion Exchange for Industrial Water Uses in Bangkok	Geronimo D. Mejia	Thesis No. 317, 1970
5022	Clarification of Bangkok Surface Water Using Polyelectrolytes	Bamroong Kulratanayan	Thesis No. 344, 1970
5023	Long Term BOD Studies	Sardar Mohammad Amjad Durrani	Thesis No. 269, 1969
5024	Treatability of Organic Wastes at 30°C	Javed Anwar Aziz	Thesis No. 314, 1970
5025	Effect of Recirculation on the Performance of Two Stage Oxidation Ponds	Saleh Mustafa Kamal	Thesis No. 325, 1970 <i>Proc. 2nd Int. Lagoon Symp.</i> , Kansas, 1970, pp. 114-132 <i>Proc. Biochemistry</i> , Jan. 1971, pp. 50-53 Thesis No. 321, 1970
5026	Factors Affecting Algal Yield from High Rate Oxidation Ponds Treating Sewage	S. C. Hsu	Research Program No. 47
5027	Harvesting of Algae Through Chemical Flocculation and Flotation	Elma D. Batallones	Thesis No. 322, 1970
5027A	Flotation as a Method of Harvesting Algae from Ponds	M. G. McGarry and S. M. A. Durrani	Thesis No. 323, 1970
5028	Study of Algal Paste Sun-Drying Techniques	Hisam-Ud-Din Ahmad Baqai	Thesis No. 441, 1971
5029	Application of the Sewage-Grown Mass Algal Culture Process to the Asian Urban Environment	Tuk-Ki Chou	Thesis No. 341, 1970
5032	Benefits and Cost of Providing Potable Water to Small Communities in Thailand	Charnvit Athikomrungsarit	Thesis No. 442, 1971 <i>Pro. 6th Int. Conf. Water Pollution Res.</i> Jerusalem, Israel, pp. 723-731 Thesis No. 443, 1971
5033	Demand for Potable Water in Small Communities of Thailand	Paichayon Shouvanavirakul	Thesis No. 444, 1971
5034	A Study of Filtration Methods for Providing Inexpensive Potable Water to Small Communities in Asia	Alberto Sevilla	Thesis No. 433, 1971 <i>Proc. 10th Sess. Natl. Conf. Agric. Sci.</i> , Bangkok, 1971 Thesis No. 422, 1972
5035	Physical and Chemical Characteristics of Bangkok Solid Wastes and Its Potential as a Fuel Source	Muhammad Jahangir	Thesis No. 445, 1971
5036	Effects of Growth Conditions on Algal Flocculation Characteristics	Golam Hossain	Thesis No. 466, 1972
5037	A Study of Mass Algal Culture Growth Limiting Factors	Chwen-Deng Lin	Thesis No. 446, 1971
5037A	Biological Nitrogen Removal by Photosynthesis for Water Reclamation	Kin-Seng Ng	Thesis No. 446, 1971
5038	Alum Recovery and Reuse in Mass Algal Production	Josephine L. Merto	Thesis No. 427, 1972
5038A	A Study of Coagulant Demand in Algal Harvesting	Vichitra Chovichien	Thesis No. 446, 1971
5039	Reclamation of Potable Water from Oxidation Pond Effluent	Munsin Tuntoolavest	Thesis No. 427, 1972
5039A	Activated Carbon Adsorption for Water Reclamation of Oxidation Pond Effluent	Nai-Ho Leung	Thesis No. 427, 1972

No.	Title	Research Worker(s)	Publications
5040	Effects of COD Loading and Detention Time on Anaerobic Pond Performance	Konnaiyar Sinnaboyar Periasami	Thesis No. 447, 1971
5040A	Effects of pH on Anaerobic Ponds Performance	Djuhanarto (Lo) Shi-Mei	Thesis No. 435, 1971
5041	Biological Disc Filters for Tropical Waste Treatment	J. Venugopalan Nair	Thesis No. 434, 1971
5041A	Variables Affecting the Performance of Biological Disc Filtration Units	Chi-Nan Hsieh	Thesis No. 465, 1972
5042	Rational Water Quality Criteria for Tropical Developing Countries	Mohammad Hanif	Thesis No. 467, 1972
5043	Solid Wastes Management: Model Development and Economic Evaluation of the Collection and Disposal System of Bangkok	E.A. Rosales Ouano	Thesis No. 411, 1972
5043A	Development of a Series Filtration Water Treatment Method for Small Communities of Asia	Nongnuch Jaksirinont	Thesis No. 468, 1972

### RECENT FACULTY PUBLICATIONS

- FRANKEL, R. J. (1973), Evaluation of Effectiveness of Community Water Supply in Northeast Thailand, *AIT Research Report*, Bangkok.
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## RESEARCH IN GEOTECHNICAL ENGINEERING

The rapid development now taking place in Asia daily poses a great number of engineering problems which require for their solution the application of the principles of Geotechnical Engineering. Soils and rocks, by virtue of being naturally occurring, are not so easily dealt with as most other engineering materials and, consequently, a far greater variety of difficulties is encountered with them in practice. Some basic principles of what have come to be called *Soil Mechanics, Rock Mechanics, Soil Engineering, Foundation Engineering and Engineering Geology* apply, to greater or lesser extent, to all natural deposits. For this reason, it is worthwhile studying the chemistry and physics of geological deposits so that the fundamental properties and behavior of this whole category of materials might be better understood. This, in turn, leads to solutions of practical problems by the application of engineering techniques based on a sound understanding of the science of the mechanisms involved. Because of great similarities in the subject matter and facilities required for its study, the field of *Agricultural Soil and Water Engineering* has been added to the specialities dealt with in the Division. The recent branch into *Airphoto Interpretation* has not only formed important links with other Divisions of the Institute, but has enabled a start to be made in the fields of earth resources exploration and planning. *Highway Materials* are also within the scope of the Division's activities.

Research at the Asian Institute of Technology in the field of Geotechnical Engineering aims to synthesise the fundamental and applied aspects of the study of geological deposits from an engineering point of view, as well as in the context of agriculture and natural resources. The emphasis, in as far as it can be consistent with the stated philosophy, is on local and regional problems and the quest for their solutions. For this reason, the Geotechnical Engineering Division maintains outstanding laboratory and field exploration facilities. The Division's 19 laboratories are excellently equipped and staffed, and a large capability is maintained for research on full-scale field projects.

In *Soil Engineering*, the main materials under study are local clays and lateritic soils, particular attention being paid to their efficient use as construction materials. A longterm program of research is being conducted on the fundamental properties of the normally consolidated clay deposits of the deltaic regions of Southeast Asia with the aim of solving the many Geotechnical Engineering problems encountered with these soils. It has been found useful, in studying the fundamental behavior of these clays, to artificially sediment samples in the laboratory under controlled conditions which simulate the natural environment; an extensive facility has been developed and built to achieve this. It has been found necessary and possible recently to conduct full scale field tests and observations of various structures. Extensive programs of work are now underway to study the stability and settlements of embankments and excavations, the load carrying capacity of piles and the longterm performance of foundations.

The last 15 years have witnessed outstanding progress and major developments in *Engineering Geology* as applied to soil and rock masses. Research in this newly established field at AIT will lay emphasis on methods of evaluating rock mass quality, geotechnical assessment of soil and rock behavior, and weathering of various rock types under tropical climates. Recently, a longterm program of investigation was initiated to study the causes of landslides in the residual terrain of northwest Thailand. The *Rock Mechanics* Laboratory is currently being developed.

In *Highway Materials*, the existing four laboratories are used for a study of all aspects of pavement design and construction and the materials involved therein. Lateritic soils and crushed rock aggregates are investigated in relation to climatic conditions. Work in the laboratories includes studies of the properties of bituminous materials, and concrete and bituminous surfaces are observed for longterm performance under traffic conditions.

Improved utilization of soil and land resources is essential to the development of agriculture in Asia. Research in the field of *Agricultural Soil and Water Engineering* emphasises means of obtaining increased crop production. The three soil science laboratories are used for work on the evaluation of soils and land for crop production, choice of crop in relation to soil, soil improvement and reclamation, the effective use of fertilizers, and economic aspects of crop production.

The *Airphoto Interpretation* laboratory has only recently been established at AIT. It is sufficiently well equipped to enable important contributions to be made in the fields of exploration, coastal engineering, land resources, water resources management and planning, flood prediction and protection, agriculture and forestry, rural and urban planning, and environmental planning and control. It is planned to greatly expand and develop this aspect of the Division's activities in the immediate future.

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**RESEARCH PROJECTS COMPLETED OR IN PROGRESS SINCE  
JANUARY 1973**

**6062 QUALITY IN SOIL SAMPLING**

- a) Dr. J.D. Nelson, Prof. E.W. Brand and Prof. Z.C. Moh
- b) Faculty research project
- c) Completed
- d) Great difficulties are experienced in obtaining good undisturbed samples of normally consolidated clays, especially where the sensitivity is high. A study was made to examine this problem in relation to the Bangkok Clay, but it is felt that the results of the work will be useful in other areas where the soil conditions are similar. The factors investigated were sampler type, sample shape and sample size. Strengths were measured in the laboratory using unconfined compression and undrained triaxial tests for a comparison with field vane results. The degree of disturbance was determined from residual pore pressure measurements prior to shear.  
The results obtained proved that considerable disturbance occurred to samples even when very careful sampling and handling techniques were adopted. Methods were devised, however, for the correction of measured shear strengths so that realistic design values were obtained. A statistical analysis of the data obtained was also performed.
- e)
  - (i) NELSON, J.D., BRAND, E.W., MOH, Z.C. and MASON, J.D. (1971), The Use of Residual Stress to Define Sample Quality, *Proc. IGOSS Symp. Quality in Soil Sampling*, Bangkok, Vol. 1, pp. 82-87.
  - (ii) NELSON, J.D., BRAND, E.W. and MOH, Z.C. (1971), A Probabilistic Approach to the Correction of Measured Soil Strengths, *Proc. Conf. Applic. of Statist. and Probability to Soil and Struc. Engng.*, Hong Kong, pp. 357-370.

**6079 A RATIONAL METHOD FOR DETERMINING THE IN-SITU COEFFICIENT OF EARTH PRESSURE AT REST**

- a) Ming-Fang Chang (Supervisor: Prof. Z.C. Moh)
- b) Graduate student thesis project
- c) Completed
- d) Most of the available testing methods for determining the coefficient of earth pressure at rest give only the 'apparent' value. A new testing concept was developed and a new testing method was proposed for the determination of the *in situ* coefficient of earth pressure at rest for clays. This concept and method derive principally from the recognition that the traditional testing method needs improvement and from a study of the "at rest" state of soil in an elastic condition, experimental investigations were carried out to prove the validity of the proposed testing method and to investigate the reliability of the test results. It was found that the proposed new method was reliable and gave more realistic value of  $K_0$  for soft clays.
- e) Thesis No. 510, AIT, 1973.

**6080 DEVELOPMENT OF PORE PRESSURE IN SOIL**

- a) Chitchai Anantasech (Supervisor: Dr. J.D. Nelson)
- b) Graduate student thesis project
- c) Completed
- d) This work was carried out to investigate the pore pressure response of an artificially sedimented clay (kaolinite) and Bangkok Clay under different drainage conditions, together with the pore pressure response of an artificially sedimented clay (kaolinite) under different consolidation pressures, load increments and  $K_0$  values. It was found that the pore pressure response was not significantly affected by variations in consolidation pressure, load increment and drainage conditions for both undrained and drained conditions. However, there were pronounced differences in pore pressure response under anisotropic consolidation and partially drained conditions.
- e) Thesis No. 511, AIT, 1973.

**6081 DILATATIONAL CHARACTERISTICS OF SEDIMENTED KAOLINITE**

- a) Roque Ernesto (Supervisor: Dr. J.D. Nelson)

- b) Graduate student thesis project
- c) Completed
- d) A study of the effect of soil structure on dilatation was carried out on an artificially sedimented kaolinite clay. Various soil structures were produced by using different pore fluids, viz. distilled water, sodium chloride and sodium hexametaphosphate. Conventional oedometer tests and isotropically consolidated-undrained triaxial compression tests with pore pressure measurement were conducted in this investigation. In the triaxial tests, the samples for different soil structures were first consolidated to a maximum past pressure of 120 lb/in<sup>2</sup> and then allowed to swell under smaller consolidation pressures prior to shear.

It was observed that the magnitude of rebound decrements did not affect appreciably the stored strain energy. The strength of the bonds and the tendency of the soil to dilate increased with higher overconsolidation ratios. The greater the amount of locked-in strain energy released after failure of interparticle bonds, the greater was the tendency of the soil to dilate. Furthermore, it was observed that the dispersed soil, with weaker bonds, exhibited a slightly greater tendency to dilate than the flocculated soils.

- e) (i) Thesis No. 512, AIT, 1973.
- (ii) NELSON, J.D. (1973), Influence of Clay Fabric on Bonds and Dilatation, *Proc. Int. Symp. Soil Structure*, Gothenburg, pp. 153-159.

#### 6082 UNDRAINED DIRECT SHEAR STRENGTH CHARACTERISTICS OF BANGKOK CLAY AT RANGSIT

- a) Somchai Sangariyanavich (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) A research study of the shear strength of Bangkok Clay in both the Weathered and Soft Clays at Rangsit was carried out using unconsolidated-undrained direct shear tests on 6 in. x 6 in. x 3 in. specimens. The specimens were cut from large undisturbed samples so as to investigate the effects of anisotropy and orientation of the direct shear plane. A short series of consolidated-undrained tests was also performed to compare the undrained strength of specimens consolidated *in situ* and in the laboratory.

The test results indicated that the shear box tests give values of undrained shear strength in the range of those determined from the vane shear tests. The unconsolidated-undrained tests yielded values of undrained shear strength greater than those obtained from the consolidated-undrained tests, whereas the undrained strengths given by the CU direct shear test were somewhat lower than those determined from CU triaxial tests. The effects of anisotropy and reorientation of the principal stresses caused a variation of undrained shear strength on the various shear planes in a random way.

- e) Thesis No. 513, AIT, 1973.

#### 6083 SIZE EFFECTS ON THE UNDRAINED STRENGTH OF BANGKOK CLAY AT RANGSIT

- a) Truong-Hoang-Vinh-Phuong (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) This research was carried out to investigate the effect of specimen size on the undrained strength of the Weathered and Soft Bangkok Clays at Rangsit. Unconfined compression tests were performed on specimens with diameters and heights of 1.4 in. x 2.8 in., 2 in. x 4 in., 3 in. x 6 in., 4 in. x 8 in., 5 in. x 10 in., and 6 in. x 12 in. taken from depths ranging from 1.3 m to 8.5 m. Unconsolidated-undrained triaxial tests without pore pressure measurement were carried out on 1.4 in. x 2.8 in., 2 in. x 4 in., 3 in. x 6 in. and 4 in. x 8 in. specimens from the same depths. Field vane tests were performed at 1.0 m intervals to 8.5 m with four-bladed vanes with diameters and heights of 3 in. x 6 in., 4 in. x 8 in., 5 in. x 10 in., 6 in. x 12 in. and 6 in. x 3 in.

The results of this investigation revealed that size effects on the undrained strength of Bangkok Clay are not very important, even though fissures and vertical cracks can be seen in the Weathered Clay. The vane strengths were generally higher than the strengths measured in the laboratory. On the basis of the strength increase factor  $s_u \sqrt{\sigma_{v0}}$  the soil profile was divided into three zones which could be useful for future design purposes.

- e) Thesis No. 514, AIT, 1973.

**6084 THE APPLICABILITY OF MULTIPLE STAGE TRIAXIAL TESTS IN BANGKOK CLAY**

- a) Wan-Ning Liu (Supervisor: Prof. Z.C. Moh)
- b) Graduate student thesis project
- c) Completed
- d) It has been suggested that the multiple stage principles of compression testing of soil can be applied to determine the shear strength parameters of a soil. The technique used is to load a single specimen to failure at several different consolidation pressures. In the past, the multiple stage test has been used successfully for testing some unsaturated and saturated soils, and an investigation of the applicability of this method to the Bangkok Clays was carried out. Both isotropically and anisotropically consolidated undrained tests with pore pressure measurements were performed on Weathered Bangkok Clay, Soft Bangkok Clay and artificially sedimented marine clay. It was found that the values of  $\bar{c}$  and  $\bar{\phi}$  determined from multiple stage tests did not give good agreement with the results of conventional single stage tests. The results also showed that disturbance during the stage shearing processes may have a large influence on the pore pressure response characteristics of the soil.
- e) Thesis No. 515, AIT, 1973.

**6085 ANISOTROPY OF STRENGTH CHARACTERISTICS OF BANGKOK CLAY**

- a) Mohammad Aslam Qureshi (Supervisor: Prof. Z.C. Moh)
- b) Graduate student thesis project
- c) Completed
- d) This thesis presents the results of an investigation of the anisotropy of the strength characteristics of Weathered and Soft Bangkok Clay at Rangsit. Ten-inch diameter undisturbed samples of the Bangkok Clay from depths of 2 m, 5 m and 7 m were obtained. Specimens cut from these with their vertical axes parallel and perpendicular to the *in situ* direction of the major principal consolidation stress were tested. The combined effect of the inherent, or intrinsic, anisotropy and the anisotropy of the stress system acting on the soil in the ground (stress anisotropy) were investigated in this research.  

The anisotropically consolidated-undrained test results showed that the Bangkok Clay from the three depths investigated is anisotropic with respect to the strength parameters, the pore pressure parameter A at failure and the strain at failure. The angle of shearing resistance,  $\bar{\phi}$ , was different for the horizontal and vertical specimens but this difference was not very significant in producing the strength anisotropy. The difference in the undrained strength was found to be mainly due to the difference in pore pressures developed in the two types of specimens.
- e) (i) Thesis No. 516, AIT, 1973.  
(ii) QURESHI, M.A. and MOH, Z.C. (1973), Anisotropy of Strength Characteristics of Bangkok Clay, *AIT Research Report No. 44*.

**6086 VARIATION OF IN-SITU STRENGTH AND PORE PRESSURES OF BANGKOK CLAY WITH DEPTH**

- a) Yuh-Ming Wu (Supervisor: Prof. Z.C. Moh)
- b) Graduate student thesis project
- c) Completed
- d) This investigation was to determine the variation with depth of the *in situ* undrained shear strength and pore pressure of Bangkok Clay at Rangsit. Undisturbed samples were taken from 1.5 m to 10 m and 12.5 m to 14 m by continuous sampling. The stress-strain and strength properties were determined under the *in situ* stress conditions.  

It was found that the normalized stress-strain relationships of all the soil samples throughout the Weathered and Soft zones did not show normalized behavior. The maximum obliquity ratio was reached at a strain slightly earlier than the maximum deviator stress for the Weathered Clay; for the Soft Clay, the maximum obliquity was reached at a strain which coincided fairly well with the maximum deviator stress; for the Stiff Clay, the maximum obliquity ratio was reached much earlier than the maximum deviator stress. The normalized stress-strain curves and the effective stress path characteristics indicated that both the Weathered Clay and Soft Clay were slightly overconsolidated and the Stiff Clay was fairly overconsolidated. The undrained shear strength was found to decrease with depth for the Weathered and Stiff Clays, but to increase with depth for the Soft Clay.
- e) (i) Thesis No. 517, AIT, 1973.

(ii) WU, Y.M. and MOH, Z.C. (1973), Variation of In-Situ Strength and Pore Pressures of Bangkok Clay with Depth, *AIT Research Report No. 41*.

**6087 PROBABILISTIC DEFINITION OF THE STRENGTH OF A UNIFORM SOIL DEPOSIT**

- a) Chaisith Keesookpun (Supervisor: Dr. J.D. Nelson)
- b) Graduate student thesis project
- c) Completed
- d) This experimental investigation was carried out to study the natural variation of soil strength and the effect of sample spacing and population size on the measurements of shear strength. Undisturbed samples used in this investigation were taken from the AIT test site at Rangsit at a depth of 3 m. A soil sample at the same depth was also used to produce artificially sedimented clay samples. Unconsolidated-undrained triaxial tests without pore pressure measurement were carried out to determine the undrained shear strength of the soils. The test results were presented in the form of a histogram and a theoretical frequency distribution was fitted to the observed data.

The results obtained showed that the variation of soil strength at the 3 m depth (in the Weathered zone) could be fitted by the Pearson Type I and the Beta I distributions. The strength variation for the artificially sedimented clay was found to be normally distributed and the amount of scatter in the distribution was much less than that of the natural soil deposit. In determining the strength variation of this soil deposit, the sample spacing had no significant effect on the results obtained. The accuracy in estimating the distribution parameters depended on the number of observations. In actual sampling of relatively few samples, the true mean can be predicted with some confidence limits by means of statistical analyses.

- e) Thesis No. 518, AIT, 1973.

**6088 PROBABILISTIC DEFINITION OF SOIL STRENGTH FROM DIFFERENT TYPES OF SAMPLERS**

- a) Eriworj Chantawong (Supervisor: Dr. J.D. Nelson)
- b) Graduate student thesis project
- c) Completed
- d) This investigation was the outcome of Project No. 6062 and was concerned with the probabilistic analysis of soil strength from different types of sampler. The samplers were 10 in. and 3 in. diameter cylindrical, 3 in. square. All the soil samples were taken from the same sampling area, 5 m x 20 m at Rangsit. Some artificially sedimented samples were also used. A total of 130 soil strength observations were made on the samples, and these were represented by mathematical models for their distribution curves. The definitions of soil strength were obtained by using 95% confidence intervals in the frequency curves. The various distributions used were: (a) Pearson Type I distribution, (b) Beta I distribution, and (c) Normal distribution.

- e) Thesis No. 519, AIT, 1973.

**6089 COMPRESSIBILITY OF STIFF BANGKOK CLAY**

- a) Hon-Kuen Chuang (Supervisor: Prof. Z.C. Moh)
- b) Graduate student thesis project
- c) Completed
- d) The purpose of this study was to investigate the compression behavior and pore pressure development and dissipation during one-dimensional consolidation of the Stiff Bangkok Clay at Rangsit. Undisturbed samples of the Stiff Bangkok Clay obtained from a depth of 13.5 to 14.6 m were tested with pressure increment ratios of 0.25, 0.5, 1.0 and 2.0, and with pressure increment durations of 24, 48 and 168 hours. Pore pressure measurements were made throughout the tests, and the results were used to explain deviations from the theoretically predicted values. It was found that pore pressure dissipation was a function of the pressure increment ratio. Below an average degree of consolidation of 50%, the Terzaghi theory could be used for the prediction of pore pressure dissipation; beyond this point, however, the theory of Davis & Raymond (1965) gave better agreement.

- e) Thesis No. 520, AIT, 1973.

6090 RESPONSE OF SOME FIELD PIEZOMETER SYSTEMS UNDER UNDRAINED LOADING IN CLAY

- a) Warakorn Mairaing (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) The response characteristics of combinations of seven field piezometers and three measuring systems were studied in the laboratory by installing the piezometers in a large cylindrical specimen of remoulded Soft Bangkok Clay which was loaded isotropically under undrained conditions. A few tests were carried out under drained conditions. Five of the piezometers were of the hydraulic type while the other two were pneumatic. The measuring systems were an electrical transducer, a pressure gauge and a mercury manometer.

The results indicated that the response times were proportional to the volume factors of the piezometers. Although this general behavior can be predicted theoretically, the actual response times deviated greatly from the theoretical predictions. Pressure increment, back pressure and method of installation were all found to affect system response. This work was continued as Project No. 6105.

- e) Thesis No. 521, AIT, 1973.

6091 STUDY OF THE FOUNDATION PERFORMANCE OF FOUR STRUCTURES IN BANGKOK

- a) Nopadol Luangdilok (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) It is well-known that data pertaining to the performance of full-scale engineering structures is difficult to find in the published literature. In the Bangkok area, as elsewhere with deep deposits of soft clays, many structures show signs of distress after a period in use which ranges from architectural cracking to structural failure. Four distressed structures, each quite different, were selected for study in this investigation. Each of these had been damaged because of foundation inadequacies. The object of the work was to study the case history of each structure, to ascertain the cause of the foundation failure and to determine whether or not this could have been predicted prior to construction.

A single-storey factory at Phrapadaeng, which was designed and built as a rigid reinforced concrete frame with a suspended concrete floor and brick panel infills, was the first study. This light structure is supported on 30 groups of piles about 18 m in length supported in the Stiff Bangkok Clay. The site was filled with 2 m of sand prior to construction of the factory. The investigation showed that failure of some of the pile groups had occurred about five years after the factory was built, and that this was attributable mainly to the build up of negative skin friction on the piles. A simple soil-structure interaction model was fairly successfully used to predict the failure.

Some oil storage tanks at Chonnonsri exhibited such large differential settlements after one year in use that they became unserviceable. It was found by investigation and analysis that the piles supporting the base of the tanks were overloaded and that large settlements of the tips in the Stiff Bangkok Clay were inevitable.

A six-storey hospital at Samsen was built as a reinforced concrete frame supported on small pile groups of different lengths. The interior column loads were transmitted to short piles located only in the Soft Bangkok Clay, and the large settlements of these relative to the longer piles supporting the exterior columns resulted in severe structural damage early in the life of the building.

The Phra Phathom Chedi at Nakhon Pathom is a monument of great historical and religious significance on which construction was commenced more than twelve centuries ago. A close examination revealed that this immense structure, weighing about 250,000 tons, has settled differentially and extensive damage is visible on the surface of the Chedi. A full investigation of this structure is a large undertaking and only a preliminary survey and analysis was possible. Useful results were obtained from the subsurface exploration and laboratory testing carried out. An analysis was conducted in an attempt to trace the settlement history of the Chedi throughout its life. This project was continued as Project No. 6168.

- e) (i) Thesis No. 522, AIT, 1973.
- (ii) BRAND, E.W. and LUANGDILOK, Nopadol (1975), A Longterm Foundation Failure Caused by Dragdown on Piles, *Proc. 4th Southeast Asian Conf. Soil Engng.* Kuala Lumpur, pp. 4.15 - 4.24.

#### 6092 STRUCTURAL ASPECTS OF BAMBOO REINFORCED SOIL CEMENT

- a) Abdul Hamid (Supervisor: Mr. F.H.P. Williams)
- b) Graduate student thesis project
- c) Completed
- d) The engineering properties of soil-cement and bamboo were studied to consider the possible use of bamboo reinforced soil-cement for structural purposes in low cost housing projects. It was found that soil-cement had a higher modulus of elasticity in compression than in tension. In tension the specimens behaved elastically and gave a brittle fracture, while in compression there was evidence of some plastic deformation before failure. Bamboo was found to have a high tensile strength with the node being the weakest point. The bond strength between the soil-cement and the bamboo, however, was low and more work is required to determine the behavior of the bond strength over periods longer than 28 days. The strength of beams of bamboo reinforced soil-cement 28 days old were found experimentally to agree fairly well with the theoretical strengths determined from the properties of the material. At 14 days, the experimental beam showed lower strengths than theoretically calculated. A comparison of costs in Pakistan of bamboo reinforced soil-cement and of reinforced concrete to carry similar loads, and the present uncertainties of the long-term performance of bamboo reinforced soil-cement, suggest that it would not be advisable to recommend this for low cost housing at this time.
- e) Thesis No. 523, AIT, 1973.

#### 6093 STRAIN FIELD BENEATH A VIBRATING FOOTING

- a) Tsong-Hwei Lee (Supervisor: Dr. J.D. Nelson)
- b) Graduate student thesis project
- c) Completed
- d) Sand beds having two states of density were prepared to observe the three components of strain and the variation of these strains with depth from the surface and with distance from a surface wave source. From the measured strain distribution in the soil, estimations of the stress distribution beneath the footing were made. The measured values of strain amplitudes were then compared with those predicted using elastic half-space theory. It was found that the vertical strain amplitudes varied with depth in a manner similar to that predicted by theory. It was also observed that the maximum strain was located along the axis of symmetry at a depth approximately equal to the radius of the footing. On a plane near the surface the maximum strain occurred at a distance of about one-third to two-thirds of the radial distance from the axis. On the plane on which the maximum strain amplitude occurred, the corresponding vertical pressure tended to exhibit a parabolic distribution.
- e) Thesis No. 524, AIT, 1973.

#### 6094 A STUDY OF THE AGGREGATE IMPACT TEST IN RELATION TO AGGREGATES IN THAILAND

- a) Kuo-Chang Fan (Supervisor: Mr. F.H.P. Williams)
- b) Graduate student thesis project
- c) Completed
- d) A study has been made of the aggregate impact test in relation to the Los Angeles test, aggregate crushing test, water absorption, and specific gravity for samples of a number of aggregates in Thailand. Samples were chosen to give information on (a) the variation within one quarry (andesite), (b) limestones of different strengths, and (c) a range of different rock types.

It was found that the results of the aggregate impact test could be used to predict the other test results. Because of the portability of the impact test apparatus and the ease of carrying out the test, it is suggested that this test method would be useful in this area. For aggregates taken from the same quarry, there was very good correlation between the aggregate impact value and the bulk specific gravity. For weak aggregates, the modified aggregate impact test gave a wide range of values for aggregates of different strengths. The study of samples of andesite from Saraburi showed that some of the more weathered materials had relatively high water absorption values. These differences could be detected by the aggregate impact test. The bitumen absorption of the weathered aggregate was higher than that of unweathered aggregate and this could account for some of the reported difficulties in using aggregates from this quarry.

- e) Thesis No. 525, AIT, 1973.

**6095 SKID RESISTANCE OF ROAD SURFACES AND AGGREGATES WITH REFERENCE TO TO BANGKOK**

- a) Ruey-Shyong Chang (Supervisor: Mr. F.H.P. Williams)
- b) Graduate student thesis project
- c) Completed
- d) Skidding has been shown by many investigators to be a contributory factor to road accidents, especially when road surfaces are wet. There are no accident data available in Bangkok from which the contribution of skidding to road accidents can be assessed but it is estimated that this is appreciable. In this study, measurements of the skid resistance value were made on the different types of road pavement surfaces in Bangkok, viz., Portland cement concrete, bituminous seal-coat, bituminous semi-grout, and bituminous plant-mix surfacings. Also, laboratory experiments were carried out to determine the polished-stone value on a range of road-stones which are available in Thailand. It was found that a large number of road surfaces were dangerously slippery when wet. It was also found that the basalt group of road-stones have long-lasting skid resistance characteristics.
- e) Thesis No. 526, AIT, 1973.

**6096 ONE-DIMENSIONAL CONSOLIDATION CHARACTERISTICS OF WEATHERED NONG NGOO HAO CLAY**

- a) Adisorn Thumaprudti (Supervisor: Dr. A.M. Richardson)
- b) Graduate student thesis project
- c) Completed
- d) An experimental study of the consolidation characteristics of Nong Ngoo Hao Clay in the zone which has been subjected to tropical weathering was carried out using the one-dimensional consolidation test with a conventional lever-arm consolidometer, without pore pressure measurement, and a hydraulic consolidometer, with pore pressure measurement. The test results showed that the soil compressibility increases with depth and is practically unaffected by the loading conditions. There exists an apparent overconsolidation ratio in the Weathered Clay which decreases with depth and which is a function of the degree of weathering and its effect on soil particle cementation. The coefficient of consolidation and the coefficient of secondary compression were found to be functions of the effective stress, the load increment duration and the load increment ratio, as well as the rate of pore pressure dissipation.  
This project was closely related to the major Project No. 6113.
- e) Thesis No. 705, AIT, 1974.

**6097 EFFECTS OF SOIL STRUCTURE ON SWELLING CHARACTERISTICS OF CLAY**

- a) Charat Suddiprakarn (Supervisors: Dr. A. Kazi & Prof. Z.C. Moh)
- b) Graduate student thesis project
- c) Completed
- d) Two groups of soils were artificially produced from natural Soft Rangsit Clay (mainly kaolinite and montmorillonite, with a little illite and quartz), each group undergoing three different processes. In the first group, the natural clay was sedimented and consolidated in NaCl solutions of 35, 15 and 5 mg/l concentrations. In the second group, the natural clay was sedimented and consolidated in a 35 gm/l NaCl solution and then leached with fresh water to concentrations of 25, 10 and 7 gm/l. Two types of tests, namely (1) consolidation and rebound tests, and (2) swelling pressure tests, were carried out in water and in NaCl solutions of the same concentrations as those of the pore fluids. The test results showed that swelling was more affected by elastic rebound than by osmotic pressure. The amount of elastic rebound seemed to depend on fabric, being smaller in more parallel fabric, while osmotic pressure appeared to depend on both salt concentration and fabric, being larger in more parallel fabric. Furthermore, it was found that, for the same salt concentration, the leached soils swelled more than the unleached soils.
- e) Thesis No. 697, AIT, 1974.

**6098 SHEAR STRENGTH CHARACTERISTICS OF WEATHERED NONG NGOO HAO CLAY UNDER ISOTROPICALLY CONSOLIDATED UNDRAINED COMPRESSION**

- a) Chang Rong Teng (Supervisor: Dr. A.M. Richardson)
- b) Graduate student research project

- c) Completed
- d) An investigation of the shear strength characteristics of Weathered Nong Ngoo Hao Clay was performed by isotropically consolidated undrained triaxial tests with pore pressure measurement. Samples were taken from 1.0–1.5 m and 2.5–3.0 m in the weathered zone. Results were compared between normally consolidated clay and apparently overconsolidated clay, and they were also compared with those obtained on the same clay under anisotropic consolidation by WANG (1974) (Project No. 6107). It was found that, at consolidation pressures less than the critical pressure, the Weathered Clay behaved in some aspects like a slightly overconsolidated clay. For specimens consolidated at consolidation pressures higher than the critical pressure, the soil behaved like a normally consolidated clay. The critical pressures at 1 m and 2.5 m depths are the same. The magnitude of the critical pressure determined by the final water content from triaxial consolidation tests are approximately the same as those obtained by consolidation tests on the same clay performed by THUMAPR'DTI (1974) (Project No. 6096).

Under controlled strain loading, the soil particles are not allowed to attain any position of equilibrium under a continuing increasing external stress. Under incremental stresses in controlled stress tests, these soil particles continuously undergo rearrangement as full pore pressure response is developed. Therefore, at any consolidation pressure, stress controlled tests result in a higher pore pressure build up and lower effective confining pressure. The triaxial test results showed that the cohesion and pore pressure parameter A are dependent upon the rigidity of the soil skeleton. This results from the weathering process which may cause the development of particle bonds in the soil skeleton. A more rigid soil skeleton yields a higher cohesion but a lower pore pressure parameter A at failure.

This project was closely related to the major Project No. 6113.

- e) Thesis No. 699, AIT, 1974.

#### 6099 AN EXPERIMENTAL INVESTIGATION OF STRAINS CAUSED BY A VIBRATING FOOTING ON SAND

- a) Chuchat Bunnag (Supervisor: Dr. R.P.Brenner)
- b) Graduate student thesis project
- c) Completed
- d) Model tests were performed under laboratory conditions in order to obtain a better understanding of the strain distribution in soil under a circular footing undergoing steady-state vertical oscillations. Four sand beds with two different densities and moisture contents were used as elastic half-space models. The vertical and radial strain components were measured by means of soil strain sensors embedded within the sand along lines extending radially from the source of excitation and the axis of symmetry. In order to evaluate the dynamic properties of the soil, the vertical component of surface displacement along radial lines extending from the source was also measured using vertical velocity transducers. From the measured strain amplitude, the stress distribution beneath the footing could be determined.

The test results showed that the variation of strain amplitude was consistent with the theory. Measured resonant frequencies agreed fairly well with predicted ones, and the maximum strain occurred at a depth approximately equal to the radius of the footing. The tests also revealed that the presence of moisture decreased the strain amplitude and increased the resonant frequency, because of enhancement of material damping. The results also showed that the vertical stress distribution beneath the footing exhibited a character intermediate between a "rigid base" type and a "parabolic" type distribution.

- e) Thesis No. 704, AIT, 1974.

#### 6100 STABILITY OF A TRIAL EXCAVATION IN NONG NGOO HAO CLAY

- a) Rafiq Essa (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) This investigation was carried out to examine the methods of analysis available for excavation failures in soft clays. A full-scale test excavation was carried out in Soft Nong Ngoo Hao Clay at the site of the proposed new Bangkok International Airport. This excavation was fully instrumented, and was monitored during and after construction. Undrained shear strengths were measured by field vane, Dutch cone, unconfined

compression and direct shear tests. The effective shear strength parameters were also determined by ordinary CIU and CAU triaxial tests. Stability of the actual and theoretical slip surfaces were analysed using the total stress approach ( $\phi = 0$  analysis) by Swedish, Janbu and Stability Chart methods. The effective stress approach ( $c, \phi$  analysis) was also used to analyze the stability, and for this purpose Swedish, Bishop and Janbu methods of analysis were used.

The failure of the excavation took place two months after construction without any external cause, and a rotational slip appeared to have occurred. The actual slip surface, which was determined on the basis of strength profiles inside and outside the failure zone, was approximately circular in shape and generally agreed well with the critical slip surfaces found theoretically. The results of the effective stress analyses showed that a wide variety of factors of safety at failure could be established analytically, and it was by no means clear which design procedure to adopt. Valuable comparative experimental and theoretical data were obtained from this project.

This project was closely related to the major Project No. 6113.

- e) Thesis No. 700, AIT, 1974.

6101 LABORATORY DETERMINATION OF IN-SITU AND APPARENT COEFFICIENT OF EARTH PRESSURE AT REST

- a) Liu Hung Hai (Supervisor: Prof. Z.C. Moh)  
 b) Graduate student thesis project  
 c) Completed  
 d) The conventional methods of determining  $K_o$  values only give an "apparent"  $K_o$ , and CHANG (1973) (see Project No. 6079) developed a new method called the Allowable Deviator Stress Testing Method (ADSTM) for determining the in situ  $K_o$  value. This research was aimed at confirming the reliability and feasibility of this method and comparing the differences between the apparent  $K_o$  and the in situ  $K_o$  values. Four different methods, namely Allowable Deviator Stress Testing Method, Preconsolidation Pressure Simulating Method, Traditional Testial Testing Method and Andraws Interpolating Method, were employed to determine  $K_o$  values for both natural and artificially sedimented clays. The results showed that the ADSTM is feasible and reliable for normally consolidated clays, but the reliability of this method for overconsolidated clays is still uncertain. For normally consolidated clays, the  $K_{of}$  is larger than the  $K_{oa}$ . It is also concluded that  $K_o$  is not uniquely related to any one basic soil property. The  $K_o$  value of a soil deposit is dependent upon the soil type, manner of deposition, stress history and age of deposit.  
 e) Thesis No. 701, AIT, 1974.

6102 EFFECT OF ANISOTROPY ON SHEAR STRENGTH OF NONG NGOO HAO CLAY

- a) Abdulah Memon (Supervisor: Dr. A.M. Richardson)  
 b) Graduate student research project  
 c) Completed  
 d) The in-situ anisotropy of a deposit of soft marine clay was measured using a vane borer and various configurations of vanes. Vanes with triangular blades with apex angles of  $60^\circ$ ,  $90^\circ$  and  $120^\circ$  was used in addition to vanes with rectangular blades with height to diameter ratios of 2.0 and 0.5. The relationship between undrained shear strength to failure plane orientation was obtained at depths of 1, 2, 3, 4, 5, 6, 7, 5 and 9 m below the surface of the deposit. The lowest value of undrained shear strength was measured on horizontal planes. The ratio of undrained shear strength on the horizontal plane to that on the vertical plane varied from 0.65 to 0.75. The relationships between undrained shear strengths measured on the horizontal plane,  $S_h$ , the vertical plane  $S_v$ , and planes inclined at an angle of  $\beta$  to the horizontal,  $S_\beta$ , which were measured with triangular vane blades having apex angles of  $2\beta$ , could adequately be described by a simple elliptical relationship.  
 The in-situ test results were compared with the results of UU triaxial tests with various specimen orientations, and it was concluded that the undrained shear strength of the Nong Ngoo Hao Clay varied within wide limits depending on the way in which the clay was brought to failure.  
 This project was closely related to the major Project No. 6113.  
 e) (i) Thesis No. 702, AIT, 1974.

- (ii) RICHARDSON, A.M., BRAND, E.W. and MEMON, A. (1975), In-Situ Determination of Anisotropy of a Soft Clay, *Proc. Conf. In-Situ Measurement of Soil Properties*, ASCE, Raleigh, North Carolina (in press).

6103 INTERPRETATION OF DUTCH CONE AND VANE SHEAR TESTS IN SOFT CLAYS

- a) Prakob Wirojanagud (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) A large number of Dutch cone and vane borer tests were carried out on a site where the Soft Bangkok Clay is 15 m thick. The cone resistance was correlated with the vane shear strength to give  $q_c = 19 s_u$  for the Soft Clay and  $q_c = 14 s_u$  for the Weathered Clay (top 4 m). The local friction correlation gave  $q_f = 0.47 s_u$ . Investigation was also made of the effect of rate of penetration of the Dutch cone on the measured resistance, together with the effect of the rate of rotation of the in-situ vane. The rate effect was pronounced for both tests but was thought to be of small significance for the normally slow rates of strain.
- A small hand cone penetrometer was designed and manufactured, and this was found to be most useful for use in soft clays. Consistent correlations were obtained with the Dutch cone and with the vane borer.
- This project was closely related to the major Project No. 6113.
- e) (i) Thesis No. 709, AIT, 1974.  
 (ii) BRAND, E.W., MOH, Z.C. and WIROJANAGUD, Prakob (1974), Interpretation of Dutch Cone Tests in Soft Bangkok Clay, *Proc. European Symp. Penetration Testing*, Stockholm, Vol. 2:2, pp. 51-58.  
 (iii) BRAND, E.W. (1974), Comparison of Hand Cone and Dutch Cone Resistance, *Proc. European Symp. Penetration Testing*, Stockholm, Vol. 2:2, pp. 117-119

6104 STABILITY ANALYSIS OF A TEST EMBANKMENT ON NONG NGOO HAO CLAY

- a) Prapote Boonsinsuk (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) A test embankment was built rapidly to failure on Soft Bangkok Clay in order to examine the many available methods of stability analysis, of strength measurement and of prediction of excess pore pressures. Total and effective stress analyses were carried out on circular and non-circular slip surfaces employing various strength parameters and modes of failure.
- From the investigation, total stress analysis using the Fellenius method with vane shear strengths appeared most suitable and yielded the theoretical safety factors at failure of 1.2 to 1.35 depending on the mode of failure assumed. Excess pore pressures could be predicted closely by the three-dimensional elastic solution and from Skempton's and Henkel's solutions before local yielding and dissipation of excess pore pressures took place. Effective stress analysis was applicable only when the failure surface, excess pore pressures and strength parameters were accurately known. Case studies of other embankment failures in Bangkok Clay revealed that the bearing capacity factor,  $N_c$ , at failure is about 4.0.
- This project was closely related to the major Project No. 6113.
- e) (i) Thesis No. 696, AIT, 1974  
 (ii) BRAND, E.W., MOH, Z.C. and WIROJANAGUD, Prakob (1974), Interpretation of Dutch Cone Tests in Soft Bangkok Clay, *Proc. European Symp. Penetration Testing*, Stockholm, Vol. 2:2, pp 51-58.

6105 SYSTEM CHARACTERISTICS AND THE RESPONSE OF FIELD DIEZOMETERS

- a) Sataporn Quvijitiarn (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed

- d) This project was an extension of the work started at AIT by MAIRANG (1973) (Project No. 6090), in which equipment was successfully developed to measure the response of field piezometers when embedded in 30 cm diameter soil specimens subjected to isotropic stress changes. The equipment was further refined in this project to enable strict control of the volume factor and the loading conditions, and automatic recording was adopted. Piezometers and measuring systems were constructed to give predetermined shape factors and volume factors, the effects of which were measured in terms of piezometer response. The test results for response times were compared with theoretical predictions and good agreements were obtained, especially for high values of volume factor. Some difficulty was experienced, however, in assigning the correct value of shape factor to each piezometer.
- e) Thesis No. 710, AIT, 1974.
- 6106 ONE-DIMENSIONAL CONSOLIDATION CHARACTERISTICS OF SOFT NONG NGOO HAO CLAY
- a) Somporn Reinmanorom (Supervisor: Dr. A.M. Richardson)
- b) Graduate student thesis project
- c) Completed
- d) The one-dimensional consolidation characteristics of Soft and Medium Nong Ngoo Hao Clays were determined in the Bishop type hydraulic consolidometer with pore pressure measurement. It was found that the compressibility characteristics were not significantly affected by load increment duration, and the void ratio was essentially a function of pressure. However, the compressibility characteristics were slightly affected by this load increment ratio, the lower load increment ratio resulting in a higher compressibility. The compression-time curves were significantly affected by the load increment ratio; Type I curves were obtained with load increment ratios higher than 0.5, and Type III curves were obtained with load increment ratios smaller than 0.25. Both Type I and Type III curves obtained from this investigation could be well predicted by the theory of Wahls. The rate of pore pressure dissipation was a function of both load increment ratio and load increment duration. The rates of primary and secondary consolidation were closely related to the rate of pore pressure dissipation.  
This project was closely related to the major Project No. 6113.
- e) Thesis No. 703, AIT, 1974.
- 6107 UNDRAINED SHEAR STRENGTH CHARACTERISTICS OF WEATHERED NONG NGOO HAO CLAY UNDER  $K_0$  CONDITIONS
- a) Wang Chi-Ho (Supervisor: Dr. A.M. Richardson)
- b) Graduate student research project
- c) Completed
- d) This project was concerned with the investigation of the undrained shear strength characteristics of Weathered Nong Ngoo Hao Clay under  $K_0$  anisotropic consolidation. Undisturbed samples taken from depths of 1.1 – 1.3 and 2.6 – 2.9 m were tested under undrained conditions with pore pressure measurement. Both controlled strain and controlled stress type tests were employed. The results led to the following conclusions: (1) a critical pressure exists in the Weathered Clay, normalized behavior being only valid for the normally consolidated range, (2) the undrained strength increases with apparent overconsolidation ratio, (3) the undrained strength is a function of consolidation pressure, (4) anisotropic effects result in a lower  $A_f$  and  $e_f$  for the  $(\sigma_1 - \sigma_3)_{max}$  failure criterion, and (5) the undrained shear strength is lower in controlled stress tests.  
This project was closely related to the major Project No. 6113.
- e) Thesis No. 706, AIT, 1974.
- 6108 DIRECT SHEAR STRENGTH OF NONG NGOO HAO CLAY
- a) Wang En-Shiou (Supervisor: Prof. Z.C. Moh)
- b) Graduate student thesis project
- c) Completed

- d) A research program was conducted to study the direct shear strength of Nong Ngoo Hao Clay. The samples were obtained from the site for the proposed new international airport of Bangkok. The program consisted of three series of direct shear tests to study (1) strain rate effects, (2) anisotropy of UU strength, (3) anisotropy of CU strength. The results of the strain rate series of tests showed that, by using different strain rates to test specimens from the same depth, the water content in the failure zone changed; the slower the strain rate, the lower the water content in the failure zone at failure. The test results on anisotropy showed that the unconsolidated undrained strength varied with the specimen orientation, but often only to a small extent. The consolidated undrained tests gave a lower strength value for the Weathered Clay than the unconsolidated undrained tests. The effect of anisotropy in the CU tests was similar to that in the UU series of tests.

This project was closely related to the major Project No. 6113.

- e) Thesis No. 707, AIT, 1974.

6109 A PRELIMINARY STUDY OF SOME FACTORS AFFECTING THE PERFORMANCE OF PROTECTIVE FILTERS

- a) D.W.R.M. Weerakoon (Supervisor: Prof. E.W. Brand)
- b) Graduate student thesis project
- c) Completed
- d) This investigation was commenced with graded base and filter materials satisfying accepted standard filter criteria. The original intention was to study an expected progressive migration of base material in order to devise a basis for the design of filter thickness. It was experimentally found that no such migration or any other form of failure occurred with the materials used. It was also found that a sudden failure due to sand boiling occurred in the case of filters with larger particle sizes than prescribed by Terzaghi's criteria. Tests carried out with uniform base and filter materials indicated that the critical seepage gradient varied in some regular pattern with the variation of particle size ratio and filter thickness.

- e) Thesis No. 708, AIT, 1974.

6110 UNDRAINED SHEAR STRENGTH CHARACTERISTICS OF SOFT NONG NGOO HAO CLAY UNDER  $K_0$  ANISOTROPIC CONSOLIDATION

- a) Wirote Chaiyadhuma (supervisor: Dr. A.M. Richardson)
- b) Graduate student thesis project
- c) Completed
- d) In this investigation of undrained shear strength characteristics of Soft Nong Ngoo Hao Clay under  $K_0$  anisotropic consolidation, undrained triaxial test with pore pressure measurement were carried out on undisturbed samples taken from depths of 5.5–6.0 m and 7.0–7.6 m from the Nong Ngoo Hao test site. The testing program was divided into three series and each series was divided into two sub-series which consisted of the samples from the two depths. The first series was strain-controlled tests; the second and third were stress-controlled tests with durations of one hour and one day respectively.

The value of  $K_0$  for the Soft Nong Ngoo Hao Clay was found to be fairly constant at about 0.63. The maximum past pressures estimated from undrained shear strength vs consolidation pressure were found to be a little higher than those from the strength envelopes. For strain-controlled tests, the strength parameters from Mohr-Coulomb envelopes were found to be higher for the anisotropically consolidated samples. For stress-controlled tests, the effect of creep in the long duration tests resulted in lower undrained shear strengths, lower angles of shearing resistance, increased excess pore pressures, and higher values of the A-parameter. For normally consolidated samples, the  $\phi$  and  $\bar{\phi}$  values were found to be somewhat insensitive to the testing method, whether stress-controlled or strain-controlled. For overconsolidated soils, the values of  $\phi$  and  $\bar{\phi}$  obtained from strain-controlled tests were lower for shallow depths and higher for deeper depths than those determined by the short-duration stress-controlled tests.

This project was closely related to the major Project No. 6113.

- e) Thesis No. 658, AIT, 1974.

**6111 A REVIEW OF CASE HISTORIES OF STABILITY FAILURE ON SOFT CLAY**

- a) Huynh-Anh-Dang (Supervisor: Prof. E.W. Brand)
- b) Special studies project
- c) Completed
- d) This study was aimed at the collection and re-evaluation of many cases of embankment failures on soft clays. Only short-term failures were examined, on the basis of total stress analyses, and the effects of variations in some of the important parameters were studied for several of the case histories. Several of the reported failures indicated factors of safety at failure well above 1.0, but some indicated factors below 1.0. Attempts were made to correlate the calculated factors of safety with some simple properties of the subsoil but this proved to be rather difficult. A major conclusion to be drawn from this study was that many of the case histories available in the technical literature are something less than reliable in their presentation of the geotechnical information.
- e) Special Studies Report No. 25.

**6112 EFFECTS OF LEACHING ON PROPERTIES OF ARTIFICIALLY SEDIMENTED RANGSIT CLAY**

- a) Siu-Mun Woo (Supervisor: Prof. Z.C. Moh)
- b) Doctoral dissertation
- c) Completed
- d) The Soft Bangkok Clay is known to have formed under essentially marine conditions and, subsequent to its deposition, it is believed to have been subjected to leaching. This clay is characterized by high sensitivity, very low undrained shear strength and high compressibility. The purpose of this study was to examine the mechanism and effect of leaching on the properties of Bangkok Clay by artificially sedimenting samples in the laboratory under controlled conditions. Samples of artificially sedimented Rangsit Clay were prepared in a salt solution (33g/l NaCl) and leached to different degrees of salinity of 25 g/l, 10 g/l and 7 g/l. Laboratory experiments were performed to study changes in soil properties due to leaching. Emphases were placed on the general index properties, swelling behavior, one-dimensional consolidation and undrained shear strength (CIU) characteristics.

The results showed that leaching did not have any significant effects on the physical properties of the soils, such as plasticity and activity, but the ion concentrations in both the free pore water and the adsorbed layers of the clay particles decreased. Leaching of salt from the soil pores was found to have the two major effects of increasing the interparticle repulsion and weakening the interparticle bonding. The magnitude of swelling increased with the degree of leaching. For the four leached soils, the general consolidation characteristics were quite similar. However, values of  $\sigma_{vm}$ ,  $c_v$ ,  $k$  and rate of excess pore pressure dissipation all decreased. Due to the weakening of particle bonding and increases in interparticle repulsion, both the undisturbed and remolded shear strength of the soils decreased by about 20%, with a slight increase in the sensitivity (from 2 to 5). Leaching also lowered the development of excess pore pressure during shear, the magnitude of which was believed to be related to the structure of the leached soils.

- e) Dissertation No. D14, AIT, 1975.

**6113 PERFORMANCE STUDY OF TEST SECTIONS FOR THE NEW BANGKOK AIRPORT AT NONG NGOO HAO**

- a) Prof. Z.C. Moh, Prof. E.W. Brand, Dr. J.D. Nelson, Mr. Ruangvit Choivittayathanin and Mr. Suvit Viranuvut.
- b) Sponsored research project (Northrop Airport Development Corp.)
- c) Completed
- d) It was planned to build the new Bangkok airport on about 8,000 acres of flat land at

Nong Ngoo Hao, which is flooded for the majority of each year. In this part of Bangkok, the subsurface soil conditions are particularly troublesome. The site is covered by Soft Bangkok Clay to a depth of about 15 m, which poses serious problems for the site development. The main soil engineering problems that would be encountered during the design and construction of an airport on this site would all be associated with the extremely low strength and high compressibility of the Soft Clay. This necessitated an extensive program of investigation and testing to provide adequate information for design.

The Geotechnical Engineering Division planned a program of field and laboratory research which would also greatly add to the available information and experience on the behavior of soft clay deposits. A test site was selected at Nong Ngoo Hao on which four full-scale, instrumented test sections were built as follows:

- (1) Embankment, 80 m long, built rapidly to failure.
- (2) Embankment, 200 m long of varying height, for the long-term observation of settlements.
- (3) Embankment, 100 m long, for long-term observations of settlement and creep.
- (4) Excavation, 80 m long, built to failure.

These test sections were heavily instrumented with piezometers, settlement points and lateral movement gauges. The piezometers were of several different types but were mainly of the hydraulic, closed system variety, and were manufactured at AIT. Very good pore pressure and settlement data were obtained throughout all the tests.

In conjunction with the field tests, a comprehensive program of exploration laboratory testing was initiated to obtain the many parameters necessary for complete analyses of the stability and deformations of each full-scale test section. In this respect, this large project has been integrated with several others which have been completed or are in progress within the Geotechnical Engineering Division (see Projects Nos. 6096, 6098, 6100, 6102, 6103, 6104, 6106, 6107, 6108 & 6110). The huge quantity of laboratory and field data collected during this project has been invaluable, and these will form the basis of a continuing program of research for some years.

- e) (i) GEOTECHNICAL ENGINEERING DIVISION, AIT (1973 a & b), Performance Study of Test Sections for New Bangkok Airport at Nong Ngoo Hao, *Progress Reports Nos. 1 & 2 submitted to Northrop Airport Development Corp., Bangkok.*
- (ii) GEOTECHNICAL ENGINEERING DIVISION, AIT (1974), Performance Study of Test Sections for New Bangkok Airport at Nong Ngoo Hao, *Final Report submitted to Northrop Airport Development Corp., Bangkok.*
- (iii) Thesis No. 696, AIT, 1974  
 Thesis No. 698, AIT, 1974  
 Thesis No. 699, AIT, 1974  
 Thesis No. 700, AIT, 1974  
 Thesis No. 702, AIT, 1974  
 Thesis No. 703, AIT, 1974  
 Thesis No. 705, AIT, 1974  
 Thesis No. 706, AIT, 1974  
 Thesis No. 707, AIT, 1974  
 Thesis No. 709, AIT, 1974
- (iv) BRAND, E.W., MOH, Z.C. and WIROJANAGUD, Prakob (1974), Interpretation of Dutch Cone Tests in Soft Bangkok Clay, *Proc. European Symp. Penetration Testing*, Stockholm, Vol. 2:2, pp. 51-58.

#### 6114 FEASIBILITY STUDY ON THE STABILIZATION OF NONG NGOO HAO CLAYS

- a) Prof. Z.C. Moh and Mr. S.M. Woo
- b) Sponsored research project (Northrop Airport Development Corp.)

- c) Completed
  - d) The proposed new Bangkok International Airport at Nong Ngoo Hao was to be constructed on a piece of flat land approximately 1 m above sea level. The subsols at the site are highly compressible and have a very high moisture content. In view of the necessity of building embankments to support runways and taxiways and the high moisture contents of the subsoils in their natural state, the use of a stabilization technique to improve the soil properties appeared to be desirable. The primary objectives of this study, therefore, were (a) to evaluate the feasibility of stabilization of the Nong Ngoo Hao Clay at very high moisture contents, (b) to determine the response of the Nong Ngoo Hao Clay at very high moisture contents, (b) to determine the response of the Nong Ngoo Hao clay to chemical stabilization, and (c) to determine the economic level of stabilization for design purposes. The three primary stabilizers included in the study were hydrated lime, quick lime and cement. Combinations of lime and cement were also under study and, in addition, rice hull ash was tested as a secondary additive in conjunction with lime. The results showed that the clays were responsive to all the stabilizers investigated, but the percentage of stabilizer required to meet the design criteria varied considerably. The amount of stabilizer required also increased with soil depth.
  - e) (i) MOH, Z.C. and WOO, S.M. (1973), A Feasibility Study on Stabilization of Nong Ngoo Hao Clays, *Progress Report submitted to Northrop Airport Development Corp., Bangkok.*
  - (ii) GEOTECHNICAL ENGINEERING DIVISION, AIT (1974), A Feasibility Study on Stabilization of Nong Ngoo Hao Clays, *Final Report submitted to Northrop Airport Development Corp., Bangkok.*
- 6115 PAVEMENT DESIGN TESTS CARRIED OUT IN-SITU AT NONG NGOO HAO FOR THE NEW BANGKOK AIRPORT
- a) Mr. F.H.P. Williams
  - b) Sponsored research project (Northrop Airport Development Corp.)
  - c) Completed
  - d) Pavement design tests were carried out on Nong Ngoo Hao Clay as part of the program of research work to establish the design requirements and procedure of the runway pavements. Three test sites were selected for this study, and these were chosen to represent surface-dry, intermediate and surface-wet conditions. The program of plate bearing tests, CBR tests and vane tests was designed to cover depths ranging from 10 to 200 cm. This work was correlated with the extensive soil data obtained at the site on Project No. 6113.
  - e) WILLIAMS, F.H.P. (1973), Pavement Design Tests Carried Out In-Situ at Nong Ngoo Hao, *Report submitted to Northrop Airport Development Corp., Bangkok.*
- 6116 PERFORMANCE OF THE DEEP BORED PILES FOR THE THA CHANG BRIDGE, BANGKOK
- a) Prof. E.W. Brand
  - b) Faculty research project
  - c) Completed
  - d) The Tha Chang Bridge across the Chao Phraya River in Bangkok is a 280 m long prestressed concrete bridge. The centre span of 114 m was designed to be hinged at the centre and cantilevered from two main piers. The piled foundations for these piers are of particular note since they are composed of 1.5 m diameter bored piles which were installed to a depth of about 45 m. Each pile was designed for a maximum load of 410 tons. It was decided to investigate the performance of one of the piles by installing some simple strain measuring devices at various depths in the concrete and loading the piles to 900 tons. The electrical resistance gauges functioned erratically and yielded unreliable results, but the gauges which consisted of tensioned high tensile steel wires performed very well and gave valuable data. It was found possible to evaluate the distribution of load along the length of the pile and to observe the change in this with time. It was found that, contrary to the design assumption, most of the load

was supported by the pile shaft. Further, the load-settlement relationships indicated that the pile would have a very high factor of safety under the working loads. The information collected will be invaluable to the future design of this type of pile in soil conditions similar to those found in Bangkok.

- e) PROMBOON, Suebsak, BRAND, E.W. and BUCHLI, C. (1972), Observations on the Deep Bored Piles for the Tha Chang Bridge, Bangkok, *Proc. 3rd Southeast Asian Conf. Soil Engng*, Hong Kong, pp. 135-140.

#### 6117 TRAFFIC INDUCED GROUND VIBRATIONS AT WAT PO

- a) Dr. J.D. Nelson and Mr. Suvit Viranuvut
- b) Sponsored research project (Department of Public Works, Ministry of Interior, Thailand)
- c) Completed
- d) The Buddha image at Wat Po, Bangkok has begun to exhibit some cracking within the past four or five years. Because the primary consolidation should have been completed about 100 years ago, it was believed that the distress was caused by vibrations induced by heavy traffic on nearby streets. Measurements were made of the vibrations at various locations near the Wat, and these showed that the vibrations currently produced by the traffic are not of sufficient magnitude to cause structural damage. However, it was reasoned that the vibrations in the past could have been much greater than at present because of the poor conditions of the nearby roadways until recently. It was concluded that the structural damage was probably caused by a deterioration of the ancient foundation structure, and that this should now be investigated.
- e) (i) NELSON, J.D. and VIRANUVUT, Suvit (1973), Traffic Induced Vibrations at Wat Po, *Report submitted to Department of Public Works, Ministry of Interior, Thailand*.  
(ii) NELSON, J.D. and VIRANUVUT, Suvit (1973), Traffic Induced Vibrations at Wat Po, Bangkok, *Geotech. Engng*, Vol. 4, pp. 15-30.

#### 6118 HYDRAULIC CONDUCTIVITY AND STRUCTURAL PROPERTIES OF SOME LOWLAND SOILS IN THAILAND

- a) Mr. J.L. Petersen and Mr. M. Rashid
- b) Sponsored research project (DANIDA, Copenhagen).
- c) Completed
- d) The water regime of a soil is of decisive importance for the ability of the soil to support plant growth and for the microbiological reactions taking place in the soil. Because many tropical lowlands have been used for decades solely for the cultivation of rice, it is expected that such soils would have poorly developed structural aggregates. In order to gain information which could be applied when making considerations concerning the suitability of such soils for crops other than rice, an investigation was made of the structural properties and the hydraulic conductivity of five alluvial soils from Thailand; these soils were designated as BK, SB, KL, KK and KS. Undisturbed samples were taken in the field, and these were used for hydraulic conductivity tests, moisture retention tests and physical and chemical tests in the laboratory.  
The investigation showed that the alluvial clay soils investigated have subsoils which are rather impermeable to water. The only exception is an acid sulphate soil. An effective utilization of the soils with impermeable subsoils for crops other than rice will require that the permeability of the subsoil is increased. This may possibly be accomplished merely if the subsoil is allowed to dry out. Special problems can be expected in the BK soil which has a high content of adsorbed sodium and magnesium. It was also concluded that the soil treatment involved in the preparation of the land for rice cultivation produces a structureless, highly dispersed, and almost impermeable surface layer. However, after drying, the soil returns to a condition where it has a higher hydraulic conductivity and probably a better developed soil structure. This condition is not changed even if the soil is rewetted.
- e) (i) PETERSEN, J.L. (1974), Hydraulic Conductivity and Structural Properties of

Some in Thailand, Report submitted to DANIDA, Bangkok.

- (ii) PETERSEN, J.L. (1974), Hydraulic Conductivity and Structural Properties of Some Lowland Soils in Thailand, *AIT Research Report No. 52*.

6119 PRELIMINARY STUDY OF GEOTECHNICAL ASPECTS OF THE PROPOSED TOWN GAS PROJECT, BANGKOK

- a) Dr. A.M. Richardson and Mr. Ruangvit Chotivittayathanin
- b) Sponsored research project (Japan International Co-operation Agency)
- c) Completed
- d) This preliminary investigation was performed to obtain typical soil profiles and soil properties at selected locations along the route of a proposed main gas supply for Bangkok. The scope of the study included boring and sampling to depths of 30 m, together with undrained strength tests and consolidation tests in the laboratory. The results of this work paved the way for a preliminary design of the distribution system.
- e) DIVISION OF GEOTECHNICAL ENGINEERING, AIT (1974), Preliminary Study of Relationship of Geotechnical Properties of Bangkok Subsoil to Feasibility of a Town Gas Distribution Project, Report submitted to Japan International Co-operation Agency, Bangkok.

6120 GEOTECHNICAL ENGINEERING ASPECTS OF PHRA PATHOM CHEDI

- a) Prof. E.W. Brand, Dr. R.P.B. Brenner, Mr. Suvit Viranuvut and Yu Gau Yih
- b) Sponsored research project (Public Works Department, Thailand) and graduate student special studies project.
- c) Completed
- d) Phra Pathom Chedi is one of the most important historical and religious monuments of Thailand. It is situated in Nakorn Pathom province, 56 km. south-west of Bangkok. It is believed that the Chedi was originally erected sometime between the years 200 & 400 B.E. (343 & 143 B.C.) when Buddhism was first introduced to Thailand. The original structure was probably hemispherical in shape and took the form of an Indian stupa. Some years later, a large pagoda was built over the former one in the style of a Khmer prang. Finally, in 1853 under King Rama IV, reconstruction was commenced to give the Chedi the bell shape it has today. Since 1915 no restoration or reconstruction has been undertaken on the Chedi, and the structure has deteriorated badly in recent years. LUANGDILOK (1973) (Project No. 6091) provided some subsurface data, and carried out preliminary settlement and stability analyses. These, however, did not provide adequate data to enable full conclusions to be drawn about the performance of the Chedi foundation, and in 1974 the Public Works Department sponsored the necessary further study.

The main objective of this investigation was to obtain geotechnical engineering information sufficient for an assessment of the past foundation performance of the Chedi and for its imminent restoration. The scope of the investigation was:

- (1) Determination of the soil profile and its variations at the site of the Chedi.
- (2) Determination of the engineering properties of the soils beneath the Chedi.
- (3) Installation of some simple instrumentation to enable future monitoring of the Chedi settlements and *in-situ* pore pressures.
- (4) Evaluation of the settlement and stability history of the Chedi, and assessment of the effects of any restoration works on future settlements and stability.

The extensive program of investigation, testing and analysis enabled full conclusions to be drawn. It showed that there are slight variations in the soil profile beneath the Chedi which could have resulted in differential settlements. It is certain, however, that the magnitudes of these differentials are far lower than the theoretical predictions made. These predictions, though, do give some indication of the high bending moments that might have been induced in the structure, which might be partially responsible for the cracking in the Chedi. Predictions of rate of settlement usually underestimate the actual rates so it is fairly certain that all settlements of the present Chedi have finished. Further settlements would be induced if additional load were added to the Chedi during the restoration work, although it was thought certain that the addition of even a few thousand tons would result in only very small settlements. The present stability position

of the Chedi was considered to be satisfactory, although there are possible large zones of plastic yield under the Chedi. The addition of a few thousand tons would probably have little effect on the overall stability of the structure.

- e) (i) Special Studies Report No. 45
- (ii) BRAND, E.W., BRENNER, R.F., CHOTIVITTAYATHANIN, Ruangvit and VIRANUVUT, Suvit (1974), Progress Report on Investigation of the Geotechnical Engineering Aspects of Phra Pathom Chedi, Report submitted to Public Works Department, Bangkok.
- (iii) DIVISION OF GEOTECHNICAL ENGINEERING, AIT (1974), Geotechnical Engineering Aspects of Phra Pathom Chedi, Report submitted to Public Works Department, Bangkok.

#### 6121 MEASUREMENT AND INTERPRETATION OF TRAFFIC-INDUCED VIBRATIONS ALONG A DIVIDED HIGHWAY

- a) Dr. R.P. Brenner and Mr. Suvit Viranuvut
- b) Sponsored research project (Thai Petrochemical Company Ltd., Thai Polymer Company Ltd, Tripetch Polymer Company Ltd, Siam Polymer Company Ltd, Thai Detergent Alkylate Company Ltd.
- c) Completed
- d) Traffic vibrations were measured by means of velocity transducers and evaluated in order to assess the existing vibration level to which structures and people were exposed along a portion of Sukhumvit Highway south of Chonburi, Thailand, in whose vicinity there had been planned a large petrochemical complex which was expected to introduce new sources of vibration. The results showed that, with the vehicles at present in use and the loads currently permitted in Thailand, vibrations did not pose a problem to people or structures at their present locations, since they did not attain levels perceptible to humans, and were far below the level for possible structural damage. Roughness of the road surface appeared to be the most important variable influencing vibration intensity. However, for more severe surface irregularities, such as a bridge abutment, the peak particle velocity of ground motion at the edge of the road did not exceed 3.2 mm/sec.
- e) (i) BRENNER, R.P. and VIRANUVUT, Suvit (1976), Measurement and Interpretation of Traffic Vibrations along a Divided Highway in Thailand, Proc. 1st Conf. Road Engng Assoc. Asia and Australasia, Bangkok (in press).
- (ii) ASIAN INSTITUTE OF TECHNOLOGY (1975), An Environmental Background Survey of the Area near the Proposed Site of the Petrochemical Complex in Chonburi Province, Report submitted to the Sponsors, Bangkok.

#### 6122 SOME ENGINEERING PROPERTIES OF PROPOSED CORE MATERIALS FOR BAN CHAO NEN DAM

- a) Prof. E.W. Brand, Mr. Suvit Viranuvut and Mr. K.F. Chui
- b) Sponsored research project (Electric Power Development Co. Ltd, Thailand)
- c) Completed
- d) A brief program of investigation was carried out to examine the suitabilities of six possible core materials for the Ban Chao Nen Dam, a high earth dam to be constructed in west Thailand. Classification, compaction, permeability and strength tests were carried out on each of the samples. High pressure constant head permeability tests and consolidated undrained triaxial tests with pore pressure measurement (CIU tests) were carried out on large compacted specimens. The stress-strain and strength data indicated the typical plastic behaviour of the compacted lateritic clays. A maximum deviator stress was attained in only a few of the CIU tests, and it was necessary to express shear strength parameters in terms of strain criteria. The angle of shearing resistance,  $\phi$ , generally varied between about 35° & 40° for the materials.
- e) BRAND, E.W. (1975), Some Engineering Properties of Proposed Core Materials for Ban Chao Nen Dam, Report submitted to Electric Power Development Co. Ltd, Bangkok.

6123 EVALUATION OF SUBSOIL CONDITIONS FOR A PROPOSED NAVAL DOCKYARD AT POM PRACHUL, BANGKOK

- a) Dr. A.S. Balasubramaniam, Mr. Ruangvit Chotivittayathanin, Mr. Suvit Viranuvut and Mr. Rauf A. Chaudhry
- b) Sponsored research project (Peter Fraenkel & Ptnrs., London, Electro consult S.p.A., Milan, and Consulting Architects and Structural Engineers Assoc. Ltd., Bangkok)
- c) In progress
- d) Phase I of the investigation, completed in January 1973, consisted of field and laboratory tests carried out to determine the strength and compressibility characteristics of the Soft Bangkok Clay and Stiff Bangkok Clay for stability analyses and settlement computations. The field tests included Dutch Cone tests and vane tests. Correlation factors were established between the two types of test, and the data was also used to estimate the depths of the Soft Clay at a large number of locations.  
Phase II of the investigation is in progress and includes *in situ* and laboratory permeability tests specially carried out to study the problems associated with dewatering. Also, the effective stress strength parameters of the Soft Clay and Stiff Clay are being determined by carrying out isotropically and anisotropically consolidated undrained triaxial tests, together with fully drained triaxial tests. These parameters are to be used in the calculations of the long-term stability of deep excavations.
- e)
  - (i) GEOTECHNICAL ENGINEERING DIVISION, AIT (1975 a & b), Preliminary Study of Evaluation of Subsoil Conditions for a Proposed Naval Dockyard, Bangkok, *Reports Nos. 1 & 2 submitted to Peter Fraenkel & Ptnrs., Bangkok.*
  - (ii) GEOTECHNICAL ENGINEERING DIVISION, AIT (1975), Effective Stress Strength Parameters for Soft Clay and Stiff Clay from Naval Dockyard Site, Pom Prachul, Bangkok, *Report No. 3 submitted to Peter Fraenkel & Ptnrs., Bangkok.*

6124 ASIAN INFORMATION CENTER FOR GEOTECHNICAL ENGINEERING

- a) Division of Geotechnical Engineering and Library & Information Center
- b) Sponsored project (International Development and Research Centre, Canada, and AIT)
- c) In progress
- d) The Asian Information Center for Geotechnical Engineering -- AGE -- was founded at AIT in January 1973 under the joint sponsorship of the Division of Geotechnical Engineering and the Library and Information Center. AGE serves as a clearing house in the Asian region for information on soil mechanics, foundation engineering, rock mechanics, engineering geology, earthquake engineering and other related fields. AGE works in cooperation with national societies, universities, government agencies, research organizations, engineering and consulting firms, contractors, etc., both inside and outside the Asian region. Information is collected on all phases of geotechnical engineering research and projects which are of *relevance to Asia*, including investigations, feasibility studies, design and construction activities. Both published and unpublished data are collected, abstracted and disseminated.

In addition to acting as a central repository of geotechnical information for practicing engineers, teaching and research staff, companies and research organizations, AGE regularly brings out a number of publications (see below). The basic ingredients of all abstracts published by AGE are currently being stored in the large computer available at AIT. The computer program now being developed will soon enable information to be retrieved quickly and conveniently from the data 'bank' on the basis of keywords and classification information. It is hoped and anticipated that AGE will collaborate with other information services throughout the world in the near future in an effort to make geotechnical and related information available on a world-wide basis from a central data bank.

AGE is guided by a Policy Advisory Committee and a Technical Committee whose members are renowned specialists from all parts of the world. At least one Liaison Officer from each of the Asian Countries has been appointed to provide close links between AGE and its users. At present AGE has a large number of subscribers to its services and publications; these subscribers are located in 17 Asian and nine non-Asian Countries. There is a full-time staff of five together with many part-time staff.

- e) Regular publications of AGE are:
  - (i) Asian Geotechnical Engineering Abstracts (quarterly)

- (ii) AGE Current Awareness Service (quarterly)
- (iii) AGE Journal Holdings List (annual)
- (iv) AGE Conference Proceedings List (annual)
- (v) Asian Geotechnical Engineering Directory (biennial)

**6125 STABILITY ANALYSIS OF THE RESBAIT TEST BUND USING PREDICTED PORE**

- a) Vincent F. Porrazzo (Supervisors: Prof. E.W. Brand & Dr. J.D. Nelson)
- b) Graduate Student Special Study Project
- c) Completed
- d) This analysis was carried out to examine the effectiveness of the Morgenstern-Price method of stability analysis for a low embankment on soft clay. The test embankment described in Project No. 6028 was reanalysed by the Morgenstern-Price method using measured shear strengths and predicted pore water pressures. A total stress analysis was first carried out on Phases I & II of the RESBAIT embankment using vane shear strengths. Effective stress analyses were then carried out using pore pressures predicted from elastic theory on the three assumptions that the pore pressure at a point was given by (i) the vertical component of stress, (2) Skempton's equation containing the major and minor principal stresses and the pore pressure parameter A, and (3) Henkel's equation containing the three principal stresses and the parameter  $\alpha$ .  
 The predicted pore pressures were nearly everywhere higher than those measured. The theoretical factors of safety at failure, however, were all greater than unity. When Skempton's predicted pore pressures were used, the effective stress analysis gave a factor of safety at failure of only 1.01; since the pore pressures are known to have been in error, however, this result was not regarded as significant. It was generally found that the Morgenstern-Price method of slope stability analysis was rather cumbersome to use for the embankment on soft clay, and it appeared to offer no advantages over other simpler methods.
- e) Special Study Report No. 23

## THESIS RESEARCH TOPICS FOR 1974-75

1. Effects of Vibration due to Pile Driving
2. Effects of Applied Stress Path on the Stress-Strain Behaviour and Strength Characteristics of Soft Bangkok Clay
3. Effects of Rate of Loading on the Stress-Strain Behaviour of Soft Bangkok Clay under Undrained Conditions
4. Controlled-Strain Oedometer Tests on Nong Ngoo Hao Clay
5. Engineering Geology of the Chao Phraya Plain
6. Stress-Strain Behaviour and Strength Characteristics of Weathered Nong Ngoo Hao Clay
7. *In Situ* and Laboratory Permeability of Bangkok Clay at Nong Ngoo Hao and Rangsit
8. Predictions of Subsidence in the Bangkok Area
9. Stress-Strain Behaviour and Strength Characteristics of Soft Nong Ngoo Hao Clay under Extension Conditions
10. Some Engineering Properties of Deep Bangkok Soils
11. Effects of Drying-Wetting on Strength Behavior of Two Lateritic Soils
12. Effect of Roots on the Undrained Shear Strength of a Colluvial Soil
13. Settlement of Friction Piles on Soft Bangkok Clay
14. The Relationship between Stress Path Behavior of Overconsolidated Saturated Clay and Maximum Past Pressure
15. Dynamic Behavior of 200 MW Turbo-Generator Foundation at South Bangkok Thermal Plant: Comparison between Measured and Predicted Behavior
16. Stress-Strain Behavior and Shear Strength Characteristics of Weathered Bangkok Clay under Extension Conditions
17.  $K_0$  Determination by Hydraulic Fracturing
18. Heave of Soil due to Pile Driving
19. The Effective Stress Strength Parameters of a Compacted Lateritic Soil
20. Analysis of the Foundation Performance of Phra Pathom Chedi
21. A Feasibility Study of the Use of Lime Piles for Soil Stabilization
22. Predictions of Movements during Construction of Embankments on Soft Clay Using Finite Analysis
23. Depth of Liming of Very Acid Soil
24. Effect of Adsorbed Magnesium on Soil Hydraulic Conductivity
25. Effects of Pudling and Compaction on Hydraulic Properties of a Clay Soil

## PROJECTS COMPLETED BETWEEN JANUARY 1969 AND JANUARY 1973

(Projects completed prior to January 1969 are found in Research Summary for January 1973)

No.	Title	Research Worker(s)	Publications
6014	Shear Strength Characteristics of Bangkok Clay in the Weathered Zone	Manoon Arayasiri (Dr. J. D. Nelson)	Thesis No. 281, 1969 Research Report No. 8, 1970 <i>Proc. 7th Int. Conf. Soil Mech. Fdn Engng</i> , 1969, Vol. 1, pp. 287-295 Thesis No. 250, 1969
6015	Effect of Time on the Undrained Shear Strength	Yip-Kee Chau (Prof. Z. C. Moh)	
6016	Shear Strength Characteristics of the Stiff Bangkok Clay	Diti Hengchaovanich (Dr. J. D. Nelson)	Thesis No. 274, 1969 Research Report No. 9, 1970 <i>Proc. 7th Int. Conf. Soil Mech. Fdn Engng</i> , 1969, Vol. 1, pp. 287-295
6017	Compressibility of Bangkok Clay in the Weathered Zone	Surindr Kanjanophas (Prof. E.W. Brand)	Thesis No. 338, 1969 Research Report No. 10, 1971 <i>Proc. 7th Int. Conf. Soil Mech. Fdn Engng</i> , 1969, Vol. 1, pp. 287-295 <i>Proc. 5th African Reg. Conf. Soil Mech. Fdn Engng</i> , 1971, Vol. 1, pp. 3.51-3.56
6019	Effect of Method of Preparation on the Compaction and Strength Characteristics of Lateritic Soils	Medhi Hongnoi (Prof. E.W. Brand)	Thesis No. 256, 1969 <i>Proc. Specialty Sess. Engng Props. of Lateritic Soils, 7th Int. Conf. Soil Mech. Fdn Engng</i> , 1969, Vol. 1, pp. 107-116
6020	Effect of Methods of Preparation on Index Properties of Lateritic Soils	Mirza Farrukh Mazhar (Prof. Z.C. Moh)	Thesis No. 264, 1969 <i>Proc. Specialty Sess. Engng Props. of Lateritic Soils, 7th Int. Conf. Soil Mech. Fdn Engng</i> , 1969, Vol. 1, pp. 23-35
6021	Stabilization of Tropical Clay with Cement and Secondary Additives	Boonjune Nithi-Uthai (Prof. E.W. Brand)	Thesis No. 282, 1969
6022	Stabilization of Lateritic Soils with Sand	Supan Ongskul (Prof. Chai Muktabhant)	Thesis No. 254 <i>Proc. Specialty Sess. Engng Props. of Lateritic Soils, 7th Int. Conf. Soil Mech. Fdn Engng</i> , 1969, Vol. 1, pp. 153-164
6023	Cast-In-Situ Piles in Bangkok Clay	Vera Suwanakul (Prof. Chai Muktabhant)	Thesis No. 260, 1969 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng</i> , 1971, Vol. 1, pp. 287-293 <i>Proc. Conf. Behaviour of Piles</i> , London, 1971, pp. 42-44
6025	Triaxial and Stabilometer Tests on Compacted Lateritic Soils	Za-Chieh Moh Arshud Mahmood	<i>Proc. Specialty Sess. Engng Props. of Lateritic Soils, 7th Int. Conf. Soil Mech. Fdn Engng</i> , 1969, Vol. 1, pp. 151-161
6026	Strength and Compressibility Characteristics of Bangkok Clays	Za-Chieh Moh	Research Report No. 7, 1969 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng</i> , 1971, Vol. 1, pp. 135-140 <i>Proc. Conf. Applic. Statist. and Probability to Soil and Struct. Engng</i> , Hong Kong, 1971, pp. 357-370
6028	Full-Scale Embankment Test in Bangkok Clay	E.W. Brand Z.C. Moh J.D. Nelson	Thesis No. 337, 1970 Special Studies Report No. 19, 1972 Special Studies Report No. 20, 1972 Special Studies Report No. 23, 1973 <i>Proc. Conf. Performance of</i>

No.	Title	Research Worker(s)	Publications
6029	A comparison between Oedometer and Stress Path Methods for Settlement analysis under Undrained Loading Conditions	Mondhien Kangsasiatiam (Prof. Z.C. Moh)	<i>Earth and Earth-Supported Structures, ASCE, Lafayette, Indiana, 1972, Vol. 1, pp. 243-272</i> <i>Proc. 8th Int. Conf. Soil Mech. Fdn Engng, 1973, Vol. 1, pp. 305-310</i> <i>Proc. 3rd Southeast Asian Conf. Soil Engng, Hong Kong, 1972, pp. 155-160</i> Thesis No. 337, 1970 <i>Proc. Conf. Performance of Earth and Earth-Supported Structures, ASCE, Lafayette, Indiana, 1972, Vol. 1, pp. 243-272</i> <i>Proc. 8th Int. Conf. Soil Mech. Fdn Engng, 1973, Vol. 1, pp. 305-310</i> <i>Proc. 3rd Southeast Asian Conf. Soil Engng, Hong Kong, 1972, pp. 155-160</i> Thesis No. 366, 1970
6030	A Comparison between Oedometer and Stress Path Settlement Analysis Methods under Controlled Loading Conditions	Chin-Poon Teoh (Prof. Z.C. Moh)	Thesis No. 363, 1970 Research Report No. 16, 1971
6031	Shear Strength Characteristics of Bangkok Clay in the Weathered Zone (Under $K_0$ Anisotropic Consolidation)	Chartri Gulachol (Prof. Z.C. Moh)	Thesis No. 364, 1970
6032	Shear Strength Characteristics of Bangkok Clay under Anisotropic Consolidation	Bashir Ahmad	Thesis No. 364, 1970
6033	Instrumented Pile Tests in Bangkok Clay	A.S. Rahim (Prof. E.W. Brand)	Special Studies Report No. 13, 1970
6034	Comparison of Strengths by Vane Shear, Unconfined Compression and Triaxial Shear Tests in Bangkok Clay	Somchai Akrapongpisai (Prof. Chai Muktabhant)	Thesis No. 331, 1970 <i>Proc. 3rd Southeast Asian Conf. Soil Engng, Hong Kong, 1972 pp. 199-204</i> Thesis No. 365, 1970
6035	Effects of Leaching on the Strength of a Recent Deltaic Clay	Javaid Ghafoor Bhatti (Prof. Z.C. Moh)	Thesis No. 367, 1970
6036	Effects of Salt Content on Properties of a Compacted Clay	Surachat Sambhandharaksa (Prof. Z.C. Moh)	<i>Proc. 1st Aust.-N. Z. Cont. Geomechanics, Melbourne, 1971, Vol. 1, pp. 16-23</i> Thesis No. 342, 1970 <i>Proc. Symp. Strength and Deformation Behaviour of Soils, Bangalore, 1972, Vol. 1, pp. 49-53</i> <i>Soils and Foundations, Vol. 15, 1975, No. 2 pp. 1-16</i>
6037	Effects of Back Pressure on Strength Behavior of Bangkok Clay	Jacob Philip (Prof. E.W. Brand)	Thesis No. 340, 1970 Research Report No. 13, 1971 Thesis No. 343, 1970 Research Report No. 14, 1972 Thesis No. 339, 1970 Research Report No. 11, 1971 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 2, pp. 142-145</i> <i>Geotech. Engng, Vol. 3, 1972, pp. 21-40</i> Thesis No. 369, 1970 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 1, pp. 1-7</i>
6038	The Permeability of Bangkok Clay	Sopon Dungkhac (Prof. E.W. Brand)	Thesis No. 340, 1970 Research Report No. 13, 1971 Thesis No. 343, 1970 Research Report No. 14, 1972 Thesis No. 339, 1970 Research Report No. 11, 1971 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 2, pp. 142-145</i> <i>Geotech. Engng, Vol. 3, 1972, pp. 21-40</i> Thesis No. 369, 1970 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 1, pp. 1-7</i>
6039	Effects of Back Pressure on the Consolidation Behavior of a Soft Clay	Byung-Hee Kang (Prof. E.W. Brand)	Thesis No. 340, 1970 Research Report No. 13, 1971 Thesis No. 343, 1970 Research Report No. 14, 1972 Thesis No. 339, 1970 Research Report No. 11, 1971 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 2, pp. 142-145</i> <i>Geotech. Engng, Vol. 3, 1972, pp. 21-40</i> Thesis No. 369, 1970 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 1, pp. 1-7</i>
6040	Pore Pressure Development during One-Dimensional Consolidation of Soft Bangkok Clay	Sang-Kyu Kim (Prof. E.W. Brand)	Thesis No. 340, 1970 Research Report No. 13, 1971 Thesis No. 343, 1970 Research Report No. 14, 1972 Thesis No. 339, 1970 Research Report No. 11, 1971 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 2, pp. 142-145</i> <i>Geotech. Engng, Vol. 3, 1972, pp. 21-40</i> Thesis No. 369, 1970 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 1, pp. 1-7</i>
6041	The Effect of Deep-Well Pumping on Land Subsidence in the Bangkok Area	Titi Paveenchana (Prof. E.W. Brand)	Thesis No. 340, 1970 Research Report No. 13, 1971 Thesis No. 343, 1970 Research Report No. 14, 1972 Thesis No. 339, 1970 Research Report No. 11, 1971 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 2, pp. 142-145</i> <i>Geotech. Engng, Vol. 3, 1972, pp. 21-40</i> Thesis No. 369, 1970 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng, 1971, Vol. 1, pp. 1-7</i>

No.	Title	Research Worker(s)	Publications
6042	Effect of Soil Structure on Dilatation	Kong-Lam Siu (Dr. J.D. Nelson)	<i>Proc. Conf. Development of Ground Water Resources</i> , Madras, 1973, Vol. 3, pp. V43-V51, and Vol. 4, pp. 2.239-2.245 <i>Proc. 2nd Int Conf. Engng Geology</i> , 1974, Vol. 1, pp. 111.21-111.21.10 Thesis No. 327, 1970 <i>Proc. 1st Aust.-N Z Cont. Geomechanics</i> , Melbourne, 1971, Vol. 1, pp. 197-203 <i>Proc. Int. Symp Soil Structure</i> , Gothenburg, pp. 153-159 Thesis No. 368, 1970 <i>Proc. 4th Asian Reg. Conf. Soil Mech. Fdn Engng</i> , 1971, Vol. 1, pp. 215-220 Thesis No. 332, 1970
6043	Shear Strength of Bangkok Clay under Vibratory Loading	Pranai Satyavanija (Dr. J.D. Nelson)	Thesis No. 328, 1970 <i>Proc. Conf. Performance of Earth and Earth-Supported Structures</i> , ASCE, Lafayette, Indiana, 1972, Vol. 1, pp. 903-928 Special Studies Report No. 17, 1971 <i>J. Soil Mech. Fdn Div. ASCE</i> , Vol. 98, 1972, pp. 987-993 <i>J. Soil Mech. Fdn Div. ASCE</i> , Vol. 99, 1973, pp. 957-977 Special Studies Report No. 18, 1971
6044	Prediction of the Modulus of Deformation of Soil under Vibratory Loading from Static Triaxial Tests	Nyok-Yeong Chong (Dr. J.D. Nelson)	Thesis No. 401, 1971
6045	Pile Cluster Capacity	Anan Taechathummarak (Prof. Chai Muktabhant)	Thesis No. 402, 1971
6046	Model Pile Test	Hong-Kuan Lo (Prof. E.W. Brand)	Thesis No. 403, 1971 Research Report No. 18, 1971
6047	Compendium of Available Data on Basic Properties of Bangkok Clay	Ren-Chung Chen (Prof. E.W. Brand)	Special Studies Report No. 19, <i>Proc. 8th Int. Conf. Soil Mech. Fdn Engng</i> , 1973, Vol. 4.2, pp. 11-12 Thesis No. 400, 1971
6048	Effect of End Conditions and Specimen Size on Measured Soil Strength	Basant Kumar Khurana	Thesis No. 405, 1971
6049	Effect of Embedment on Response of Vibrating Footings	Samuel Shing-Hay Lee (Dr. J.D. Nelson)	Thesis No. 399, 1971 <i>Proc. 4th Southeast Asian Cont. Soil Engng</i> , Kuala Lumpur, 1975, pp. 2.1-2.9 Thesis No. 409, 1971 <i>Proc. 3rd Southeast Asian Conf. Soil Engng</i> , Hong Kong, 1972, pp. 369-373 Thesis No. 404, 1971 <i>Proc. Conf. Performance of Earth and Earth-Supported Structures</i> , ASCE, Lafayette, Indiana, 1972, Vol. 1, pp. 903-928
6050	Shear Strength of Marine Clay under Rapid Transient Loading	Suvit Viranuvut (Dr. J.D. Nelson)	Thesis No. 406, 1971
6051	Shear Strength of Compacted Clay under Rapid Transient Loading	Pipat Tavarayut (Dr. J.D. Nelson)	Thesis No. 407, 1971
6052	One-Dimensional Consolidation Characteristics of an Artificially Sedimented Marine Clay	Boonlerd Leongnark tongdee (Prof. E.W. Brand)	Thesis No. 408, 1971
6053	Total Stress Stability Analysis of the AIT Test Bund	Mun-Choo Choong (Prof. E.W. Brand)	Thesis No. 409, 1971
6054	Shear Strength Characteristics of Some Artificially Sedimented Clay	Khalid Javed (Prof. E.W. Brand)	Thesis No. 410, 1971
6055	Effects of Consolidation Stress Ratio on Shear Strength of a Sedimented Clay	Viraj Rujiraapa (Prof. Z.C. Moh)	Thesis No. 411, 1971
6056	Shear Strength Characteristics of Compacted Lateritic Soils	Nilorn Boonsri (Prof. Z.C. Moh)	Thesis No. 412, 1971
6057	Cement and Lime Stabilization of Selected Lateritic Soils	Siu-Mun Woo (Prof. Z.C. Moh)	Thesis No. 413, 1971
6058	Ultimate Bearing Capacity of Spread Foundation on Bangkok Clay	Payup Pongpirodom (Prof. J.D. Nelson)	Thesis No. 414, 1971

No.	Title	Research Worker(s)	Publications
6059	Free-Standing Pile Cluster Capacity	Chamnong Wattanavaha (Prof. Chai Muktabhant)	Thesis No. 408, 1971 <i>Proc. Conf. Performance of Earth and Earth-Supported Structures, ASCE, Lafayette, Indiana, 1972, Vol. 1, pp. 903-928</i>
6060	Computer Programs for Soil Engineering Problems	Siu-Mun Woo (Prof. Z.C. Moh)	Special Studies Report No. 38, 1972
6061	Effective Stress Analysis of RESBAIT Bund Using Measured Pore Pressures	Boonsiang Boonyaratganon (Dr. J.D. Nelson)	Special Studies Report No. 20, 1972
6063	Foundation Stability of Memorial Bridge, Bangkok	E.W. Brand Boonlerd Leongnarkongdee	<i>Report to the Public and Municipal Works Department, Ministry of Interior, Thailand, 1971</i>
6064	Analysis of an Embankment Failure in Soft Clay	W.A. Ciridon (Prof. E.W. Brand)	Special Studies Report No. 21, 1972 <i>Proc. 8th Int. Conf. Soil Mech. Fdn Engng, 1973, Vol. 4.2, pp. 11-12</i>
6065	Performance of Some Driven and Cast-In-Situ Piles in Bangkok Clay	E.W. Brand Apichai Juta-Surivongse	Thesis No. 375, 1972 Research Report No. 20, 1972
6066	Performance of Sand Drains at Tha Chang Bridge	J.D. Nelson W.A. Ciridon	Thesis No. 376, 1972 <i>Proc. 8th Int. Conf. Soil Mech. Fdn Engng, 1973, Vol. 1, pp. 305-310</i>
6067	Application of the Dutch Cone in the Bangkok Area	Pham-Tien-Nam (Prof. E.W. Brand)	Thesis No. 377, 1972
6068	Effect of Anisotropic Preconsolidation on the Strength Characteristics of a Normally Consolidated Clay	Uthai Pamchareon (Prof. E.W. Brand)	Thesis No. 379, 1972 Research Report No. 39, 1973
6069	Dissipation of Pore Pressure during One-Dimensional Consolidation of an Artificial Marine Clay	Ching-Ta Tsai (Prof. E.W. Brand)	Thesis No. 378, 1972 Research Report No. 40, 1973
6070	Effects of Soil Structure on Consolidation Behavior of Artificially Sedimented Clays	Thanin Bumrungsup (Prof. Z.C. Moh)	Thesis No. 380, 1972 Research Report No. 28, 1972
6071	Effects of the Stress Ratio on the Compressibility of an Artificially Sedimented Clay	Somchai Kokkamhaeng (Prof. Z.C. Moh)	Thesis No. 381, 1972
6072	Effects of Type of Pore Fluid on Measurement of Pore Water Pressures	Mun-Choo Choong (Prof. Z.C. Moh)	Thesis No. 382, 1972
6073	A Comparison of Oedometer and Stress Path Settlement Methods under Embankments	Ren-Chung Chen (Prof. Z.C. Moh)	Thesis No. 383, 1972
6074	Effects of Pile Driving on Bangkok Clay	Surachai Sasisuwun (Prof. Chai Muktabhant & Prof. E.W. Brand)	Thesis No. 384, 1972 <i>Proc. 4th Southeast Asian Conf. Engng, Kuala Lumpur, 1974, pp. 4.1-4.8</i>
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6077	Dynamic Penetration of Projectiles	Udom Udommongkolkul (Dr. J.D. Nelson)	Thesis No. 387, 1972
6078	Compressibility of Bangkok Clay Triaxial Specimens	Somchai Kokkamhaeng (Prof. Z.C. Moh)	Special Studies Report No. 22, 1972

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## RESEARCH IN INDUSTRIAL ENGINEERING AND MANAGEMENT

The Industrial Engineering and Management field of study has been in existence at AIT since September 1970 with the purpose of preparing Asian decision makers to serve their countries better in the industrialization effort of their countries. It was administered by the Systems Engineering and Management Division during the first three years. Since August 1973, it has been administered by the Industrial Development and Management Division. General research emphasis in this field has been on Asian industrial decision making problems at the international, national and firm levels. Major areas of special attention include transfer and utilization of technology, technological development and employment generation, dynamic characteristics of industrial systems, feasibility for development of particular industries, management information and control system, management of product quality assurance, and materials management. Application of quantitative methodologies like operations research, management sciences and technological forecasting in solving such decision problems is emphasized.

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**RESEARCH PROJECTS COMPLETED OR IN PROGRESS SINCE  
JANUARY 1973**

- 7201 **FACTOR DISTRIBUTION PATTERNS FOR THE INDUSTRIAL SYSTEM OF THAILAND**
- a) Dr. Pakorn Adulbhan and Dr. M.N. Sharif  
(In conjunction with the General Electric Company)
  - b) Sponsored Research Project
  - c) Completed
  - d) This research modeled the industrial system of Thailand with some quantitative terms rather than purely a qualitative one. Attempts were made to relate the mathematical findings to more general economic circumstances and policies which have prevailed over the recent years. The assessment and interpretation of results featured in this research, if carried a stage further, would imply certain particular directions for policy.  
The introductory part of the research was the development of a comprehensive classification of industries based upon the nature of the industrial activity involved and the type of product produced. The interactions among these industrial types in the context of the flow of resources were likewise a distinct part of the study.  
The second part covered the spatial and dynamic modeling of the whole industrial system. Each of the industrial types was also modeled separately with respect to some economic factors such as employment, capitalization, and energy consumption. Employment was modeled by a gamma function while capitalization and energy consumption were modeled by negative exponential functions. The same mathematical functions were transformed to probability density functions whose parameters were predicted by regression analysis.
  - e) ADULBHAN, Pakorn, SHARIF, M.N., TABUCANON, M.T., and ALAM, K.S. (1974), *Factor Distribution Patterns for the Industrial System of Thailand*, Final Research Report submitted to General Electric Company, New York.
- 7202 **SYSTEM ANALYSIS OF LEADING MANUFACTURING INDUSTRIES IN THAILAND**
- a) Dr. Pakorn Adulbhan and Dr. M.N. Sharif  
(In conjunction with the General Electric Company)
  - b) Sponsored research project
  - c) In progress
  - d) The purpose of this study is to examine the two fast developing industries in Thailand – that is, iron and steel, and electrical and electronics industries—in depth. An attempt will first be made to analyze the two industries in terms of their growth and structure, as well as their size distribution. Their performances will be next investigated. Dynamic simulation models will subsequently be developed to represent them so that they could be used by decision makers in testing their policy options.
- 7203 **DEVELOPMENT OF A QUANTITATIVE MODEL FOR DETERMINING AN OPTIMAL PROMOTING PROCEDURE FOR INDUSTRIAL DEVELOPMENT IN THAILAND**
- a) Pornchai Tulyadhan (Supervisors: Dr. Pakorn Adulbhan and Dr. M. Nawaz Sharif)
  - b) Doctoral Dissertation
  - c) In progress
  - d) In order to accelerate industrial development in Thailand, the Board of Investment was created to render assistance and grant promotion privileges to would-be industrial entrepreneurs and investors, both local as well as foreign. The objective of this research is to develop a quantitative model for use as a short-term decision-making tool in determining: (a) the types of manufacturing industry to be promoted and (b) their corresponding capacities. The existing promotional system will first be analyzed and the growth of the country will then be investigated for the 1962–72 period. The future development potential of the manufacturing sector will be briefly identified. On the basis of the results obtained, the model will be formulated and tested in selected types of food industry.

- 7204 DEVELOPMENT OF A MULTI-LEVEL TECHNOLOGICAL FORECASTING MODEL FOR INDUSTRIAL PRODUCT SUBSTITUTION**
- a) Chowdhury H.R.M.H. Amir-E-Kabir (Supervisors: Dr. Pakorn Adulbhan and Dr. M. Nawaz Sharif)
  - b) Doctoral Dissertation
  - c) In Progress
  - d) Almost every industry, nowadays, is very much concerned with either possible technological improvements in a competitor's products or the introduction of different products having superior technological characteristics that could satisfy the same market needs. Technological forecasting will not only help to minimize the risk of all these uncertainties, it should also help management as an effective decision making tool to deal with competitors in product planning and development. The existing models deal with one-to-one substitution. In reality, multiple substitution often takes place simultaneously. Considering this, the present research aims at two objectives, namely: (a) formulation of a multi-level technological forecasting model which will be applicable to predict the rate of substitution for multiple products due to technological change, and of which existing models will be its special cases; (b) comparison of the proposed model with existing one-to-one substitution models by applying them into real world situations in the areas of intermediate and durable consumer products.
- 7301 QUEUEING APPROACH TO THE TWO-LINK MATERIALS HANDLING SYSTEM AND ITS APPLICATION IN CONSTRUCTION ACTIVITIES**
- a) Yen-Yi Tseng (Supervisor: Pakorn Adulbhan)
  - b) Graduate student thesis project
  - c) Completed
  - d) The primary purpose of this research was to extend Spaugh's two-link materials handling system (TLMHS) model for one service facility to the case of two service facilities in construction activities. Both the service time and the trip time were assumed to be translated to negative exponential distribution. The model was tested against data collected in 1972 from the Tseng-Wen Reservoir construction work in Taiwan, Republic of China. It was found to be a realistic description of the construction activities under study. It was concluded that the model should aid in determining the optimal combination of production units and hauling units in construction work.
  - e) Thesis No. 578, AIT, 1973.
- 7302 PRELIMINARY ANALYSIS OF THE LOCAL CONTENT PROBLEM IN THE THAI MOTORCYCLE PRODUCTION SYSTEM**
- a) Yuh-Gen David Chen (Supervisor: Dr. Pakorn Adulbhan)
  - b) Special Studies Project
  - c) Completed
  - d) The Thai motorcycle production system in 1973 is mainly in the assembly stage, consisting of three firms--Thai Honda Manufacturing Co., Ltd. Thai Suzuki Co., Ltd., and Siam Yamaha Co. The major issue confronting the system was that of the Thai Government's requirement that the three firms must have fifty-percent local content in their products by the end of 1973. The purpose of this study was to examine the possibility of the industrial cooperation effort among the three firms in the hope that they can satisfy the Government's local content policy in time. Data on the price of main motorcycle components were first collected. This was followed by the compilation of data on the manufacturing facilities of components that are not produced locally yet. Different combinations were examined. Finally a procedure for the industrial cooperation effort was developed.
  - e) Special Studies No. 49.
- 7303 A PLANNING MODEL FOR A PETROCHEMICAL COMPLEX IN THAILAND**
- a) Wai-Hing Chin (Supervisors: Dr. Pakorn Adulbhan and Dr. M.N. Sharif)
  - b) Graduate student thesis project
  - c) Completed
  - d) This research was concerned with the investigation for feasibility of a petrochemical complex in Thailand which included both the upstream and downstream subsystem. Using the whole petrochemical process as basis, a complex to supply the local demand was first sel-

ected. By comparing the estimated capital investment and other expenditures with the estimated return over the period of 1978 through 1982, a procedure was developed to determine the feasibility of the selected complex. It was found that the present trend of demand in Thailand appeared to justify the complex. Two modified cases with the possible importation of certain raw materials to the complex and the possible exportation of its end-products were also considered and found to be favorable to the complex.

e) Thesis No. 599, AIT, 1973.

**7304 DEMAND FORECASTING AND LONG-RANGE PLANNING FOR CRUDE OIL INDUSTRY IN THAILAND**

a) Hsing-wei Chu (Supervisors: Dr M.N. Sharif and Dr Pakorn Adulbhan)

b) Graduate student thesis project

c) Completed

d) The major objective of this study was to develop a rational forecast for the purpose of effective long-range planning for the crude oil industry of Thailand. The production records of crude oil and its products in Summit as well as crude oil throughout Thailand have been studied in this research. The analysis indicated that the demand for crude oil and its products are highly correlated with many economic parameters. By projecting their relationships, a scientific basis for choosing and adjusting the forecasts has been developed.

This study uses the techniques of linear programming, dynamic programming, and markov chain to provide an analytical framework for long-range planning, which will select the optimal strategies for an oil refinery taking into consideration the technical limitations and market competition.

e) Thesis No. 600, AIT, 1973.

**7305 ANALYSIS OF RICE MILLING CAPACITY AND ITS RELATION TO THE PROBLEM OF RICE MILLING INDUSTRY IN THAILAND**

a) Danielito T. Franco (Supervisor: Dr. Pakorn Adulbhan)

b) Graduate student thesis project

c) Completed

d) The processing of rice has for a long time been and will continue to be the largest and most widespread agro-industrial occupation in Southeast Asia, for rice grains cannot be eaten or fed to most livestock in an unprocessed form. Two major problems confront the rice milling industries of Southeast Asia in general and Thailand, one of the major rice producers, in particular. The first problem is that of heterogeneity—that is, the existence of processing units diversified in size, facilities used, and operating policies. The tendency for rice mills to proliferate gives rise to the second problem—under-utilization. This is usually reached whenever the combined technical capacities of mills in a specified area exceed its production of paddy rice. This research attempted to explore the possibilities of altering the present structure of the rice milling industry in Thailand with respect to the two problems mentioned above. It was composed of four work stages: (a) the projection of rice yield and prices for the year 1973 through 1982; (b) the identification of the provinces that have excess milling capacities; (c) the determination of the economic effects of reducing the number of small, poorly equipped mills in the provinces identified in (b); and (d) the determination of new mill requirements in the provinces having no excess milling capacity problems. The regression method was used in the first stage, while the simulation and linear programming approaches were employed in the other stages.

e) (i) Thesis No. 601, AIT, 1973.

(ii) ADULBHAN, Pakorn, FRANCO, D.T., and SHARIF, M.N. (1975). System Analysis of Rice Milling Capacity and its Relation to the Problem of the Rice Milling Industry in Thailand, *Proc. Int. Meeting of Inst. of Managt. Sci. (TIMS)*, in cooperation with *The Int. Fed. of Operational Res. Soc. (IFORS)*, Kyoto, Japan.

**7306 A SYSTEM DYNAMICS STUDY FOR PRODUCTION MANAGEMENT IN A RUBBER-PRODUCT FIRM**

a) Susanto Halim (Supervisor: Dr. Pakorn Adulbhan)

b) Graduate student thesis project

c) Completed

d) Like most countries of Southeast Asia, Thailand has been emphasizing industrialization in

its national development plan. Many firms have received promotion privileges in accordance with the nations Industrial Investment Promotion Act. The Union Rubber Products Company is one of those firms. It is a joint venture between Thai and Japanese partners. The Company produces two types of products—elastic thread for export only, and elastic braid for both export and local use. In this research a mathematical model was first developed to describe the production activities of the Company. The model includes eleven aspects, namely: (1) sale forecast; (2) customer order processing; (3) production control; (4) manufacturing; (5) inventory control; (6) raw material ordering; (7) finishing and shipping operation; (8) manhour control; (9) delivery delay; (10) quality control; and (11) customer satisfaction. Based on the developed model, simulation experiments were performed for sensitivity analysis and then for proposing some new operating policies. A comparison of the results between the existing and proposed systems showed that an improvement in operation effectiveness could be made in adopting the proposed system. The proposed system would provide higher customer satisfaction, and less fluctuation in both the production rate and the manhour level. Since technology transfer was involved in the development of the company under study, an attempt was also made to identify and trace the prominent technological change in the firm.

e) Thesis No. 605, AIT, 1973.

**7307 A QUANTIFIED MODEL FOR INDUSTRIAL PROJECT EVALUATION IN A DEVELOPING COUNTRY**

a) Kun-Li Sandra Huang (Supervisor: Dr M.N. Sharif)

b) Graduate student thesis project

c) Completed

d) A quantified model for industrial project evaluation in a developing country has been developed in this study. With the objective of bridging the gap between micro and macro economics, the model obtains the project measures for a set of projects using both tangible and intangible factors. This model can be used for comparison of investment projects for optimization of overall benefits using dimensionless indices derived from both quantitative factors.

e) Thesis No. 606, AIT, 1973.

**7308 A SYSTEM STUDY OF POLICY FORMULATION IN A FEEDSTUFF MANUFACTURING FIRM**

a) Janne E. Lan (Supervisor: Dr. Donald R. Drew)

b) Graduate student thesis project

c) Completed

d) Most of the dynamic interactions within a market have been ignored in quantitative analysis because of the misleading assumptions that the mechanisms of the market are obscure, that psychological factors predominate to the exclusion of tangible factors, and that there is little possibility of useful modeling of the market interactions. However, by employing only the information available in practical experience, at least the shape of many of these conceptual interactions can be established. Market dynamics simulation is an approach to the investigation of the behavior and characteristics of the market system. It is able to show how policies, decisions, structure and delays are interrelated to influence the growth and stability of the market system. The purpose of this study was an attempt to explore the possible relationships between the market penetration (percentage share of the market) of a private feedstuff manufacturing firm in Thailand and its policies governing changes of the feedstuff prices. The market dynamic models developed in this research also assessed the seasonal influence of price changes on feedstuff consumption under the oligopolistic and non-price competitive situations of Thailand's feedstuff market.

e) Thesis No. 607, AIT, 1973.

**7309 ANALYSIS OF SALES-ADVERTISING RELATIONSHIPS OF COMPETING BRANDS OF DETERGENT IN THAILAND TO DETERMINE OPTIMAL ADVERTISING STRATEGY**

a) Mukesh Chander Laul (Supervisor: Dr. Pakorn Adulbhan)

b) Graduate student thesis project

c) Completed

- d) This study shows the relationships of advertising and promotion to the entire business enterprise system in a detergent industry. A sales-advertising model for competing brands of detergents has been developed using the criterion of profit maximization. For the analysis of advertising strategy, a number of models such as, KOYCK (the first order lag) model and higher order lag models, have been tried. KOYCK model using lag of the variables fitted reasonably well the data obtained from one manufacturer, and hence it was used for determining optimal advertising expenditures.  
The second part of this study deals with the types, importance, and management practice of promotional activities. Conceptual models utilizing the incremental matrix, game theory and payoff matrix approaches have been developed to determine the best promotional strategy among a set of available strategies.
- e) Thesis No. 602, AIT, 1973.
- 7310 A SYSTEMS DYNAMICS STUDY FOR CAPACITY EXPANSION OF AN AUTOMOBILE PRODUCTION FIRM
- a) Nee Oung (Supervisor: Dr. Pakorn Adulbhan)
- b) Graduate student thesis project
- c) Completed
- d) The automobile production industry is one of the fast growing industries in Thailand. This is probably due to the pressure from the Thai Government through the increasingly strict car-importation policy and the attractive investment policy. Nevertheless, little information is known about the dynamics behavior of the firm in this industry. The Siam Motors and Nissan Company was selected as the production system of reference in this research. The Company is a 100 percent Thai firm, with almost all technologies imported from Japan. It has been in existence since 1962 and has progressed through these years. Recently its management decided to triple the production capacity in order to add the popular pick-up car, which was previously imported, to its production line. Using the system dynamics approach, the system model for the Company was developed within the framework of existing management operating policies. It included eight submodels, namely: (1) sales forecasting and order filling; (2) production planning; (3) production control; (4) material ordering; (5) imported build-up vehicles; (6) labor flow; (7) profit; and (8) cash flow. The model was tested for its validity. Anticipated after-expansion conditions were then incorporated into the model for the purpose of testing the appropriateness of the existing operating policies. Such policies were found to be still feasible for the after-expansion environment. However, certain changes were proposed for the possible overall improvement of the Company's operations. Development of major technological changes in the firm were then traced to find their possible impact on its growth. It was concluded that the system dynamics approach can be used by the automobile production firms in the developing environment like that of Thailand for testing appropriateness of their management operating policies.
- e) Thesis No. 603, AIT, 1973.
- 7311 A SYSTEMS APPROACH TO THE INDUSTRIALIZATION IN NEPAL
- a) Stalin Man Pradhan (Supervisor: Dr. E. Axilrod)
- b) Graduate student thesis project
- c) Completed
- d) The process of industrialization is a very complex problem. This research has been aimed to formulate a simple macro-economic model from the existing data. The model attempted is intended to lay the foundation for applying the systems approach to industrialization planning in Nepal.  
The whole economy of Nepal has been studied in order to perceive as clearly as possible a broader economic picture of the country. The Fifth Five Year Plan (1975-80) has also been prepared with necessary projections. A separate chapter on "System Approach to Human Resources Development" has been included because of its importance.  
Finally, necessary suggestions are made for future work.
- e) Thesis No. 598, AIT, 1973.
- 7312 A STUDY OF TECHNOLOGICAL FORECASTING AND ITS APPLICATION IN AUDIO-VISUAL ELECTRONICS INDUSTRY
- a) Wong Wai Nam (Supervisor: Dr. M. N. Sharif)

- b) Graduate student thesis project
  - c) Completed
  - d) In this study an attempt has been made to predict the technological development as well as to develop technological index functions for quantifying technology for three audio-visual products—radio, monochrome TV and color TV. The effect of technological change on industrial planning and the market forecasting models based on the change in technology have also been studied.
  - e) Thesis No. 604, AIT, 1973.
- 7313 A STUDY FOR FEASIBILITY OF FREON PRODUCTION IN THAILAND**
- a) Shan-Fu Huang (Supervisor: Dr. Pakorn Adulbhan)
  - b) Graduate student thesis project
  - c) Completed
  - d) The abundant deposits of fluorite ore and the growing demand for airconditioning in Thailand were the incentives which led to this study. The major objective of this study was to investigate the feasibility for Freon production in Thailand using locally produced fluorite. The organization of the study was basically divided into three subsystems—estimation of demand for Freon, supply of input materials, and evaluation of investment opportunity. Estimation of Freon demand was made by direct contacting with both the consumer and dealer sides. Appropriate forecasting techniques together with judgement were then used to estimate the demand for Freon. Concerning the availability of basic input materials for Freon production, an attempt was first made to investigate the historical and present condition of the fluorite production industry, its prospect as well as the interrelationship that Freon production industry might have on it. A quantitative procedure was then developed to express the initial cost as a function of production capacity, acceptable rate of return, and payback period. A family of curves covering a certain range of production capacity was drawn and could be used by prospective investors as a guideline in their decision making process.
  - e) Thesis No. 281, AIT, 1974.
- 7314 CHARACTERISTICS OF SELECTED MANUFACTURING INDUSTRIES IN HONG KONG**
- a) Hoi-Sing Yuen (Supervisor: Dr. M.N. Sharif)
  - b) Graduate student thesis project
  - c) Completed
  - d) The purpose of this study was to portray the characteristics of the manufacturing industry of Hong Kong. It included the consideration of the resource base and economic background which reflects the export oriented feature of the colony and the investigation into the industrial structure of the manufacturing industry in terms of the trading, production, investment, technological change and innovation, productivity and employment characteristics. Analysis of the growth pattern and factors influencing growth were also included. Detailed accounts of the textile industry in the manufacturing operations, production, export, technological and employment characteristics have also been presented.
  - e) Thesis No. 793, AIT, 1974.
- 7315 AN INVESTIGATION INTO THE NATURAL GAS INDUSTRY IN BANGLADESH**
- a) Nazim Uddin Ahmed (Supervisor: Dr. M.N. Sharif)
  - b) Graduate student thesis project
  - c) Completed
  - d) The purpose of this study was to develop a basic framework for the utilization of natural gas in the domestic sector in Bangladesh. The following models were developed: (1) Demand model for domestic consumption of natural gas; (2) Cost model for consumers using natural gas; (3) Cost model for the gas company to supply natural gas through pipelines to the domestic consumers; and (4) Cost model for the domestic consumers using other fuels. These models were then analyzed in terms of costs, revenue, profit, etc., for a period of 20 years. Then costs were compared for different alternative fuels. It was observed that additional investment by the gas company in the domestic sector will not contribute significantly towards the profitable utilization of natural gas in Bangladesh. For optimal utilization of natural gas, it would be better to invest in construction of distribution network for

industrial and power generation sector rather than for domestic sector.

- e) Thesis No. 783, AIT, 1974.

7316 FACTOR DISTRIBUTION PATTERN FOR SOME SELECTED INDUSTRIES IN THAILAND

- a) Khondakar Shamsul Alam (Supervisor: Dr. M.N. Sharif)  
b) Graduate student thesis project  
c) Completed  
d) This research has been aimed at understanding the behavior of different industries of the developing countries in general and Thailand in particular with regard to different factor inputs, namely employment, capitalization and energy, so that some general conclusions can be arrived at to aid the policy makers to design an effective industrial system. The specific purpose had been to attack the problem mathematically, so that a quantitative criteria could be developed to explain the behavior of industries both with respect to time and space.

Attempts have been made to fit the factor inputs to common mathematical functions so that a quantitative relationship could be established to conform to statistical probability density functions. Gamma function was used to represent the behavior of the factor inputs for each industry on the basis of time and space. This was found to fit nicely. After fitting the gamma function mathematically, the function was reduced to conform to statistical probability density functions and regression analysis was carried out for the parameters of the fitted gamma functions for statistical inferences and analysis of the factor inputs over the location of industries (space) and time period.

- e) (i) Thesis No. 784, AIT, 1974.  
(ii) This research is part of the report Factor Distribution Patterns for the Industrial System of Thailand submitted to the General Electric Company, New York, in Nov. 1974.

7317 A COMPARATIVE STUDY OF INDUSTRIAL ESTATES IN MALAYSIA, KOREA AND INDONESIA

- a) Yu-Chin Chan (Supervisor: Dr. M.N. Sharif)  
b) Special studies project  
c) Completed  
d) The general purpose and objective of this study was to compare the development of the industrial estates in Malaysia, Korea and Indonesia.

In this study, basic concepts pertaining to development of industrial estates have been explained. The economic backgrounds, infrastructure and education or technological programs have also been discussed to identify the difference in the basic structure among the three countries.

In order to give a comparative picture of the industrial estates of these countries, the distribution, type, size and sponsorship of industrial estates have been studied and presented in tabular format.

- e) Special Studies No. 55

7318 A STUDY OF THE CHARACTERISTICS AND PROSPECTS OF THAILAND'S PULP AND PAPER INDUSTRY

- a) Singha Chiamsiri (Supervisor: Dr. Pakorn Adulbhan)  
b) Graduate student thesis  
c) Completed  
d) The structure of Thailand's pulp and paper industry was investigated by means of a forward-backward linkage model to identify weaknesses and strengths of the linkages among the major elements of the industry. A measure of the linkages is defined as the percentage of domestic production to total domestic consumption. Domestic pulp production provides the backward linkage and domestic paper production provides the forward linkage of the industry. It was found that the forward linkage of Thailand's pulp and paper industry is "moderate", having a linkage of about 55 percent, while the backward linkage is "very weak", providing a linkage of only 28 percent.

A study on the characteristics of the structure of the industry, in terms of the distribu-

tions of sizes regarding employment, capitalization and other economic indicators such as energy consumption, production capacity, assets, sales, value of raw materials and manufacturing value-added, was done in order to provide a basis for comparison with other industries. The distribution was described by density function where possible. Otherwise, the distribution was described in terms of its important statistics such as mean, standard deviation and coefficient of variation. Dynamic characteristics of the structure of the industry were also identified in the period 1969-1973.

Problems and investment possibilities were also identified during the course of the study. The pulp and paper industry in Thailand has promising prospects as indicated by increasing domestic consumption of paper products and abundant resources of raw materials for paper-making.

- e) Thesis No. 786, AIT, 1974.

7319 CHARACTERISTICS OF THE INDUSTRIAL SYSTEM IN THE KAOHSIUNG EXPORT PROCESSING ZONE

- a) Arthur Wen-Chih Hsu (Supervisor: Dr. Pakorn Adulbhan)
- b) Special studies project
- c) Completed
- d) This study attempts to analyze the characteristics of the industrial system in the Kaohsiung Export Processing Zone (KEPZ).

The development of KEPZ was first described. Emphasis was given to the following aspects: the historical background, geographic environment resources bases, function, objective, and performance. This was followed by an analysis of the technology transfer process through the KEPZ system and a quantitative assessment of technological development. Performance of the KEPZ system was compared with that of Taiwan. An attempt was then made to trace out the barriers encountered and problems incurred in the process of technological development in relation to KEPZ system.

- e) Special Studies No. 50.

7320 PRELIMINARY ANALYSIS OF BANGLADESH INLAND WATER TRANSPORTATION SYSTEM WITH SPECIAL EMPHASIS ON THE DEVELOPMENT OF NARAYANGANJ RIVER PORT

- a) Habibullah Khan (Supervisors: Dr. M.N. Sharif and Dr. Pakorn Adulbhan)
- b) Special studies project
- c) Completed
- d) This study is a preliminary analysis of Bangladesh Inland Water Transportation system. The work involves the analysis of various interacting and interrelated subsystems like river and water ways, river port, mechanized vessel, cargo traffic, etc.

Predictions on future inland water transport cargo traffic volumes have been made using linear regression and exponential model fittings and through factor analysis. A correlation coefficient of 0.98 has been found for the two variables: (i) tons of cargo carried and (ii) ton-miles of cargo moved through inland water transport.

The study also covers an analysis of Narayanganj river port in the areas of future volume of cargo traffic, utilization of port facilities, etc.

- e) Special Studies No. 51.

7321 ANALYSIS OF THE LOCATION OF KEY INDUSTRIES IN THAILAND

- a) Boonjong Limudomporn (Supervisor: Dr. Pakorn Adulbhan)
- b) Graduate student thesis
- c) Completed
- d) This study was concerned with the decision problems of the management on plant location in Thailand. Emphasis was given to the key industries as defined by ECAFE. An attempt was first made to find the location of plants in the key industries throughout the country on the provincial basis. In an attempt to describe how the management made their decisions in selecting the plant site, a questionnaire containing essential decision factors were sent to firms in the Bangkok area. The result were then analyzed extensively. Finally a brief description was made of the 10 relatively new investment zones scattering all over the country.

- e) Thesis No. 789, AIT, 1974.

7322 CHARACTERISTICS OF THE ELECTRICAL AND ELECTRONICS INDUSTRIES IN THAILAND

- a) Suvit Nantavithya (Supervisor: Dr. Pakorn Adulbhan)
- b) Special studies project
- c) Completed
- d) This study was concerned with the characteristics of electrical and electronic industry in Thailand. The electricity generation in Thailand was first described. It was followed by the development of the industry in each class. Quantitative analysis of two economic parameters, namely, capitalization and employment, were considered in this study. The geographical distribution of firms in conjunction with capitalization & employment in the industry was next analyzed. It was followed by the growth of the industry. The analysis of the structure of capitalization & employment were carried out in four categories—small firms, large firms, product types, and promoted firms. The results of small firms were represented in the form of distribution function, namely, gamma and negative exponential distribution for employment and capitalization respectively. For large firms, promoted firms, and product types basis, mean, standard deviation, and coefficient of variation were determined.
- e) Special Studies No. 52.

7323 CHARACTERISTICS OF THE MANUFACTURING SYSTEM IN SINGAPORE WITH A CASE STUDY OF THE TEXTILE AND GARMENT INDUSTRIES

- a) Samuel Pai-Jin Ngo (Supervisor: Dr. Pakorn Adulbhan)
- b) Graduate student thesis project
- c) Completed
- d) This research has been aimed at the analysis of the growth and expansion of the manufacturing sector in Singapore, the illumination of the important features and characteristics of that sector and of the various industrial major groups comprising it, and the investigation of the development and characteristics of the textile and garment industries in particular.  
A brief account of Singapore's economic history was presented and the rationale of industrialization was derived therefrom. The resource base specific to the industrial development process in the Republic and the role of the Government in the initiation and guidance of that process were thereafter identified.  
The growth of the manufacturing sector and the performance of the industrial major groups comprising that sector for the period 1960–1971 were analyzed in terms of number of establishments, employment, output, gross value added and direct exports. The impact of foreign investments and the Pioneer Industries Program on manufacturing growth and development was then assessed.  
The structure and characteristics of the manufacturing sector were presented and discussed. This was followed by a detailed study of the development and characteristics of the textile and garment industries.
- e) Thesis No. 792, AIT, 1974.

7324 AN INVESTIGATION OF THE INDUSTRIAL PRODUCT CERTIFICATION PROGRAM IN THAILAND

- a) Mana Rangsihamras (Supervisor: Dr. Pakorn Adulbhan)
- b) Special studies project
- c) Completed
- d) This study was concerned with the quality certification program of industrial products in Thailand. It was carried out by investigating the practice of the Thai Industrial Standards Institute (TISI), which is the only legal organization certifying standard products in the country. Historical development of TISI as well as the criteria and procedures in selecting the products to be standardized were reviewed. It was found that 73 standards were approved by the Standards Council and published in the Government Gazette by the end of February 1974. These standards lead to the certification procedure for licensing which includes testing and surveillance programs. Up to the end of June 1974, forty one licenses have been issued by TISI. Voluntary and compulsory licenses were distinguished. The performance of TISI practice which includes standardized products, products to be standardized, product categorization, issued licenses and growth of the TISI's certification Program was then analyzed. Quality characteristics of TISI standards were also detailed out. The certification schemes of selected Asian countries were summarized to provide a broader

view of certification practice in the region.

- e) Special Studies No. 53
- 7325 **A STUDY ON THE DEVELOPMENT OF FERTILIZER INDUSTRY IN PAKISTAN WITH A CASE STUDY OF UREA PROCESS MODELING**
- a) Muhammad Yousuf Rawal (Supervisors: Dr. Pakorn Adulbhan and Dr. H.E. Hoelscher)
- b) Graduate student thesis
- c) Completed
- d) In the past decades, industrialization has been promoted by the Pakistan Government to increase the rate of economic growth. Emphasis has been on the agro-based import-substitution, and export oriented industry. Amongst the agro-based industries, fertilizer industry has been a main one as fertilizer application is the key to increased productivity, the present objective of the country's agricultural policy. This study attempted to analyze the development of the fertilizer industry in Pakistan, including its structure and growth. Various types of fertilizer were subsequently examined. Urea was found to be the key type. Using past data of an existing urea plant as basis, a simulation model was developed for the purpose of finding means to further improve the productivity of its type. The model was found to be quite satisfactory.
- e) Thesis No. 794, AIT, 1974.
- 7326 **SYSTEM ANALYSIS OF THE TEXTILE INDUSTRY IN THAILAND WITH EMPHASIS ON ITS STRUCTURES AND PERFORMANCE, 1961-1973**
- a) Bundit Silawatshanani (Supervisor: Dr. Pakorn Adulbhan)
- b) Graduate student thesis
- c) Completed
- d) This study was aimed at the analysis of the textile industry in Thailand during the period 1961-1973. Historical background and the present state of development were first described. Structures of the industry in terms of the type and number of establishments, production capacity and employment were systematically analyzed. Other industries which are closely associated with the textile industry were briefly described. An assessment of the performance of the industry with regards to productivity was made. Forecast on fabric consumption in Thailand was carried out with the use of statistical techniques. Technical studies such as production process, quality control were reviewed in order to provide a clear picture on how the technological change has the significant impact on the development of the textile industry. Major factors that stimulate the rapid growth and problems faced by the industry were discussed throughout the text. Finally, strategies and policy implications for further development of the textile industry were proposed.
- e) Thesis No. 795, AIT, 1974.
- 7327 **A PRELIMINARY STUDY ON MANUFACTURING INDUSTRY IN THE REPUBLIC OF CHINA**
- a) Ching-Jiunn Huang (Supervisor: Dr M.N. Sharif)
- b) Special studies project
- c) Completed
- d) In this study, the characteristics of the industrialization process in Taiwan during the past twenty years and the growth pattern of the manufacturing industry were identified. The structural changes of the manufacturing industry were also discussed. Its purpose was to present a reasonably comprehensive survey of the present situation and future prospects of the manufacturing industry in Taiwan's economy.
- This study also aimed at describing Taiwan's manufacturing industry by identifying the leading industries in the 4 five-year plans, according to their relative contribution. Especially for 1972, large industrial companies have been discussed on the basis of size analysis, e.g., sales, sales growth, income, return and employment.
- At the end an attempt has been made to give a brief account of the courses of further development of the various important branches of industry arranged in the order of priority.
- e) Special Studies No. 54.
- 7328 **FACTOR DISTRIBUTION PATTERNS FOR THE INDUSTRIAL SYSTEM OF THAILAND**
- a) Mario T. Tabucanon (Supervisor: Dr. Pakorn Adulbhan)

- b) Graduate student thesis project
- c) Completed
- d) This research analyzed the industrial sector of Thailand in an attempt to describe an industrial system in quantitative terms. Thailand has many different types of industry, some of which, especially those industries which are efficient accelerators for industrial development – mining, metallurgical, metal-processing, engineering, electrical and electronics, cement and allied products and prefabrication of construction materials – were considered separately in addition to modeling the industrial system. Dynamic and spatial behaviors were the main attraction in the study with respect to employment, capitalization, and energy consumption. Employment was modeled by a gamma function and negative exponential function modeled the remaining two economic factors.
- e) (i) Thesis No. 787, AIT, 1974.  
(ii) This research is a part of the final research report, Factor Distribution Patterns for the Industrial System of Thailand, submitted to the General Electric Company, New York, on November 15, 1974.

7329 CHARACTERISTICS OF THE IRON AND STEEL INDUSTRY IN THAILAND

- a) Vanida Vongpivat (Mrs.) (Supervisor: Dr. Pakorn Adulbhan)
- b) Graduate student thesis
- c) Completed
- d) This study was concerned with the characteristics of the iron and steel industry in Thailand. The development of the industry was first described. The time-series geographical distribution of firms by size (in terms of employment and capitalization) was then quantitatively analyzed. Firms were divided in two groups—small firms and large firms—small firms being those which have no more than 20 employees or 2 million Baht capital. The iron and steel industry was classified into 3 categories, according to the Factory Act of the Royal Thai Ministry of Industry—classification 59, classification 63, and classification 64. Gamma Gamma functions were used to fit the employment distribution of small firms for the whole industry as well as the three categories. Negative exponential functions were used to fit the capitalization distribution of small firms. Important statistics like mean, standard deviation were subsequently derived. Such statistics were also derived by direct computation for large firms. The industry was also grouped into 23 product types. No distribution could be used to fit them. Important statistics are alternatively computed directly for comparison purpose. Promoted firms were then analyzed separately. Case studies were made on selected firms in the industry for the purpose of tracing the development of technological capability.
- e) Thesis No. 791, AIT, 1974.

7330 DEVELOPMENT OF A QUANTITATIVE MODEL FOR THERMAL ELECTRIC POWER GENERATING SYSTEM PLANNING

- a) Le-Chen Young (Supervisor: Dr. M.N. Sharif)
- b) Graduate student thesis project
- c) Completed
- d) This study deals primarily with the problem of planning a new thermal electric power generating system. The planning objective for the electricity generating system is to choose the new installation so as to minimize the total discounted costs over a given period of years. It is assumed that the generating plants are fully integrated and the installation decisions will take place annually and all new plants will come on power at the beginning of the year. The optimum installed capacity in each year and the best types of units to be installed are calculated by means of a model employing dynamic programming method. Results from the output of the model are used to establish principles for making decisions about the installation pattern and unit types to be used.
- e) i) Thesis No. 785, AIT, 1974.  
ii) YOUNG, I.C., SHARIF, M.N. and ADULBHAN, Pakorn, (1975), Optimal Installation Decisions for Thermo-Electric Energy Conversion, *Proc. Mechanical Engng. Congr.*, Iran.

7331 AN INVESTIGATION INTO THE PROSPECTS OF JUTE MANUFACTURING INDUSTRY OF BANGLADESH

- a) Ghazi Anwar Uddin (Supervisor: Dr. M.N. Sharif)
- b) Graduate student thesis project

- c) Completed
  - d) The purpose of this study was threefold: (i) to study the characteristics of the existing system of jute industry in Bangladesh; (ii) to study the effect of man-made fibre on jute industry; and (iii) to analyze the future prospect of jute products in the world market. A simple procedure has been developed in this study for adopting available mathematical models for forecasting technological substitution of jute by synthetic fibres.
  - e) i) Thesis No. 788, AIT, 1974.  
ii) SHARIF, M.N., and UDDIN, G.A. (1975), A Procedure for Adapting Technological Forecasting Models, *Int. J. of Technological Forecasting and Social Change*, Vol. 7, No. 1.
- 7332 CHARACTERISTICS OF TEXTILE INDUSTRY IN TAIWAN—REPUBLIC OF CHINA
- a) Ing-Kuan Lin (Supervisor: Dr. Pakorn Adulbhan)
  - b) Graduate student thesis
  - c) Completed
  - d) This study deals with the characteristics of the textile industry in Taiwan for the period 1961–1972. An overall perspective of the development of textile industry was first described. This was followed by an analysis of the employment and wage structure. The production performance of the textile industry was then examined. The sales of the textile industry was first described. This was followed by an analysis of the employment and wage structure. The production performance of the textile industry was then examined. The sales of the textile products and the financial structure of the textile industry were analyzed. Finally, the significance of the textile industry in relation to national economic development was examined. In this part, attempts were also made to assess the effects that the textile industry induces.
  - e) Thesis No. 790, AIT, 1973.
- 7333 THE PRODUCTION CHARACTERISTICS OF KOREAN MANUFACTURING INDUSTRIES WITH EMPHASIS ON IRON AND STEEL INDUSTRY
- a) Nam-Soo Suh (Supervisor: Dr. M. N. Sharif)
  - b) Graduate student thesis project
  - c) Completed
  - d) This study is an analysis of various production characteristics of Korean manufacturing industries and specifically iron and steel industry.  
An overview of the Korean economy provides a background for analyses relating to manufacturing industries, classification of the industry, number of establishments and workers, production costs and employees, remuneration, gross output and value added, productivity, and comparison by size of number of workers and regional distribution based on province. The analyses of raw materials, classification, number of establishments and workers, production investment, gross output and value added, productivity, and comparison by size of number of workers and comparisons based on type of ownership and type of workers of the selected industry, iron and steel industry were then made.  
Finally, technological progress was discussed – technological progress, changes in output and technology in a Cobb-Dougllass world, and application of the measurement theory of technological changes to iron and steel industry.
  - e) Thesis No. 782, AIT, 1974.

### THESIS RESEARCH TOPICS FOR 1974–75

1. Integer Goal Programming
2. A Study of Production Technologies for Motorcycle Industry and their Effect on Employment Generation
3. System Analysis of the Metal-related Industry in Taiwan District, Republic of China
4. System Analysis of the Manufacturing Sector in the Philippines with a Case Study of Textile and Garment Industries
5. Characteristics of the Metal-related Industry in Korea

6. Selection of Production Technology Using Goal Programming
7. Some Locational Aspects of Subregional Industrial Growth with Reference to Punjab
8. A Methodology to Determine Appropriate Technology in a Manufacturing Industry
9. Analysis of Sugar Industry in Thailand with Emphasis on the MaeKlong River System
10. Development of a Dynamic Market Penetration Model for Technology-Based Electric Home Appliances
11. Impact of Gasoline Price Increase on the Automobile Tire Industry in Thailand.
12. A Framework for Future Development of the Fertilizer Industry in South Vietnam
13. A Composite Development of the Fertilizer Industry in South Vietnam.
14. A Comparative Study of the Characteristics of Manufacturing Sectors in Sabah and West Malaysia with a Case Study on Forest Based Industries.
15. Characteristics of the Manufacturing Sector in Taiwan District, Republic of China, with a Case Study of Food Industry.
16. Characteristics of the Petroleum and Chemical Industries in Singapore.

**PROJECTS COMPLETED BETWEEN JANUARY 1969 AND JANUARY 1973**

No.	Title	Research Worker(s)	Publications
7102	The Development of a Sub-inter-industry Model in Thailand with Emphasis Centering around the Automobile Assembly Industry	Supparat Mongkornkarn (Dr. Pakorn Adulbhan)	Thesis No. 484
7103	Systems Analysis of Cargo Handling Management at the Port of Bangkok	Vanchai Rijiravanich (Dr. Pakorn Adulbhan)	Thesis No. 485
7106	A Framework for Feasibility and Plant Location of Automobile Industry	Madhab Chandra Bora	Thesis No. 501
7107	The Design of a Management Information and Control System for Plant Maintenance Activities in an Oil Refinery	Ah Lay Chia (Dr. Pakorn Adulbhan)	Thesis No. 474
7108	A Study of Management Control in a Mass Production Industry	Min-Lang Chou (Dr. Pakorn Adulbhan and Dr. Donald R. Drew)	Thesis No. 469
7109	System Analysis of Product Quality Assurance Management in a Selected Process Industry	Swee Cheng Foo (Dr. Pakorn Adulbhan)	Thesis No. 473
7110	Feasibility Study of a New Transport Vehicle Industry for the Developing Countries of Asia	Remesh Chand Gupta (Dr. Donald R. Drew)	Thesis No. 472
7111	A Study of Management Control on a Batch Production Industry	Sunchai Klinpikul (Dr. Pakorn Adulbhan)	Thesis No. 479 The Utilization of Linear Programming in Optimizing the Production Activities of a Cement Plant, <i>Proc. 26th Ann. Conf. &amp; Conv., &amp; Am Inst. Engrs, Washington, D. C., May 20-23, 1975.</i>
7112	Economic Design of Multiproduct Assembly Line	Bing-Nan Lin (Dr. Pakorn Adulbhan)	Thesis No. 502
7113	A Study of Inventory Control in Hospital Pharmacy	Maw-Tzong Lin (Dr. M. Nawaz Sharif)	Thesis No. 507
7114	A Systems Approach to Improving Production Management for an Automobile Manufacturer in Thailand	Kandasamy Paramasivan (Dr. Pakorn Adulbhan)	Thesis No. 503
7115	A Study of Management Control in a Continuous Process Industry	Beng Long Teng (Dr. Pakorn Adulbhan and Dr. Donald R. Drew)	Thesis No. 504
7116	A Study of Management Control in a Unit Assembly Industry	Yuen Lee Yeh (Dr. Pakorn Adulbhan and Dr. Donald R. Drew)	Thesis No. 476
7120	Reliability Approach to SCRAM System Optimization in Nuclear Reactor Design	Udorn Khunvichai (Dr. M. Nawaz Sharif)	Thesis No. 477

## RECENT FACULTY PUBLICATIONS

- ADULBHAN, Pakorn (1973), Implications of Industrial Engineering Education in National Industrial Development, *Proc. 5th A. Tech. Seminar*, The Engng. Inst. of Thailand, Bangkok.
- ADULBHAN, Pakorn (1973), Some Aspects of Quantitative Decision Making in Operations Management, *Managt Dev. Seminar*, P.T. Caltex Pacific Indonesia.
- ADULBHAN, Pakorn and SHARIF, M.N. (1973), A Framework for Studying the Effectiveness of Technology Transfer Through the Industrial Systems in Developing Countries, *Proc. 2nd Int. Conf. on Production Res.*, Copenhagen, Denmark.
- ADULBHAN, Pakorn, SHARIF, M.N., TABUCANON, M.T. and ALAM, K.S. (1974), Factor Distribution Patterns for the Industrial System of Thailand, *Final Research Report* for the General Electric Company.
- ADULBHAN, Pakorn, and HOELSCHER, H.E. (1974), Management Development Crisis, *Proc. 1974 Workshop Reg. Inst. Higher Education and Dev. (RIHED)*, Vientiane, Laos; and *Natn. Dev.*, April 1975.
- ADULBHAN, Pakorn (1975), Industrial Engineering Education in Southeast Asia and Its Implications in Industrial Development, *Engng. Education in SE. Asia*, UNESCO, Jakarta, Vol. 5.
- ADULBHAN, Pakorn and KLINPIKUL, Sunchai (1975), The Utilization of Linear Programming in Optimizing the Production Activities of a Cement Plant, *Proc. 27th Conf. and Convention Am. Inst. Ind. Engrs (AIIE)*, Washington, D.C., U.S.A.
- ADULBHAN, Pakorn, FRANCO, D.T. and SHARIF, M.N. (1975), System Analysis of the Rice Milling Industry in Thailand with Emphasis on Its Capacity Problems, *Proc. XXII Int. Meeting Inst. Managt Sci. (TIMS)*, in cooperation with *The Int. Fed. Operational Res. Soc. (IFORS)*, Kyoto, Japan.
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- HOELSCHER, H.E. (1973), Cooperation Between Industry and Engineering Education Institutions on the Training Level, *UNESCO-sponsored Reg. Seminar on Education-Industry Cooperation in Education and Training*, Manila, The Philippines.
- HOELSCHER, H.E. (1973), Some Perspective on Industrialization and Technology Transfer, *Reg. Conf. on Dev. Planning*, (sponsored by the Dev. Acad. of the Philippines), Tagaytay City and *The All-Pakistan Conf. on Ind.*, sponsored by the World Bank and US AID, Karachi, and *Chemical Ind. Dev. CP&E*, 1974.
- HOELSCHER, H.E. (1974), Development Processes, *TECHNOS*, January.
- SHARIF, M.N. (1974), Management Decision Making Through Operations Research, *Business Review*, Bangladesh, Vol. 2, No. 3, August.
- SHARIF, M.N. (1974), Role of System Engineering Education in Developing Countries, *Proc. IFAC Int. Symp.* (sponsored by the Int. Fed. of Automatic Control and the Int. Fed. of Operational Res. Soc.), New Delhi.
- SHARIF, M.N. and GHAZI, A.U. (1975), A Procedure for Adapting Technological Forecasting Models, *The Int. J. of Tech. Forecasting and Social Change*, Vol. 7, No. 1, January
- SHARIF, M.N. (1975), Identification of the Areas of Research and of Cooperation Between Institutes of Engineering Education and Industry in the Context of Relevant Technological Change in the Developing Countries of Asia, *J. Engng Education in SE Asia*, Vol. 5, April.
- YOUNG, I.C., SHARIF, M.N. and ADULBHAN, Pakorn (1975), Optimal Installation Decisions for Thermo-Electric Energy Conversion, *Proc. Mech. Engng Cong.*, Pahlavi University, Iran.
- SHARIF, M.N. and ADULBHAN, Pakorn (1975), A Mathematical Model for Industrial Project Evaluation, *OMEGA - The Int. J. of Managt Sci.*, Vol. 8 No. 3.



## RESEARCH IN COMMUNITY AND REGIONAL DEVELOPMENT

The research program in the Division of Community and Regional Development reflects an integrated approach to the problems of development in the South-East Asian region. The fundamental framework of the program is a systems-analytic framework, covering both the technical aspects and socio-economic aspects of development. The human side of the development problem is given as much emphasis as the technical side.

The Division attempts to tackle development problems within the broad framework in which they occur. Its programs are balanced between rural development and urban development, and its emphasis is on the systematic treatment of development problems in rural areas, urban areas, and the transportation systems that form the communication networks between them.

Rural development is emphasized in the research program in the field of Agricultural Systems Engineering and Management. Although this field is engineering based it treats agricultural problems in their totality, from the points of view of both production and management. But this field does not stand on its own. It is supported by two more programs in agricultural development in other divisions: Irrigation Engineering in the Division of Water Resources Engineering, and Agricultural Soil and Water Engineering, in the Geotechnical Engineering Division (see Agricultural Engineering on page 169). Within the Division of Community and Regional Development it is supported by research on rural transportation systems, rural development and regional planning and development.

Transportation research in the Division covers both rural and urban transportation problems, as well as regional transportation networks and their contribution to development. Research has been directed towards planning balanced transportation systems and operating the planned systems efficiently. Studies have been directed towards the development and applications of system dynamics to a wide spectrum of problems in air, land and water transportation. As an example of a combined Divisional activity, a regional planning model has been developed for the Bicol River Basin in the Philippines.

The Human Settlements program covers a wide range of development problems, with particular emphasis on urban development and regional development, and a growing emphasis on rural development. Within the program, studies on housing, land use, public policy, development administration, and a variety of social and economic aspects of urban and regional development form the basic core of the research. Again, a systems approach is adopted, with an emphasis on finding the most suitable and efficient way to tackle specific problems.

The variety of research topics in the Division of Community and Regional Development can be discerned by examining the following research summaries. They should also serve to indicate the integrative character of the Division's approach to the problems of development in the region.

**DIVISION OF COMMUNITY AND REGIONAL DEVELOPMENT  
FACULTY AND SENIOR STAFF**

Chairman: *Dr P.A. Cowell*

**Professors**

*Eric A. Axilrod\** B.A., Southern Methodist; M.A., Ph.D.,  
Harvard. (*Economics and Management*)

*Donald R. Drew\** B.S., Purdue; M.S., Ph.D., Texas A & M;  
former Division Chairman. (*Systems  
Engineering*)

**Associate Professors**

*P.A. Cowell* B.Sc., M.Sc., Ph.D., Durham.  
(*Agricultural Engineering*)

*J.H. de Goede* Drs, Free University of Amsterdam.  
(*Social Development Planning*)

*Myong-Chan Hwang* LL.B., M.P.A., Seoul National; Ph.D., Syracuse.  
(*Human Settlements Planning*)

*Laurence A.G. Moss\** B.A., British Columbia; M.C.P., M.A., California.  
(*Human Settlements Planning*)

**Assistant Professors**

*Shlomo Angel* B.Arch., Ph.D., California.  
(*Human Settlements Planning*)

*Stanley Benjamin* B.Arch., Manitoba; M.Arch., Harvard.  
(*Urban and Regional Planning*)

*R.H.B. Exell* M.A., D.Phil., Oxford. (*Applied Mathematics*)

*Gajendra Singh* B.Sc. A.E., Pantnagar; M.S., Rutgers; Ph.D.,  
California. (*Agricultural Systems Engineering*)

*Lal Chand Wadhwa* B.Sc., Punjab; B.Eng. (C.E.) Inst. of Engineers (India);  
M.Eng., D.Eng., AIT. (*Systems Engineering and  
Management*)

*Wai-Ling Woo* B.Sc., National Taiwan; M.Eng., D.Eng., AIT.  
(*Transportation Systems Engineering*)

**Associated Faculty**

*Tienchai Pradisthayon* B.Sc., Chulalongkorn; Ph.D., Glasgow.

*Keith R. Emrich \** B.Sc., Iowa State; Ph.D., Pittsburgh.

*Boonlert Leoprapai \** B.Econ., Hitotsubashi; M.A., Pennsylvania;  
M.A., Ph.D., Massachusetts.

*Thomas M.N. Ratnasabapathy\** B.Sc. (Eng.), Ceylon; M.Eng., AIT.

*N. Brito Mutunayagam\** B.Sc., Kerala; M.Eng., AIT.

***Kaya Saricali\****

**B.S., Middle East Technical University; M.Sc., AIT.**

***Jugal Kishore Agarwalla***

**B.Eng., Gauhati University; M.Eng., AIT.**

**\*This list includes all faculty and staff holding appointment in the period since January 1973. Those who no longer hold appointment are indicated by an asterisk.**

**RESEARCH PROJECTS COMPLETED OR IN PROGRESS SINCE  
JANUARY 1973**

**7501 ANALYSIS OF THE PATPONG MULTI-STORY PARKING GARAGE OPERATION**

- (a) Byun, Joon-Ho (Supervisor: Dr. Donald R. Drew)
- (b) Graduate student thesis project
- (c) Completed
- (d) A considerable amount of research has been done on parking problems, but most of the studies have been about parking characteristics during peak periods. Emphasis has been placed on the analysis of the whole working day by means of a macro-simulation. Efforts have also been made to develop formulae for the parking-duration characteristics of drivers in the Patpong district in the Bangkok metropolitan area.  
Both data collection and analysis of data are essential initial steps in the study of parking characteristics. Data were analyzed to discover the arrival pattern of drivers at the Patpong parking garage. Parking duration was formulated and correlated with field observations to achieve the goal of developing the system model.  
Finally, the system model was developed to permit experiments to be carried out; validation was obtained by using the Chi-square test.
- (e) Thesis No. 572, AIT, 1973

**7502 ECONOMIC EFFECTS OF THE LAMPANG-CHIENG MAI HIGHWAY IN NORTHERN THAILAND**

- (a) Sophon Agatvipat (Supervisor: Prof. John Hugh Jones)
- (b) Graduate student thesis project
- (c) Completed
- (d) The objective of this study was to investigate the effect of the Lampang-Chieng Mai Highway on the economic development of the region in which it is located. The study area traversed by the highway comprises six amphurs. Studies of traffic were conducted to explore the patterns of transportation as an aid to understanding the usage of this highway. Indirect benefits studied were those associated with the development of agriculture, forestry, and social activity.  
The methods used in this analysis were a combination of cross-sectional and time-series analysis. Time-series changes in agricultural production, mineral production, and social activity, were compared to data for a reference area. It was found that the Lampang-Chieng Mai Highway seemed not to affect agricultural production, forest production, nor social development in the study region. Due to its competitive situation with rail transportation, the number of passengers that travelled by rail and the revenue collected decreased from those stations which have access to the new road. Neither rail carload freight nor less-than-carload freight showed any development that could be imputed to the presence of the new highway.
- (e) Thesis No. 573, AIT, 1973.

**7503 ECONOMIC EFFECTS OF THE RECONSTRUCTED PATTANI-NARATHIWAT HIGHWAY IN SOUTHERN THAILAND**

- (a) Somkiat Lertpanyavit (Supervisor: Prof. John Hugh Jones)
- (b) Graduate student thesis project
- (c) Completed
- (d) The objective of this research was to investigate the effect of the reconstructed Pattani-Narathiwat Highway on the economic development of the area traversed by it. Traffic studies were conducted to determine the patterns and trends of the traffic on the highway. Detailed analyses of the economic benefits, mainly indirect benefits, which might have been induced by the improvement of the highway are presented. Indirect benefits were evaluated from the development of agriculture, forestry, and social activity.  
The research utilized a combination of time-series and cross-sectional analysis techniques to investigate the changes in economic activity. Time-series changes in agricultural production, forest production, and social activity were analysed by comparing the data

with those of a datum area, which had similar environmental conditions and supposedly was not influenced by the highway improvement. The research sought further to investigate the competitive effect on railway traffic. Rail carload and less-than-carload freight and the number of passengers carried by the railway, and their corresponding revenues were studied in detail. It was found that only despatched carload freight revenue experienced a loss after the opening of the reconstructed Pattani-Narathiwat Highway.

(e) Thesis No. 574, AIT, 1973.

**7504 EVALUATION OF DRIVERS' UTILIZATION OF THE AMBER PHASE OF TRAFFIC SIGNALS**

(a) Shyu Heng-Shyong (Supervisor: Prof. John Hugh Jones)

(b) Graduate student thesis project

(c) Completed

(d) The purpose of this study was to evaluate the effect of drivers' utilization of amber time on starting delay, intersection capacity, and potential conflict. Four signalized intersections in Bangkok were investigated. A time-lapse photographic technique was used to gather the field data.

Observations were made by reviewing the photographs to obtain the number of vehicles entering the intersection after the beginning of the amber phase, the entry time of the first vehicle on one movement, and the entry time of the first vehicle on the following movement. Statistical distributions were used to analyze the observed data. Measurements were made of headways, time required for the last vehicle to clear the intersection, and starting delay. Intersection capacity and potential vehicular conflict were evaluated. Relationships were established to express the effect of the drivers' utilization of amber time on starting delays, intersection capacity, and potential conflict.

(e) Thesis No. 575, AIT, 1973.

**7505 EVALUATION OF GREEN-ARROW SIGNALS AT A T-JUNCTION IN BANGKOK**

(a) Prabeer Kumar Sikdar (Supervisor: Prof. John Hugh Jones)

(b) Graduate student thesis project

(c) Completed

(d) The right-turning movement at an intersection contributes to the capacity problem and may cause hazards of conflict. Many studies have been devoted to devising efficient methods for handling this movement at signalized intersections.

The present study was conducted to evaluate a modified signal indication displaying an improved signal sequence at a signalized T-junction which had an early cut-off sequence. The criteria of intersection operation that were evaluated are: capacities, starting delays, and hourly volumes for the major movements of the three approaches.

The data for this study were collected using a time-lapse photographic technique during the morning and afternoon peak traffic periods. The flow under saturated conditions for one particular movement as a whole was considered for determining the capacity of that movement. Flows at two levels of saturation were obtained from the cumulative distribution curves. An indirect method, measuring the number of vehicles entering during the first 15 seconds, and the first 20 seconds, of the green phases was used to evaluate the starting delays of the three movements. The observations of 'before' and 'after' conditions were compared statistically using the F-test and Student's t-test at the 5- and 10-percent levels.

Among the favourable effects of the modified signal indications were a significant improvement in capacities of the individual major movements of the approaches, an increase in the flow of the straight-through movement of the approach having no right-turn, and an increase in the hourly volume handled by the three principal movements. This study did not show a significant improvement in the starting delays of right turners from the through road.

(e) Thesis No. 576, AIT, 1973.

**7506 COMPUTER SIMULATION OF OPTIMUM SIGNAL SETTINGS AT SALADAENG INTERSECTION, BANGKOK**

- (a) Ting Kuo-liang (Supervisor: Prof. John Hugh Jones)
- (b) Graduate student thesis project
- (c) Completed
- (d) The Computer simulation of optimum signal setting at Saladaeng intersection has been organized into two parts. The first was a field experimental study. By using a cine camera, the traffic demands and the operating characteristics of the intersection were obtained. The second part was the development of computer simulation model. The program was written macroscopically using the cycle length as the scanning period. The optimum cycle length was found through simulation after the validation of the model by field data. It was determined that 145 sec and 175 sec would be the most suitable cycle length for the morning and the evening peak traffic periods, respectively. The optimum signal setting would reduce the average vehicular delay from that produced by the police-controlled, long-cycle length operation ordinarily used during the peak-hour periods.
- (e) Thesis No. 577, AIT, 1973.

**7507 SYSTEMS ANALYSIS FOR OPTIMIZING AIT STAFF TRANSPORTATION SERVICE**

- (a) Vu Dinh Quy (Supervisor: Dr. M. Nawaz Sharif)
- (b) Graduate student thesis project
- (c) Completed
- (d) The purpose of this study was to find an optimal solution for the problem of transporting AIT faculty and staff between Bangkok and AIT Rangsit campus so as to provide a desired level of service at a minimum cost to the Institute over the next ten year period. In addition, the study also considered the feasibility of building houses on campus for faculty and staff accommodation, and also the problem of transporting students residing on campus to and from Bangkok during weekends and holidays.  
The equivalent uniform annual cost has been used as a means for selecting the best out of all possible alternatives. The bus schedules have been prepared using computerized algorithm and minimal chain decomposition methods.
- (e) Thesis No. 579, AIT, 1973.

**7508 SYSTEM ANALYSIS APPLIED TO EQUIPMENT SELECTION IN A MULTI-PLANT COMPANY**

- (a) Kwong Pui Tam (Supervisor: Prof. E. Axilrod)
- (b) Graduate student thesis project
- (c) Completed
- (d) This paper deals with several cost models for equipment selection in multi-plant company. The models are especially suitable for selection between numerical control and conventional machines. However, applications to other equipment are possible. In order to compare different equipment, the annual cost of the production system using different equipment should be calculated. The model first divides costs into fixed and variable according to their sensitivity towards production volume. Annual fixed cost is minimized by varying (1) the equipment's retirement age or (2) both the age of the equipment when purchased and the service period of the equipment. The minimum annual fixed cost is then combined with the variable cost to form the total annual cost which is again minimized by varying the order quantity. Equipment selection then depends on the total annual cost computed from the model.  
In multi-plant company, the parent plant receives components produced by its subsidiaries which may be located in different geographical regions. Such production systems have several inventory structures and three of them are incorporated into the basic equipment selection model to form three different selection models. Other factors taken into consideration in the models include set up costs and production quantities.
- (e) Thesis No. 597, AIT 1973.

**7509 DETERMINATION OF AN OPTIMUM PROGRAM FOR LAYING NEW UNDER-GROUND TELEPHONE CABLES**

- a) Varaporn Pichetvivatana (Supervisor: Dr. R.H.B. Exell)
- b) Graduate student thesis project
- c) Completed
- d) In the Telephone Organization of Thailand pipes are laid at one time to meet the whole demand forecasted for a twenty year period, but cables are laid twice in the twenty year period to meet the forecasted demand every ten years. It is the purpose of this study to determine the most economical program for laying pipes and cables in phases.  
The method developed has been applied to one section of a new distribution network planned for the Nakorn Pathom area. The cost of the chosen section of the network has been calculated for a range of different time intervals between pipe-laying and cable-laying operations. The results show that it should be most economical to lay the pipes every twenty years and to lay the cables every four or five years. It is, therefore, concluded that the Telephone Organization of Thailand have adopted the best policy for pipe laying, but that it would be more economical for the Organization to lay the cables more frequently than they do at present.  
A second more general model involving costs of replacing old cables and pipes, and allowing for costs varying with time is proposed.
- e) Thesis No. 608, AIT, 1973.

**7510 A SYSTEMS MODEL FOR INDICATIVE PLANNING IN THE PHILIPPINES**

- a) Rene S. Santiago (Supervisor: Dr. R.H.B. Exell)
- b) Graduate student thesis project
- c) Completed
- d) A systems model is developed, under conditions of limited data, based on the source of the problems and the motive for planning – the people themselves.  
Five interrelated problem areas were identified and modeled from verbal descriptions and simple analytical expressions found in the literature. These areas are: population, education, agriculture and land use, urbanization and housing, and employment. The areas were viewed as interlocking subsystems whose outputs serve as indicants for planning efforts in the Philippines.  
Varying levels of aggregation among the five subsystems emerged from the modeling work. The population module is sufficiently detailed to break down ages into 5-year cohorts and pinpoint age-correlated variables. Education ranks second in global refinement with categorization of 3 sequential stages of formal schooling to simulate the actual flow of pupils. Classification of population into urban and rural permits determination of the number of cities in a hierarchy. Others are macrostructured.  
Implications of the simulation results and of the systems model to planning were discussed in conclusion.
- e) Thesis No. 609, AIT, 1973.

**7511 INDUSTRIAL LOCATION IN TAIWAN**

- a) Yeun-Yi Wang (Supervisor: Dr. R.H.B. Exell)
- b) Special studies project
- c) Completed
- d) The present distribution of manufacturing industries among the fifteen regions of Taiwan that contain over 97% of the manufacturing employment and capital investment has been studied with the help of a system of location quotients. An attempt has been made to explain this distribution in terms of current theories of industrial location.  
The major influences on the distribution such as the location of raw materials, labour supply, and port location, have been determined for several classes of industry. Generally speaking theoretical models seldom fit the situation in the real world and few of the theories are applicable in Taiwan, but some features of the theories were found to be useful.
- e) Special Studies Project Report No. 27, AIT, 1973.

**7512 THE DYNAMICS OF URBAN PUBLIC TRANSIT OPERATIONS**

- a) Parthasarathi, N.V. (Supervisor: Dr. Donald R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) It is increasingly becoming difficult for an urbanite to get about an urban area quickly, conveniently, safely and at a relatively low cost. After briefly outlining some of the major problems that are causing the urban transportation crisis, the research brings out that the hitherto adopted conventional planning approaches are more directed toward the symptoms rather than toward the disease, mainly as a result of the lack of understanding of the cause-and-effect feedback characteristics of this socio-technological system. It has been shown that the systems dynamics approach is better suited for this purpose, and a general urban public transit model has been developed using this approach.  
Bangkok has been taken as a case study to test the validity of the model and computer simulation runs using Bangkok data have been presented in the research.  
The research then proceeds to test the various policies in order to achieve the objective of developing a balanced transportation system for Bangkok. Sensitivity analysis indicates that many of the parametric values assumed are insensitive to policy changes and that superfluous data is being collected under present day modelling techniques and planning methodologies.  
It is hoped that using a model of the type presented in the research, future transit planners will be better able to tackle the problems of urban transportation.
- e) Thesis No. 612, AIT, 1974.

**7513 AN URBAN TRANSPORTATION PLANNING METHODOLOGY FOR DEVELOPING COUNTRIES**

- a) Abraham, P.C. (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)
- b) Graduate student thesis project
- c) Completed
- d) In the West, transportation studies have taken complex shapes casting doubt as to whether the planning process is more important than the plan itself; while in the developing countries of Asia, it has been no more than a piecemeal, or a 'shot in the dark' approach mainly due to the lack of funds and facts. Hence the research was to identify the problem areas of transportation in developing countries, with a view to proposing a new methodology to substitute its traditional approach of long drawn out and expensive planning processes leading to sophisticated planning models which are unsuited to the Asian situation.  
Systems approach to transportation planning solicits a well defined and properly structured goal package based on the values and norms in the society. Generation of alternatives is achieved through identifying the roles of users, non-users and suppliers when transportation is viewed as a totality. For the evaluation and plan selection a combined cost-effectiveness-efficiency model is used. Three scarce resources—time, space and energy—are singled out to be the controlling design considerations in planning. The concepts of traffic architecture, of designing buildings and roads together, upholding environmental values and promoting the freedom of mobility are yet other links in the methodology. The research then identifies the problem areas of Bangkok and explores how the 'Thaiway system' conforms to the city's transportation requirements—both for the present and future.
- e) Thesis No. 613, AIT, 1974.

**7514 ANALYSIS OF THE DEVELOPMENT OF THAILAND'S COASTAL AND INLAND WATERWAYS SYSTEM**

- a) Surapon Chaiprasit (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)
- b) Graduate student thesis project
- c) Completed
- d) Thailand is a country which has both inland and coastal waterways. Besides providing

water for agricultural purposes, the river and canal system in the Central Plain of the country also has a role in carrying commodities. Rice and maize, for example, are shipped via these inland waterways in large amounts. Except the import and export traffic at the Port of Bangkok and some ports in the Southern Region, the volume of the coastal shipping is relatively small.

This research is to analyse the problem of making optimum use of Thailand's inland and coastal waterways. When compared with the other modes of transport, the waterways of the country are under-developed. Siltation is a major problem which reduces the navigable depth of the rivers and canals.

Graphs and binary connectivity matrices in the network theory, and freight movements in the regions were used to describe the competitiveness of water transportation with land transportation. It was found that in the Central Plain the inland waterways still had the dominant place in transporting commodities. Trucking has become more competitive as the highway system is developed rapidly. In the coastal area, coastal shipping lagged behind railway and highway in terms of freight carried.

e) Thesis No. 614, AIT, 1974.

**7515 A STUDY OF THE DYNAMIC INTERACTION BETWEEN TRANSPORTATION AND TALL BUILDINGS**

a) Lamduan Srisakda (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)

b) Graduate student thesis project

c) Completed

d) This thesis has been aimed at the study of the dynamic interaction between transportation and tall buildings by using the technique of System Dynamics. Three distinct eras are identified in the evolution of the phenomenon of tall buildings: (1) the stable era before the invention of the elevator; (2) the unstable era since the elevator; and (3) the restoration of equilibrium due to congestion on transportation networks that serve the buildings. To study this phenomenon, the transportation-tall building model is constructed and then tested with the real world performance. The area of Amphor Bangkok, Bangkok, is used as a case study area. Finally, by using the developed model, investigation is made on the consequences of adopting some hypothetical policies.

e) Thesis No. 615, AIT, 1974.

**7516 THE DYNAMICS OF HIGHWAY TRANSPORTATION GROWTH IN TAIWAN**

a) Yu Teh-Yi (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)

b) Graduate student thesis project

c) Completed

d) The purpose of this research is to study the probable application of dynamic systems approach on the investigation of Taiwan highway transportation growth. A dynamic model is first constructed to describe the existing highway transportation system. Using data of 1966 as initial values, a simulation is driven through 2000. The results of the simulation show the future tendency of the growth from which some findings are revealed and discussed.

The model is then improved by feeding in the considerations of some new policies, environmental changes, and geographical limitations. Due to these considerations, two negative feedback loops are introduced. The future growth of Taiwan highway transportation is predicted by the simulation of the improved model. It is found that per capita income is one of the most sensitive generators of transportation demand. As long as the per capita income grows, the transportation demand will increase continuously despite the limits on population and land use. The simulation also exposed the advantages and disadvantages of the existing transportation system.

e) Thesis No. 616, AIT, 1974.

**7517 A STUDY OF GROUND ACCESS AND PARKING OPERATIONS AT BANGKOK INTERNATIONAL AIRPORT**

a) Chiu Chang - Hsien (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)

- b) Graduate student thesis project
- c) Completed
- d) The problem of access to airport and parking operations has received increased attention in the public media as major airports experience congestion caused by recent rapid increases in air travel demand.

This study has approached the general problem of ground transportation at Bangkok international airport by means of two different methods separately; one could be referred to as the general approach and the other as the multiple regression method. Field studies at the airport have analysed and quantified the problem of existing ground transportation systems through the general approach, and also established relationships between air passengers and requirements for vehicles serving airport functions and users by using the linear multiple regression model; the related findings and results are given and, in passing, some considerations are suggested for improving airport utility and ground transportation systems.

Applications of findings and resulting models are presented in Chapter VI in order to facilitate interpretation of the results of this study.

- e) Thesis No. 617, AIT, 1974.

#### 7518 THEORY AND APPLICATIONS OF TRAFFIC STREAM DYNAMICS

- a) Chang, Kuei-Lin (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)

- b) Graduate student thesis project
- c) Completed

- d) A study of information feedback phenomenon in car-following situation was undertaken in an attempt to describe the basic stimulus-response policy existing in the driver-vehicle-road complex. Three car-following models were selected for this study. The modeling techniques used were based on concepts of system dynamics, a theory of system structure that permits an analyst to represent, symbolically and mathematically, the interactions governing the time history behavior of complex machine systems.

Additionally, since the traffic emission and fuel consumption are causally related to the behavior of the traffic, the model was extended to include the many interrelated sectors in order to investigate and evaluate their inter-relationships in the hope of attaining a better understanding of traffic operation characteristics.

Furthermore, another aspect of this study was to describe the highway automation, one possible means of increasing highway capacity and safety. Emphasis was placed on how to apply the principles of car following in developing appropriate longitudinal control system for the improvement of human shortfalls in driving performance.

- e) Thesis No. 618, AIT, 1974.

#### 7519 THE DYNAMICS OF TRANSPORTATION AND URBAN DEVELOPMENT

- a) Zia S. Arif (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)

- b) Graduate student thesis project
- c) Completed

- d) This research has been aimed at constructing a Systems Dynamics model for the dynamics of transportation and urban development. Though impact of transportation on urban growth and form has been vastly recognised, little progress has been made in satisfactory quantification of this interaction.

This study has been able to develop a model which can be used as a planning tool in testing the effect of various urban transportation alternatives, thus providing a step forward in attempts to rationalize decision making. Besides this, a new direction for further research has been ascertained by this study.

To check validity, the historical development of Bangkok was simulated and it was seen to agree with actual past growth, thus confirming the effectiveness of the model in making future projections.

Sensitivity analysis was done which revealed the insensitiveness of the parameters used in the model.

Five policies have been tested for Bangkok to establish the practical utility of the model.

- e) Thesis No. 619, AIT, 1974.

**7520 ANALYSIS OF THE RELATIONSHIP BETWEEN TRAFFIC CONGESTION AND AIR POLLUTION**

- a) Tan, Team-Chye (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)
- b) Graduate student thesis project
- c) Completed
- d) Transportation studies have historically concentrated their focus on inventories of travel and other urban area social and economic characteristics, with relatively little attention given to the interrelationships between environmental problems and transportation planning and other urban systems.  
This study is an attempt to combat the environmental problem—traffic-air-pollution—systematically from the transportation engineering point of view. Two system dynamics models are formulated, namely, Urban Air Pollution Dynamic Micro-Model and Urban Air Pollution Dynamic Macro-Model. The application of the Micro-Model shows the derivation of the relationship between traffic congestion and air pollution, and also provides information for transportation short-range planning. The application of the Macro-Model yields the dynamics simulation of the macro-system. Through simulation of different air pollution control alternatives, an economical study of decision making for air pollution control policy can be made.
- e) Thesis No. 620, AIT, 1974.

**7521 AN EVALUATION OF THE ALTERNATIVE NETWORK SCHEMES AS A REGIONAL FRAMEWORK**

- a) Hsu Chao-Shiung (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)
- b) Graduate student thesis project
- c) Completed
- d) The problem of evaluating the alternative network schemes is to compare the merits of each network system under a given travel condition. There are four patterns of network systems evaluated in the research: parallel, rectangular, hexagonal and triangular network systems. It was assumed that trips are generated with equal frequency at all points in an infinite plane, and that the directions of these trips are uniformly distributed. Mathematical models which represent the average travel time for the four network systems are derived under the assumption that trips are made by the quickest route. The ultimate objective is to find the system of network that minimizes the average travel time.  
From the comparisons of the average travel time between the four alternative schemes, the hexagonal network pattern is shown to be the most effective one when the travel speed on main-highway is very near to that on local road. But when the speed ratio of the two highway systems is higher, the square grid will have the minimum travel time for short trips and triangular pattern for long trips.
- e) Thesis No. 621, AIT, 1974.

**7522 A SYSTEM DYNAMICS MODEL OF SIGNALIZED NETWORKS**

- a) Jong, Cheng-Hsin (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)
- b) Graduate student thesis project
- c) Completed
- d) This research is preliminary study of the applications of system dynamics approach to the investigation of the traffic behavior and intersection performance at signalized intersections.  
System dynamics models were developed for fixed-time signal intersections with and without turning movements, and for vehicle-actuated signal intersections, with and without turning movements. Also traffic behavior and intersection performance at progressive signal systems, simple diamond interchanges, split or three-level diamond interchanges, and triangular network were studied by using the basic models developed. It was proved that the dynamic model developed can be used for setting optimum cycle length and optimum green times at a fixed-time signalized intersection. Basically, the

dynamic model simulating the traffic behavior at a progressive signal system can simulate the traffic behavior at simple diamond interchange, split or three-level diamond interchange, and triangular network with same concept and similar model structure. Therefore, only the computer outputs of progressive signal system were presented. Through this study, it can be found that the system dynamics approach can describe the traffic behavior at a signalized intersection more simply and easily than the conventional approach.

e) Thesis No. 622, AIT, 1974.

**7523 THE RELATIONSHIP OF TRANSPORTATION TO THE INDUSTRIAL DEVELOPMENT IN THE BICOL RIVER BASIN IN THE PHILIPPINES**

- a) Mariano R. Santiago (Supervisor: Dr. Donald R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) This research deals with the relationship of transportation to the industrialization of the Bicol River Basin in the Philippines as part of a bigger economic model being done for the Government of the Philippines and the US Agency for International Development. The dynamic simulation approach developed by J.W. Forrester has been used throughout the study and data used were a combination of actual and assumed constants. Shippers were assumed to choose from four different modes of transportation on the basis of several factors aside from the actual out-of-the-pocket cost. Road links were assumed to be composed of a pair of nodes where production or consumption are based. From the selection of modes, the model proceeds to determine the growth of the trucking industry in the region, considering the gross revenue earned and the cost of vehicle operations.
- e) Thesis No. 623, AIT, 1974.

**7524 A METHODOLOGY FOR THE COMPARISON OF ALTERNATIVE TECHNOLOGY**

- a) Vinod Kumar Tuli (Supervisors: Dr. Donald R. Drew and Dr. Wai-Ling Woo)
- b) Special studies project
- c) Completed
- d) Efficient improvement in transportation system depends at least in part, upon good analysis. Analysis which clarifies the consequences that result from making changes to the system and illustrates possible trade-offs contributes to an understanding of the issues raised by the various choices.  
This study considers the various aspects of goals and objectives and what criteria should be kept in mind while formulating them. Various factors have been illustrated which are important to the evaluation of alternative transport systems or technologies. A cost model has been developed for a transit system in an urban area and different elements of an urban transportation system have been alluded to. Cost-effectiveness technique has been considered and it is explained how this technique is better and more flexible compared to other conventional techniques.
- e) Special Studies Project Report No. 57, AIT, 1974.

**7525 THE RELATIONSHIP OF TRANSPORTATION TO AGRICULTURAL AND HUMAN SETTLEMENTS DEVELOPMENT IN THE BICOL RIVER BASIN, PHILIPPINES**

- a) Nabor C. Gaviola (Supervisor: Dr. Donald R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) Much has been said about the role of transportation in regional development. National planners and economists are in agreement that without an efficient transportation system, development will not be achieved. Transportation is an all-pervading industry; it penetrates into all phases of production and distribution of goods while at the same time the transport of persons depends on the same sector. An analysis of the relationship of transportation to agricultural and human settlements development in the Bicol River Basin, Philippines is made. A system dynamics model has been formulated to show the interactions of the different elements involved. The

primary purpose of constructing the model is to show the general structure of the system.

The model that has been formed has been tested in the computer to investigate the effects of the improvement in road conditions to the demand of goods and passenger transport as well as to the rate of consumption of urban land.

e) Thesis No. 624, AIT 1974.

**7526 A MATHEMATICAL THEORY FOR SCHEDULING ROAD DIGGING OPERATIONS IN A CITY**

a) Le Tu Hy (Supervisor: Dr. R.H.B. Exell)

b) Graduate student thesis project

c) Completed

d) A study has been made of the problem of combining road digging operations from different agencies for constructing, laying and repairing public utility services in a city in order to optimize the program with respect to cost, traffic obstruction due to digging operations and total duration of work.

In one model, CPM/PERT was recommended for combining work, in the first phase, to obtain a schedule for work on each section of road or zone. Then Boolean Algebra was used in the second phase to find a schedule for work on the entire road system.

In a second model, Boolean Algebra was also used to determine which working team should be assigned to which task at what time so that the entire project could be done in the shortest time.

The existing problem of coordinating the work of the Water Supply, Telephone, Electricity, and Road Construction and Repair Departments in Bangkok was discussed, and a general proposal was made. In this general proposal, the use of CPM/PERT was considered as a practical method, whereas the Lagrange multiplier method, Fulkerson's algorithm and linear network flow techniques were considered to be theoretically applicable in reducing the total cost of the entire project but difficult to use in practice.

e) Thesis No. 717, AIT, 1974.

**7527 RELATIONSHIP BETWEEN ROAD TRANSPORT AND RURAL DEVELOPMENT IN THAILAND**

a) Somkual Polchan (Supervisors: Dr. Wai-Ling Woo, Dr. Donald R. Drew)

b) Graduate student thesis project

c) Completed

d) Investigation of relationship between road transport and its impact on rural development in Thailand was made primarily by reviewing the role of road construction in the rural development with emphasis on the agricultural production, business activity (in terms of taxation), etc. Methods of time series and cross-sectional analysis were applied on highways in each region of Thailand. The mathematical model proposed by the road research team in Sabah in the study of relationship between road transport and rural development was reviewed and modified to suit Thailand's condition. A transport system for the development of the serviced area was introduced in this research as a basic guide for a high-efficiency policy of capital investment.

e) Thesis No. 724, AIT, 1974.

**7528 TRANSPORTATION DYNAMICS: A METHODOLOGY FOR TRANSPORTATION SYSTEMS**

a) Wu-Cheng Chen (Supervisor: Prof. Donald R. Drew)

b) Doctoral dissertation

c) In progress

d) This research aims at reviewing, applying, and evaluating a promising methodology—system dynamics—for transportation system analysis. Six diverse problem areas including the dynamics of the traffic stream, signalization analysis, port operations, the growth of highway transportation, the decline of urban public transit, and transportation and land use interactions have been selected for analysis using the system dynamics. A similar format is used in the approach to each problem area: (1) the nature of the problem is described; (2) causal relationships and feedbacks between key variables are

isolated; (3) the model is described in three complementary forms—verbal, graphical (using system dynamics symbols), and mathematical (using DYNAMO equations); (4) results are presented in the form of computer tables and graphical plots; and (5) the extensions and significance are discussed. The application of the methodology to investigating rather simple technological and policy alternatives is illustrated in each case. Possible extensions of each of the six models are suggested as well as ways in which the models can be combined to address other, more comprehensive problems. Throughout the presentation, emphasis is placed on the potential of the system dynamics methodology for solving problems in developing countries.

- e) CHEN, W.C. and DREW, D.R. (1974), Transportation and Tall Buildings, *Proc. Reg. Conf. on Tall Bldg.*, Bangkok.

7529 A REGIONAL PLANNING MODEL FOR THE INFRASTRUCTURAL DEVELOPMENT IN THE BICOL RIVER BASIN, PHILIPPINES

- a) Charng-Horng Hsieh (Supervisor: Prof. Donald R. Drew)  
 b) Doctoral dissertation  
 c) In progress  
 d) This research aims at constructing an operational, dynamic, interactive, digital computer model that can simulate the process of regional development with respect to the interfaces of agriculture, industry, infrastructure, population growth, capital accumulation and allocation, employment, and income. As the foundation of regional development, infrastructure is given special emphasis in this research. Infrastructure is broken down into institutional infrastructure (land reform and compact farm organization), physical infrastructure (water supply, irrigation, flood control, electric power, recreation, land use, housing, and transportation) and social infrastructure (health, family planning, and education).

The model is simulated on a CDC-3600 computer with a set of parameters, constants, and initial values representing the present conditions in the Bicol River Basin Region. The simulation results tend to show that the eight infrastructural projects which comprise the Bicol River Basin Development Program are inadequate to accomplish "economic take-off" in the region within the next 30 years.

For the purpose of demonstrating the capability of the model as a tool for policy testing, three policies for infrastructural development—an accelerated land reform policy for institutional infrastructure development, a feeder road construction policy for physical infrastructure development, and a negative family planning policy under social infrastructure development—are simulated using the model and the results evaluated.

- e) DREW, D.R., WADHWA, L.C., PAUL, H., and HSIEH, C.H. (1975), "Simulation Model of the Bicol River Basin Development", *Proc. 6th An. Conf. Modeling and Simulation*, Pittsburgh.

7530 A SIMULATION MODEL FOR THE INDUSTRIAL DEVELOPMENT OF THE BICOL RIVER BASIN, PHILIPPINES

- a) Himangshu Paul (Supervisor: Prof. Donald R. Drew)  
 b) Doctoral dissertation  
 c) In progress

- d) This dissertation presents a system dynamics model of the industrial development of the Bicol River Basin Region in the Philippines. The model is comprised of seven modular sectors which are interrelated through a series of direct and indirect feedback loops. These sectors are agriculture, industry, infrastructure, social overhead, population, capital, and employment, wages, and income.

The industrial sector includes three basic types of activities—mining, manufacturing, and household and business services—divided into eight industry groups; namely, non-metal mining, metal mining, agro-based industries, non-metal processing, metal processing, and durable fabrication industries. Each of the industry groups is modeled separately with consideration given to the interrelationships and feedbacks among the industry groups.

Results of the simulation of the model using a special-purpose DYNAMO processor on a CDC-3600 Computer are presented. Five simulation experiments were performed. The base run experiment uses the existing conditions and the proposed development program for the Bicol River Basin Region as inputs. An examination of the base run

results reveal that the proposed development program achieves only short-run successes and that the region does not "take-off" economically. Four other simulation experiments corresponding to different policies and strategies show that the region might be able to achieve "take-off" if sufficient emphasis is placed on the development of industries--especially agro-based industries.

- e) DREW, D.R., WADHWA, L.C., PAUL, H., and HSIEH, C.H. (1975), "Simulation Model of the Bicol River Basin Development", *Proc. 6th An. Conf. Modeling and Simulation*, Pittsburgh.

**7531 A SYSTEM DYNAMICS LABORATORY FOR REGIONAL ANALYSIS: THE BICOL RIVER BASIN DEVELOPMENT**

- a) Lal Chand Wadhwa (Supervisor: Prof. Donald R. Drew)
- b) Doctoral dissertation
- c) In progress
- d) This dissertation represents a portion of a USAID sponsored research project for developing a computer simulation model for systems planning and analysis of the Bicol River Basin in the Philippines. Although specifically formulated for the Bicol River Basin Development, the model can be applied to similar economically depressed regions with some modifications.

The model developed in this research is based on the system dynamics methodology and is capable of evaluating a wide range of policies based on economic, social, technological, and institutional alternatives in any sector. Specifically, six different policies have been examined in this research to demonstrate that the model serves as a powerful laboratory for regional analysis and planning. These policies include accelerating or decelerating land reform, allocating special funds to feeder road construction, providing additional credits for crop production, removing support for the family planning program, and stimulating export demand in agro-based industries. The likely impact of each policy has been projected over a 30-year period as reflected in selected output variables which are believed to be adequate indicators of various facets of development. The results of these and many other policies that can be tested using this model are valuable guides to formulating policies and making rational choices amongst available alternatives while the options are still open.

- e) DREW, D.R., WADHWA, L.C., PAUL, H., and HSIEH, C.H. (1975), "Simulation Model of the Bicol River Basin Development", *Proc. 6th An. Conf. Modeling and Simulation*, Pittsburgh.

**7532 REFRIGERATION USING SOLAR ENERGY**

- a) D.G.C. Wijeratna (Supervisor: Dr. R.H.B. Exell)
- b) Faculty research and special studies project
- c) Completed
- d) This study was part of a project in solar energy utilisation in Asia aimed at the development of one or more prototype units demonstrating the usefulness and economic viability of solar energy. The specific objective was to identify an area of solar energy utilisation useful to the developing countries of Asia, and to select a suitable device for preliminary investigation and development. It was concluded from a study of literature that solar refrigeration would be one of the most promising fields for further development, and that an ice maker seems to be the most useful device in developing countries. Technical features of the ammonia-water intermittent absorption system were studied in detail with special reference to the operating conditions in tropical climates.
- e) Special Studies Project Report No. 34, AIT, 1974.

**7533 SOLAR ENERGY AVAILABILITY IN THAILAND**

- a) Kaya Saricali (Supervisor: Dr. R.H.B. Exell)
- b) Sponsored research project (John F. Kennedy Foundation, Thailand) and graduate thesis project.
- c) Completed
- d) Meteorological data have been used to produce a comprehensive survey of the solar energy available in Thailand. The geographical, seasonal, and diurnal variation of global radiation

on a horizontal surface have been analysed in a manner suitable for designing and predicting the performance of solar energy equipment.

Seasonal variations of radiation were determined by making separate studies for eight 1½ month periods of the year defined by standard solar declination values.

Maps of the geographical distribution of solar radiation sufficiently detailed to show local topographical effects were prepared from careful analyses of data on cloudiness and duration of sunshine at 44 stations and from the relation between sunshine and radiation at Bangkok and Chiang Mai, the only locations from which radiation data are currently available.

Fluctuations in the daily solar radiation, which influence the design of energy storage systems, were examined in an unbroken five-year sequence of measurements for Bangkok. The frequency distribution of radiation levels in the sequence and the Markov transition probabilities between levels were determined, permitting the probability of a period of low radiation of any length to be calculated.

A method has been developed for estimating the statistics of the solar radiation fluctuations from daily sunshine measurements. It was used to determine the character of these fluctuations in the north, the north-east, and the south of Thailand.

Finally, measurements of the hourly radiation values throughout the year at Bangkok and Chiang Mai were used to determine statistics of the diurnal variation of radiation.

- e) (i) EXELL, R.H.B. and SARICALI, K. (1975), Solar Radiation in Thailand. *Proc. Mech. Engng Cong. (Energy)*, Pahlavi University, Shiraz, Iran.
- (ii) Thesis No. 725, AIT, 1974.

#### 7534 THE DESIGN AND DEVELOPMENT OF A SOLAR POWERED REFRIGERATOR

- a) Sommai Korsakoo (Supervisor: Dr. R.H.B. Exell)
- b) Sponsored research project (John F. Kennedy Foundation, Thailand) and graduate thesis project.
- c) In progress
- d) This study is part of a project to design, construct, and test a village sized solar ice-maker that operates without using oil or electricity. In this part of the study a simple unit with a collecting surface of 2 square metres is being made. An ammonia-water intermittent absorption system is to be used with regeneration by solar heat during the day and refrigeration at night. Work on this unit is providing an opportunity for the necessary equipment to be assembled and for practical experience to be acquired. Improvements in the design will be developed and a large unit of optimum design will be made in due course.
- e) Thesis No. 884, AIT, 1974.

#### 7535 A SYSTEM DYNAMICS MODEL FOR THE MARKETING CHAIN SUB-MODEL FOR THE BICOL RIVER BASIN DEVELOPMENT

- a) Guillermo Arnaeta Villazor, Jr. (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) The research was primarily aimed at developing a practical model that would represent the transfer system mechanism from producers to consumers. Rice marketing activity in the Bicol River Basin, Philippines, was taken as the starting point; from this evolved a model adaptable, with minor modifications, to any crop sector. The final model essentially consists of three interacting modules: fixed capital investment, physical facilities, and commodity flow. By simulating the step-by-step movement of the marketing chain through time, policies relating to capital financing, facility build-up, inventory, and market direction can be tested. Thus, strategies could be formulated on how this particular sector can contribute to the overall goals of the Bicol River Basin Development.
- e) Thesis No. 730, AIT, 1974.

#### 7536 A STUDY OF THE DEMOGRAPHIC SECTOR IN THE BICOL RIVER BASIN DEVELOPMENT

- a) Ismael Mejia Teylan (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project
- c) Completed

- d) The model comprises the interaction and interrelationship of the three processes of demography; – births, deaths, and migration – with reference to age. The population was broken down into six age groups, namely: child, teenager, young adult, prime aged, middle aged, and oldster. The model was built specifically to assist research on the supply of labor for the Bicol River Basin development project. Migration provided a link between the demographic model (supply of labor) and the employment model (demand for labor).
- e) Thesis No. 729, AIT, 1974.

**7537 A STUDY OF THE EMPLOYMENT SECTOR IN THE BICOL RIVER BASIN DEVELOPMENT**

- a) Jose P. Cabalu (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) This research brings to the fore one major development problem in the Bicol River Basin –the problem of employment generation. This emphasis on employment does not exclude the consideration of other important factors of the development process, but rather regards employment as an integral part of it. The approach conceived to be best suited for this purpose is dynamic simulation modeling, and based on this, a general employment sector model has been developed.  
Computer simulation runs were made using regional, as well as national, data in determining the sensitive parts of the model. Various employment promotion and labor policies have also been tested to determine possible courses of action or inaction towards the attainment of the Bicol River Basin Development Program's overall objective, which is to increase the area's per capita income.
- e) Thesis No. 711, AIT, 1974.

**7538 THE DYNAMICS OF SUPPLY AND DEMAND IN A MARKET DIRECTED ECONOMY WITH APPLICATION TO THE BICOL RIVER BASIN**

- a) Vir Chankong (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) One of the major difficulties that seems to plague the success of any commodity production planning or marketing planning is the long-term fluctuation of commodity price and production. This fluctuation is caused by the 'two coupled negative feedback loops' structure which underlies the dynamics of supply and demand interactions within a market directed economy. The vast complexity added to this basic "two-loops" structure brings about the need for systematic approaches and dynamic planning for efficient guidance and control of a market system.  
In this research, a dynamic simulation model characterising the supply-demand interactions in a commodity market system is developed using the systems dynamics approach. The Philippines rice market is taken as the particular case study. The model is a possible extension of the Dynamic Commodity Cycle Model (MEADOW, 1970) with three types of marketing channels; government, cooperatives and middleman, and incooperated. Import and export factors are also included.  
The model is validated and various policies concerning price stabilization, import-export and retail-to-farm price margins are tested.  
The utility of the model is that it can be used either as a means for testing policies or as a forecasting device.
- e) Thesis No. 713, AIT, 1974.

**7539 A SYSTEM DYNAMICS APPROACH TO THE STUDY OF ECONOMIC STAGNATION IN THE LESS DEVELOPED COUNTRIES**

- a) Malik Masood Ahmad (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) A system dynamics model, based largely upon an analytical economic model, has been

formulated to assist in understanding the dynamic behaviour of a stagnating economy. The simulation run of the model showed that a predominantly agricultural economy subjected to exploitation of its resources by foreign interests will tend to stagnate. The causes of stagnation are surveyed in detail. It is noted that the foreign investments in plantations and other export-related activities in Asian countries has in the past proved to be of little value to the native population. Rather, foreign domination of Asian societies has had many adverse effects and may well have been a major factor responsible for their stagnation.

e) Thesis No. 661, AIT, 1974.

7540 AN INDUSTRIAL EMPLOYMENT MODEL FOR TAIWAN, R.O.C.

a) Chi-Chung Yang (Supervisor: Dr. D.R. Drew)

b) Graduate student thesis project

c) Completed

d) This research is a first attempt at using large-scale simulation models on socio-economic problems. It takes into consideration the demand-supply relationships of both human resources and industrial production with special attention paid to the internal structure of the economy. This is done by incorporating input-output analysis into the simulation model.

The model is then applied to Taiwan, Republic of China. A number of simulation experiments are performed to analyze the influence and effectiveness of some selected policies to serve as an illustration of the application of dynamic model simulation. It is believed that this kind of simulation experiment can become a powerful tool for socio-economic planners in the planning process.

e) Thesis No. 731, AIT, 1974.

7541 A STUDY OF HEALTH SERVICE SYSTEMS IN THE REPUBLIC OF CHINA

a) Chao-Chi Ch'iu (Supervisor: Dr. D.R. Drew)

b) Graduate student thesis project

c) Completed

d) This research is an attempt to apply the systems approach to the study of health service systems, especially in the Republic of China. The concepts of health planning, in general, are reviewed and the status of the existing health service system in Taiwan is described. This description is verbal and subjective: so to add precision, system dynamics models of three health service sub-systems are developed. They are an Epidemic Control Model, a Chronic Communicable Disease Control Model, and a Budget, Medical Professionals and Medical Facilities Planning Model. Parameter values for Taiwan are used to quantify the models and simulation experiments are performed to illustrate their application.

e) Thesis No. 715, AIT, 1974.

7542 RELATIONSHIPS BETWEEN ENERGY, ECONOMIC GROWTH, AND THE ENVIRONMENT WITH EMPHASIS ON MALAYSIA.

a) Hwa-Chan Ng (Supervisor: Dr. D.R. Drew)

b) Graduate student thesis project

c) Completed

d) This study deals with the dynamic behavior of energy consumption in Malaysia. The variables contributing to the energy consumption system are studied in this model. The model, based on the Systems Dynamics Approach as formulated by J.W. Forrester, simulates the effects of population, gross national product, cost and depletion of resources on energy consumption.

A series of sensitivity tests is employed to study the relative effects of the variables. The impact of new resources discoveries, technological innovation and an energy crisis condition are also examined.

The model should be a useful tool to government decision makers and planners. It would serve as a laboratory to test various energy policies and their impacts.

e) Thesis No. 722, AIT, 1974.

**7543 THE RELATIONSHIPS BETWEEN DEMOGRAPHIC, SOCIAL, ECONOMIC, AND TECHNOLOGICAL CHANGE**

- a) Jane-Jane Ou (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) This research attempts to develop a system dynamics model to unravel the dynamic nature of the relationships that exist between demographic, social, economic and technological changes and provide a rationale for choice of policy options to solve development problems common to most developing countries.  
There is growing evidence from studies of development information that each sector is interrelated, and that change in one sector can be traced to changes in other sectors. But little is actually known about their dynamic behaviour or performance. The purpose of this study is therefore to characterize the functioning of the whole system of relationships at a given point in time, and to model the actual process of changes. The development of Taiwan has been investigated in this study and a system dynamic simulation model is formulated to forecast its future development. A method of choosing criteria for assigning priorities to each of the four elements is also explored. Regression analysis of data of Taiwan during the period 1960 to 1970 has been applied to derive the functional relationship between such criteria, since each such criterion has relationships with others in other sectors.
- e) Thesis No. 723, AIT, 1974.

**7544 DYNAMO PROCESSOR**

- a) T.M.N. Ratnasabapathy (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) A processor is designed and implemented for the programming of the language, Dynamo. The processor allows a single run of a program written in Dynamo with tabulated and plotted output. With the exception of reruns and user defined macros, all the facilities and functions of standard Dynamo are available. The system as designed can be implemented on machines of different sizes quite easily. The processor has been successfully tested on an IMB 1130 with 8K core store where the capacity of the Dynamo processor was 50 equations, and on a 65K core store Control Data Corporation 3600 where the capacity of the Dynamo processor is approximately 2000 equations.
- e) Thesis No. 627, AIT, 1974.

**7545 INDUSTRIAL DYNAMICS FORMULATION OF THE MANAGEMENT CONTROL SYSTEM IN THE THAI SCOTT PAPER COMPANY**

- a) Fen-Lien Chang (Supervisor: Dr. D.R. Drew)
- b) Graduate study thesis project
- c) Completed
- d) The objective of the research is to apply industrial dynamics to study the management control system of paper manufacturing industry. Thai Scott Paper Company, a well established firm is selected as the case study.  
Forrester's customer-producer-employment model includes most of important management operations of an enterprise, therefore, it is taken as the basis of the study. Several modifications are made because of the different characteristics of the industry. The most important modification is that capacity is set as the limitation of the production instead of labor supply, because the paper industry is capital intensive but not labor intensive.
- e) Thesis No. 712, AIT, 1974.

**7546 USE OF INPUT-OUTPUT ANALYSIS WITH SYSTEM DYNAMICS APPROACH FOR REGIONAL DEVELOPMENT IN TAIWAN AREA**

- a) Yuh-San Liu (Supervisor: Dr. D.R. Drew)
- b) Graduate student thesis project

- c) Completed
  - d) This thesis is to present how input-output and system dynamics models can be combined to analyze regional development in Taiwan. The model deals with a 30-year (1966–1996) period of the regional development and the shifting allocation of labor and capital between major production sectors—agriculture, industry and service—to balance the needs of the population during the development process.
  - e) Thesis No. 721, AIT, 1974.
- 7547 SYSTEM DYNAMICS FORMULATION OF MANAGEMENT CONTROL IN MASS PRODUCTION INDUSTRIES**
- a) Kong Don (Supervisor: Dr. D.R. Drew)
  - b) Graduate student thesis project
  - c) Completed
  - d) This research develops a comprehensive dynamic simulation model of mass production industries to assist in the evaluation of alternative management policies. The study consists of two main parts:
    1. General control concept of mass production industries. This includes: budget control, labor control, production control, inventory control, quality control, and sales control.
    2. System dynamics methodology. This is concerned with the formulation and use of dynamic models. The model include: raw material and production for customers, inventory, and labor flow.
  - e) Thesis No. 719, AIT, 1974.
- 7548 A STUDY OF THE ROLE OF SYSTEMS ENGINEERING IN WATER RESOURCE PLANNING**
- a) Shaine-Tea Tang (Supervisor: Dr. D.R. Drew & Dr. M. Nawaz Sharif)
  - b) Special studies project
  - c) Completed
  - d) This study uses the system dynamics approach to develop a simulation model for water resource problems.
 

The water resource system comprises a single dam, one power plant, one diversion dam, one irrigable area and one flood-drainage area, and three purposes are considered:

    - (1) for irrigation: withdrawal (consumption) use;
    - (2) for power generation: nonwithdrawal (non-consumption) use;
    - (3) for flood-control: retardation (withholding) use.
  - e) Special Studies Project Report No. 33, AIT, 1974.
- 7549 AN ANALYSIS OF THE RICE PRODUCTION AND MARKETING SYSTEM IN KOREA**
- a) Ryu Byong Seo (Supervisor: Dr. P.A. Cowell)
  - b) Special studies project
  - c) Completed
  - d) The structure of the rice marketing system in Korea was determined and the respective proportions passing through the hands of middlemen, cooperatives and government was identified, as well as prices ruling at various stages in the chain. This special study provides the data base and structural information for a computer modelling study carried out by later investigators.
  - e) Special Studies Project Report No. 48, AIT, 1972.
- 7550 ANALYSIS OF THE RICE MARKETING SYSTEM IN KOREA BY COMPUTER SIMULATION**
- a) Tran Minh Loi (Supervisor: Dr. P.A. Cowell)
  - b) Graduate student thesis project
  - c) Completed

- d) A computer simulation model based essentially on control theory and the use of a double negative feedback structure was developed for the rice market in Korea. The principal components dealt with include the farmers, middlemen, cooperatives and government. The model was tested by simulating retail price changes over the ten year period 1960–70, with reasonable agreement. Experiments were conducted on the model of the effect on market price of expanding government intervention and also of expanding the use of cooperatives.
- e) Thesis No. 610, AIT, 1973.

7551 AN INVESTIGATION OF THE VALIDITY OF MOBILITY RESISTANCE THEORIES IN WET PADDY LAND

- a) Ching Suey Shiao (Supervisor: Dr. P.A. Cowell)
- b) Graduate student thesis project
- c) Completed
- d) The purpose of this thesis was to study the validity of the Bekker and Reece theories for rolling resistance in flooded paddy land. A specially prepared plot 140 ft x 360 ft was ploughed to 6 in. depth, cultivated and flooded to a depth of 6 in. The rolling resistance of rigid wooden wheels of varying diameter and width was measured by mounting matched pairs on a single axle and towing them by cable hitched to a Land Rover situated on dry land. Soil parameters were obtained by measuring the pressure sinkage relationship of circular plates pressed into the soil. In the case of Bekker's theory, the relationship

$$p = \left( \frac{k_c}{b} + k_\phi \right) z^n \quad \text{was used}$$

and, in the case of Reece's theory

$$p = (k_1 + k_2 b) \left( \frac{z}{b} \right)^n$$

Since the surface of paddy land is cultivated and flooded it forms a two layer soil which requires adaptation of the theory if high vertical loads are placed on the wheel. Both Reece's and Bekker's equations gave similar predictions, which in the case of 42 in. diameter wheels were satisfactory, but were too high with 48 in. diameter wheels. Contrary to theoretical prediction, rolling resistance increased with increased wheel width.

- e) Thesis No. 611, AIT, 1973.

7552 AN ANALYSIS OF FARM MECHANIZATION IN TAIWAN WITH EMPHASIS ON RICE FARMING

- a) Kuan Mee Hock (Supervisor: Dr. P.A. Cowell)
- b) Special studies project
- c) Completed
- d) This study is essentially a survey and analysis of the development of farm mechanisation in Taiwan starting from 1953 based on existing literature and data. With respect to rice farming a rapid increase in the number of power tillers has been observed at the expense of draft animals. This was found to be in response to a shortage of farm labour and the low reproductive capacity of draft animals (25%). This study is part of a longer term overall plan to gather together information on the development of agricultural mechanisation in Asia.
- e) Special Studies Project Report No. 30, AIT, 1974.

7553 A DEVELOPMENT MODEL OF AN AGRICULTURAL SYSTEM IN THAILAND WITH PARTICULAR REFERENCE TO RICE

- a) Apichart Chirattiyangkur (Supervisor: Dr. P.A. Cowell)
- b) Graduate student thesis project

- c) Completed
- d) This represents the first attempt to construct a closed loop analytical control theory model of an agricultural system, in this case a rice production system. A small, aggregated, continuous-time model has been constructed with the object of determining the effect of allocating different proportions of expenditure on fertilizer, machinery, water resources, pesticides and seeds. A frequency domain analysis was conducted in this research, but was found to be too restrictive, particularly with regard to modelling the farm itself. Experience gained from this research indicated that a state space analysis in the time domain would eliminate most modelling difficulties, and will form the basis of further research.
- e) Thesis No. 714, AIT, 1974.

**7554 A SYSTEM DYNAMICS SIMULATION MODEL OF THE COMMODITY PRODUCTION SECTOR OF AGRIBUSINESS IN THE BICOL RIVER BASIN, PHILIPPINES**

- a) Julian Rollo Esquillo, Jr. (Supervisor: Dr. P.A. Cowell)
- b) Graduate student thesis project
- c) Completed
- d) This thesis project forms a part of AIT's computer model of the Bicol River Basin Development Program, a development program devoted to increasing the income of rural families in the Bicol River region of the Philippines.  
The chief strategy for developing the region is through agricultural development. In this thesis the agricultural sector was modelled in seven parts – fish production, poultry, forestry, cattle, pigs, annual crops and perennial crops. The computer program was expressed in DYNAMO language and forms a large part of the overall Bicol simulation model.  
The total model has been accepted by the Philippine Government as a basis on which to plan future development of the region.
- e) Thesis No. 716, AIT, 1974.

**7555 THE DYNAMIC BEHAVIOUR OF IMPLEMENTS DURING PENETRATION**

- a) Fallak Sher Sial (Supervisor: Dr. P.A. Cowell)
- b) Graduate student thesis project
- c) Completed
- d) A simple first order linear differential equation has been developed to predict the dynamic behaviour of soil engaging implements during penetration when connected through a real hitch point.

The solution takes the form

$$y = y_e + (y_0 - y_e)e^{-s/l}$$

where  $y$  is the depth achieved after the implement has travelled forward a distance  $s$ , starting at depth  $y_0$  and reaching equilibrium at depth  $y_e$ . Hitch length has been found to be the single major factor which determines the specific exponential path followed by the implement.

To test the validity of the governing equation many runs were taken at different hitch lengths, furrow depths as well as speeds of the tractor. The experimental results fully agreed with the theoretical ones. It has been proved that an implement, commencing from the surface, achieves approximately 63.2% of its equilibrium working depth after having travelled forward a distance equal to its hitch length.

- e) Thesis No. 726, AIT, 1974.

**7556 SELECTION OF OPTIMUM TRACTOR POWER FOR THAI AGRICULTURE**

- a) Lurwit Sermsiripan (Supervisor: Dr. P.A. Cowell)
- b) Special studies project
- c) Completed
- d) In this study a computer program was developed of a mathematical model derived by Chancellor to study the optimal amount of tractor power for use on Thai farms. Speci-

fic consideration was given to single tractor farms, multiple tractor farms and tractor contractor business.

Specific optima depend very much on the penalty costs per acre hr (D) associated with delay in cultivation. For single tractor farms of 50 acres optimum rated horsepower varied from 10 to 30 HP as D increased to .04 \$ per acre hr. For multiple tractor farms the optimum power level ranged from .3 HP/acre (D=.01 \$ per acre hr) to .55 HP/acre (D = .04 \$ per acre hr). At the contract hire rates operating at the time of the study tractor operators were working at a loss.

- e) Special Studies Project Report No. 32, AIT, 1974.

**7557 DEVELOPMENT OF A SIMULATION MODEL FOR RICE IN RESPONSE TO WATER MANAGEMENT IN THE CHAO PHYA BASIN**

- a) Lee Sung (Supervisor: Dr. P.A. Cowell)
- b) Special studies project
- c) Completed
- d) This study was initiated to determine the extent to which it would be feasible to simulate the growth of rice in response to water management and predict ultimate yield under different water management strategies. A computer model was developed which included the effects of water stress and storm damage on yield. In normal circumstances of adequate water in the Chao Phya Basin the problem reduces to one of largely simulating the effects of storm damage. However, where second and third crops of rice are grown and there is the possibility of water stress, such a model could then become of value in determining optimum use of available supplies.
- e) Special Studies Project Report. No. 31, AIT, 1974.

**7558 THE HISTORICAL DEVELOPMENT OF AGRICULTURAL MECHANISATION IN SEVERAL COUNTRIES**

- a) Fallak Sher Sia. (Supervisor: Dr. P.A. Cowell)
- b) Special studies project
- c) Completed
- d) There is widespread concern in developing countries about the social and economic effects of mechanisation of agriculture, particularly from the point of view of rural employment. In some instances mechanisation has led to increased rural unemployment; in others this has not been the case. The task of this special study was to draw together data over a wide range of countries of changes in agricultural mechanisation, rural population and agricultural output over the past 20 to 40 years, as a basis for further study. The countries considered include Australia, Canada, India, Japan, South Korea, Laos, New Zealand, Pakistan, Philippines, Thailand, Taiwan, United Kingdom, United States, South Vietnam and Western Germany.
- e) Special Studies Project Report No. 35, AIT, 1974.

**7559 THE APPLICATION OF CONTROL THEORY TO THE DYNAMIC BEHAVIOUR OF PRODUCTION AND PRICE OF AGRICULTURAL COMMODITIES**

- a) Dr. P.A. Cowell
- b) Faculty research
- c) Completed
- d) Control engineers have become increasingly interested in the potential for applying control theory in the quantitative solution of problems in economics. A continuous-time model based on a double negative feedback structure of a production-marketing system has been developed. The transfer function approach of classical control theory enables the time delay between a change in price and the response in terms of production to be modelled in a straightforward way. The model has been applied to the hog cycle phenomenon using data from the U.S. Market. The model predicts that the system is stable but underdamped and has a natural time period of 42.5 months. This compares with an observed period of 48 months. The conditions for stability may be clearly seen from a study of the Nyquist plot. This illustrates that the system is stable over a wider range of elasticities than predicted by

the Cobweb theorem. The model enables calculations to be made of the effect on price of changes in demand, supply, exports & imports, and the activities of middlemen. The longer term purpose of this research is to investigate the stability of other commodity productive systems, notably rice; this is currently being studied.

- e) P. A. Cowell, "A Classical Control Theory Approach to the Study of Dynamic Commodity Behaviour - the Cobweb Theorem Revisited", *AIT Tech. Note*, June 1974.  
P. A. Cowell, "Control Theory and the Dynamic Behaviour of Agricultural Commodities - A Solution to the Dynamic Hog Cycle Problem". Presented at *VIIIth Int. Cong. Agric. Engng*, Flevohof, The Netherlands, 1974.

#### 7560 THE DESIGN & DEVELOPMENT OF A SOLAR POWERED WATER PUMP

- a) Dr. P. A. Cowell and Dr. P. Chen
- b) Sponsored research project (Shell Company of Thailand)
- c) In progress
- d) In tropical countries there is a constant need to pump water for irrigation purposes. In many circumstances, for example with second crop rice in Thailand, gravitational supplies may be too low and water must be pumped from the feeder canal directly on to the land. The energy required to pump water for a crop of rice may exceed that required for cultivation. The recent enormous increases in the price of oil have hit the tropical farmer in two ways; first the direct cost of fuel for pumps and tractors and secondly by causing large increases in the cost of fertilizer, which requires large amounts of energy for its manufacture. Both of these changes constitute a threat to food supplies. On the other hand solar energy is abundant in the tropics and is well distributed according to the needs of the farmer - when water is required the sun is usually shining. The object of this research is to design and develop a water pump powered by solar energy for use at the farm level. The aim is to produce as cheap a unit as possible, using where possible local skills and materials. Estimates based on the rate of arrival of energy in Thailand suggest that a solar pump system operating at an overall efficiency of 3%, raising water one metre would supply one acre of land with 12 mm water per day from a solar collecting area of 1 sq. metre.

#### 7561 AN APPROACH TO URBAN DEVELOPMENT IN TAIWAN

- a) Kuo-Shong Jien (Supervisor: Dr. Donald R. Drew)
- b) Graduate student thesis project
- c) Completed
- d) This study was done in seven parts: (1) a summary of the existing urban situation in Taiwan, (2) a review of existing policies of national development, (3) a projection of future population, (4) an analysis of regional distribution of population and economic activities, (5) a comparison of alternatives for accommodating future urbanization, and (6) recommendations for approaching urban development studies about to be undertaken by the government in Taiwan.  
Two complementary approaches utilized in the study were those of land use and location theory. Other theoretical considerations included central place functions, spatial hierarchies of city systems and an urban space consumption model.  
Practical alternatives discussed are the following: (1) expansion of existing metropolitan areas, (2) selection of small cities as growth poles and (3) development of new towns.
- e) Thesis No. 594, AIT, 1973.

#### 7562 DEVELOPMENT OF A GROWTH CENTER IN THAILAND - KORAT

- a) Pradit Nopmongol (Supervisor: Mr. L. A. G. Moss)
- b) Graduate student thesis project
- c) Completed
- d) This study raised the issue of urbanization in Thailand and the problems of optimum city size. It demonstrated the complexity involved in defining and formulating meaningful criteria for the evaluation of the optimum size. The study turned to look into the problem of minimum per capita cost with respect to city size. Capital costs of a number of subsystems necessary for city expansion were estimated in a systematic way with specific reference to Korat as a typical case and the results were related to the overall

urbanization strategy for Thailand.

- e) Thesis No. 595, AIT, 1973.

**7563 ANALYSIS OF URBANIZATION STRATEGIES FOR THE EASTERN REGION OF INDIA**

- a) Ajit Kumar Gupta (Supervisor: Mr. L.A.G. Moss)  
b) Graduate student thesis project  
c) Completed  
d) This research is aimed at the analysis of urbanization strategies for the Eastern Region of India. This Region has been formed from the four States of Andhra Pradesh, Bihar, Orissa, and West Bengal. Special emphasis has been placed on the Chatanagpur 'crescent' industrial area and the Eastern coastal agricultural area. The economic characteristics of the Region and the past, present, and future demographic trends have been examined. A qualitative investigation of three major urban growth options for the Region has been carried out. The three options that have been considered are the creation of new towns, expansion of small and medium-sized existing towns, and further growth of metropolitan Calcutta. In an attempt to find a specific criteria for allocating the urban increment in the Region by the year 2000, costs of providing urban infrastructure under each alternative have been considered. The shortcomings of the previously planned new towns in India have been discussed and the design of the infrastructure of a hypothetical new town has been undertaken to remove some of these shortcomings. Finally, a strategy of urbanization is formulated, with more than half of the projected urban increase being accounted for by growth of existing towns and the rest by the other two alternatives. The research also proposes that the 'crescent' and coastal areas have potential for formation of megalopolitan-type settlements.  
e) Thesis No. 596, AIT, 1973.

**7564 LOW COST ENVIRONMENTAL SYSTEMS FOR SQUATTER SETTLEMENTS IN BANGKOK**

- a) Mathew Philip (Supervisor: Mr. Stanley N. Benjamin)  
b) Graduate student thesis project  
c) Completed  
d) The aims of this research paper are fourfold: first, to review and evaluate low cost environmental systems; secondly, to test such low cost environmental systems by application to a particular Bangkok problem; thirdly, to draw conclusions as to the most suitable environmental system for Bangkok; and fourthly, to draw out of this exercise, an approach to policy for such environmental systems.  
The method is sequenced as follows. In the first part of the study, after defining the target population, a general discussion of the present environmental systems in Bangkok is undertaken, as well as the socio-economic conditions of the affected target population. The resulting conclusions are tested in a case study to confirm, reject or expand upon the original findings. A general agreement of the findings were found to reinforce the original conclusions.  
In the next part, various alternatives for low cost environmental systems are evaluated; the major criteria for evaluation being sanitation, ecology, health, nuisances, capital costs and operational expenses.  
In the next phase, the implementation mechanics of the system are assessed. In analyzing the present situation as related to decision making, an overview of the collectivities, actors involved, and thereby, a review of the present decision making mechanisms, is outlined.  
Finally, the above three phases are further analyzed to single out the most suitable action to bring about the implementation of the appropriate low cost environmental system. In addition, policy recommendations are drawn for such low cost environmental systems. The findings from such studies are then tested within the confines of a test area; in this instance, the Din Daeng squatter settlement in the municipality of Bangkok. The impact of these low cost environmental systems on the daily life styles of the target population is also studied.  
e) Thesis No. 625, AIT, 1974.

7565 TOWARD PRINCIPLES FOR THE CONTROL OF SQUATTER SETTLEMENTS IN BANGKOK, THAILAND

- a) Nirmal Brito Mutunayagam (Supervisor: Mr. Stanley N. Benjamin)
- b) Graduate student thesis project
- c) Completed
- d) The squatter problem is one of complexity and diversity, and lasting solutions to the problem have been elusive, despite the numerous techniques and approaches that have been tried out. This is primarily because the squatter problem has not been comprehensively understood or defined.  
The objective of this study is therefore to find a comprehensive definition of the squatter problem, with specific reference to Bangkok, in Thailand, and to recommend workable principles as a basis for their control and progressive elimination.  
Proper reorganization of squatter control mechanisms can contribute to the orderly spatial growth in the city, and will promote the general well being of low income people, while preserving the legal rights of private property ownership.  
The major contributions of this study are in providing:
  - 1. a rationale for the proper identification of, and distinction between a slum and squatter settlements;
  - 2. an identification of the squatter problem in Bangkok with its entire ramifications;
  - 3. guidelines for a comprehensive policy to control of squatter settlements in Bangkok; and
  - 4. recommendation of outline programs for the successful implementation of such a policy.
- e) Thesis No. 626, AIT, 1974.

7566 CRITERIA TO EVALUATE A HOUSING POLICY FOR THE LOWEST INCOME RURAL-URBAN MIGRANTS: THE CASE OF TAIPEI

- a) Noboru Hidano (Supervisor: Mr. Laurence A.G. Moss)
- b) Graduate student thesis project
- c) Completed
- d) This study attempts to formulate criteria to evaluate housing policies for the lowest income rural-urban migrants, with special attention to the politico-socio-economic relationship between the target population and the public authorities. The study starts by analyzing the status quo of the target population, focusing on housing problems in Taipei in the late 1960's. Based upon findings from this analysis, two salient politico-economic variables are proposed to explain housing conditions of the target population. One is income (wages), and the other is a "multiplier", which is the support from the authorities to improve the housing condition of the target population. Based upon the relationship between the social groups, a housing conflict model is developed, which guides action to improve the housing condition of the target population.  
The study also discusses the explanation that can be derived from the model of the mobility of migrants in Taipei in late 1960's, and examine the impact of GNP growth on the housing issue.  
Finally this model generates criteria to evaluate housing policies, and from this "upward mobility" policies are suggested.
- e) Thesis No. 718, AIT, 1974.

## **THESIS RESEARCH TOPICS FOR 1974–75**

### **Transportation Systems Planning**

1. Study of a Special Purpose Urban Public Transportation Mode for Developing Countries
2. Coordination Among Ports Through Ship Rescheduling and Routing
3. A Study of Lock Congestion in Thailand's Inland Waterways
4. Comparative Analysis of Seoul's Public Transportation Systems
5. A Study of Bus Transportation Systems Management
6. A Methodology for Highway Maintenance Programming for Developing Countries
7. An Evaluation of Bus Routing Schemes in Bangkok
8. Considerations in the Selection of Domestic Air Passenger
9. An Appropriate Methodology for Urban Traffic Safety Analysis
10. Use of Mathematical Models in Air Transport Operations
11. Evaluation of Highway Construction and Maintenance Policy in Thailand
12. Bicol River Basin Transport Survey

### **Agricultural Systems Engineering**

1. Dynamic Behaviour of Implements During Penetration with Particular Reference to the Three Point Linkage
2. Design and Development of a Solar Powered Water Pump
3. A System Dynamics Study of the Marketing Chain of Agricultural Commodities in the Bicol River Basin
4. Application of Control Theory to the Dynamic Behaviour of Agricultural Commodities
5. The Design and Development of a Solar Powered Refrigerator.

### **Human Settlements Planning & Development**

1. Mini Squatters: Structure and Function
2. Analysis and Evaluation of Family Planning Activities of a Health Center in Bangkok
3. Urban Drop-outs
4. Land for Housing
5. Industrial Location as a Factor of Regional Development in Taiwan
6. "People's Housing Finance".
7. A Cost Indicator for Low Income Shelter
8. Highrise Building for Low Income People: An Economic Evaluation
9. An Analysis of the Forms of Spatial Development in a Lagging Region with Special Reference to North-East Thailand
10. Trade Union as a Tool for Community Development
11. Socio-Economic Factors of Resettlement in Response to Water Resource Development: Case Study in Lam Dom Noi
12. The Image of the Primate City in Rural Areas: an Information-Based Analysis of Migration

## PROJECTS COMPLETED BETWEEN JANUARY 1969 AND JANUARY 1973

(Projects completed prior to January 1969 are listed in the Research Summary for January 1973)

No.	Title	Research Worker	Publications
7001	A Framework for Systems Analysis of Port Operations and Development	Wai Ling Woo	Dissertation No. D4, 1972
7102	The Development of a Sub-interindustry Model in Thailand with Emphasis Centering Around the Automobile Assembly Industry	Supparat Mongkornkarn	Thesis No. 484, 1972
7104	Some Theoretical Considerations and Preliminary Investigations of Air Pollution from Traffic Emissions in Bangkok	Charng-Horng Hsieh	Thesis No. 486, 1972
7105	Decision Making Model for Private Contractors in Thailand	Sumate Tanthuanit	Thesis No. 487, 1972
7117	A Transportation Plan for a New Asian Megalopolis	Jer-Cheng Chen	Thesis No. 494, 1972
7118	A Technique for Establishing Priorities in Community Health Planning of Rural Areas, with a Case Study of Bang Pa-in, Thailand	Ping Wang Cheung	Thesis No. 495, 1972
7119	Optimization of Water Rate for the Bangkok Water Supply System	Tahir Husain	Thesis No. 496, 1972
7121	A Plan for Electric Power-Energy System for New Cities in Asia	Himangshu Paul	Thesis No. 471, 1972
7122	Modelling and Systems Analysis of Fish Pond Cultures	Sin Chong Phan	Thesis No. 497, 1972
7123	A System Analysis of Outpatient Care at Ramathibodi Hospital	Chom Poovichayasumlit	Thesis No. 498, 1972
7124	The Development of Medium-Size Airport-Terminal Interface Simulation Model	Chong Wo Sam	Thesis No. 478, 1972
7125	The Development of a Regional Information Center for Science and Technology at the Asian Institute of Technology	Mun-Leong Soong	Thesis No. 499, 1972
7126	The Asian Institute of Technology as a System	Boontai Tan	Thesis No. 500, 1972
7127	Analysis of Distribution Transformer Installation Criteria in Bangkok Metropolitan Area	Sukit Viwathanatepa	Thesis No. 506, 1972
7128	The Opportunity for Systems Building in Developing Countries	Lal Chand Wadhwa	Thesis No. 470, 1972
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# RESEARCH IN AGRICULTURAL ENGINEERING

An outstanding feature of all developing countries is the large number of people engaged in agriculture; in different parts of the region served by AIT the proportion may be anything from 30% to 90% of the labour force. In consequence, many of the problems of development are intimately connected with agriculture. In 1972 AIT introduced two new fields of study in Agricultural Engineering – Agricultural Systems Engineering and Irrigation and Land Development, and in 1973 Agricultural Soil and Land Resources. Since that time slight changes in emphasis and in the names of the respective fields of study have been made and from August 1975 the Institute has offered three separate fields of study, viz:

- Agricultural Systems Engineering and Management
- Irrigation Engineering
- Agricultural Soil and Water Engineering

Currently the Agricultural Systems Engineering and Management field of study is administered by the Division of Community and Regional Development, Irrigation Engineering by the Water Resources Engineering Division and Agricultural Soil and Water Engineering by the Geotechnical Engineering Division. All three fields of study are coordinated by an Agricultural Engineering Committee made up of faculty members in the Divisions.

The Agricultural Systems Engineering & Management field of study is intended to have a fairly broad connotation, and may be defined as the application of engineering principles to the solution of problems in agriculture with particular emphasis on the application of systems techniques where appropriate. Thus whereas a student may conduct research directed towards solving specific problems within the purview of Agricultural Engineering, encouragement is given to consideration of the broader social, economic and environmental impact of agricultural development using the tools of and techniques of systems engineering. Within the field of study, two principal types of research have been initiated – that directed towards a study of the behaviour of agricultural systems particularly from an economic point of view (software studies), and that concerned with the hardware aspects of agricultural engineering.

In the field of Irrigation Engineering research has been conducted on the efficient use of irrigation water and proper drainage. Further research has been conducted on the field of hydraulic structures directed towards decreasing erosion and silting up of irrigation and drainage channels. It is anticipated that this field of study will concentrate more on the 'large structure' aspect of irrigation engineering and 'farm level' studies will be undertaken in Agricultural Soil and Water Engineering.

Research in the Agricultural Soil and Water Engineering field of study has mainly been concentrated within two areas: problems associated with the reclamation of alkali soils, and the effects of paddy cultivation practice on soil physical properties.

For reports on research in the three fields of study within Agricultural Engineering, please refer to the following summaries:

**Agricultural Systems Engineering and Management** – 7549 to 7560; and the list on page 165.

**Irrigation Engineering** – 2166, 2170, 2173 (under **Hydrology**); and the list on page 26.

**Agricultural Soil and Water Engineering** – 6118; and the list on page 113.

# COMPUTER CENTER

## FACULTY AND SENIOR STAFF

***Tongchat Hongladaromp***

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***James A. Kearns, Jr***

B.Sc., M.Sc., Montclair State; Ph.D., Columbia. *Associate Director.*

***Kanchit Malaivongs***

B.Eng., Chulalongkorn; M.Eng., AIT.

## FACILITIES

The Computer Center provides computing services for the Institute as well as organizing courses and extension study related to computing technology and computer applications.

The Computer Center is equipped with an IBM370/145 computer system with one megabyte core memory and numerous virtual storage. The system is fully equipped with high speed input/output peripherals, including the modern diskette data entry equipment and high speed bulk disk storage. Diskette data preparation work stations and on-line terminals are also available.

The system is basically operated under OS/VS and VM370 operating systems and is capable of providing on-line interactive computing services as well as batch processing. Different high level languages, e.g. FORTRAN, COBOL, PLI and APL are available together with many application packages.

The Institute also has access to the computer systems at the National Statistical Office of Thailand and at the Electricity Generating Authority of Thailand.

The Computer facilities are well utilized for computer oriented courses and for faculty and student research including sponsored research projects. The Institute is planning to enlarge the system to two megabytes core memory with additional high speed bulk storage as soon as AIT's regional computer center building is completed.

# LIBRARY AND INFORMATION CENTER

## FACULTY AND SENIOR STAFF

Acting Director: *Dr Ricardo P. Pama*

<i>Hwa-Wei Lee</i>	B.Ed., Taiwan Normal; M.Ed., Ph.D., Pittsburgh; M.L.S., Carnegie-Mellon. <i>Formerly Director.</i>
<i>Ricardo P. Pama</i>	B.SCE, Mapua Institute of Technology, M.Eng., SEATO Graduate School of Engineering; Ph.D., St. Andrews. <i>Acting Director.</i>
<i>Stephen W. Massil</i>	B.A., Dip.Lib., London. <i>Formerly Associate Director.</i>
<i>Boonperm Toogmee</i>	B.A., Dip.L.S., Chulalongkorn; M.S.L.S., Florida State. <i>Head of Readers' Services.</i>
<i>Boontharee Phoonthai</i>	B.A., Thammasat; M.L.S., Queens (CUNY). <i>Reference Librarian.</i>
<i>Yada Sarakul</i>	B.Ed., Dip.L.S., Chulalongkorn. <i>Acquisitions Librarian.</i>
<i>Nuatip Rasmibhuti</i>	B.A., Dip.L.S., Chulalongkorn; M.L.S., Peabody. <i>Cataloguing Librarian.</i>
<i>Siri Kanokploy</i>	<i>Serials Librarian</i>
<i>Auimporn Intarakoses</i>	<i>Processing Librarian</i>

## ASIAN INFORMATION CENTER FOR GEOTECHNICAL ENGINEERING

<i>J.B. Dissanayake</i>	B.Sc.(Eng.), M.Sc.(Eng.), Ceylon. <i>Senior Research Associate.</i>
<i>Jamshed A. Danish</i>	B.E., Karachi; M.Eng., AIT. <i>Research Associate.</i>
<i>Alpha Attaboornakul</i>	B.A., Chulalongkorn; Dip.L.S., Wales. <i>Information Specialist.</i>

## FACILITIES FOR RESEARCH

The AIT Library constitutes one of the best collections in engineering and related subjects in Southeast Asia. At present, the collection which contains 70,000 volumes of books and technical publications is growing at the rate of 10,000 volumes annually. The collection also contains a little more than 2,000 journal titles of which two-thirds are current subscriptions. To enable the users to easily search and retrieve the journal literature, the Library subscribes to nearly 200 abstracting and indexing journals. In addition to books and journals, the Library also collects a very large number of technical publications on microfilm and microfiche, maps, vertical file materials, and a growing number of audio-visual materials.

As a first attempt to provide specialized information service on subjects of major importance in Asia, an Asian Information Center for Geotechnical Engineering (AGE) was founded in January 1973 in collaboration with the Division of Geotechnical Engineering and with the support of the International Development Research Centre, Canada (see Project No. 6124 in the section devoted to the Division of Geotechnical Engineering).

## RESEARCH ACTIVITIES

Experimentation of computerized library and information services has been undertaken by the Library and Information Center since 1968. Currently in operation are an acquisitions and accounting system, a serial control and listing systems, and an information storage and retrieval system for AIT publications and student theses. Other projects under investigation and development at present are:

1. an information storage and retrieval system on computer for the AGE data fields,
2. a computer based union list of serials of cooperating libraries in Bangkok; a pilot stage is being supported by UNESCO.

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# LANGUAGE AND MEDIA CENTER

## FACULTY AND STAFF

Director: *Mrs Jeanne M. Brand*

### Associate Professor

*Jeanne M. Brand*, B.A. Cert. Ed., Leeds.

### Assistant Professors

*John E.M. Barnes*, M.A., Lancaster

*Mark Ellis*, M.A., Cambridge, Dip.ESL, Leeds.

*John A. Kirk*, M.A., Cambridge, Cert.Ed., Bangor.

### Staff

*Robert M.J. Therault*, B.A., California State.

*Billie-Jean Lynch*, B.A. Santa Clara

## FACILITIES AND ACTIVITIES

Students reach the Institute with a wide variety of linguistic backgrounds and a considerable range of ability in English. Since all teaching at the Institute is in English, it is necessary for students to achieve as high a standard of competence in the language as possible. The Language and Media Center helps students to derive greater benefit from their degree programs while at AIT, helps them to achieve more effective communication with faculty and students from other countries, and enables them to develop a skill which is likely to prove of considerable importance in their future careers.

In addition to three levels of English instruction offered concurrently with the engineering programs, the LMC offers a Pre-Degree term of intensive English instruction for those students whose language ability is very weak. After this term of intensive instruction, students are able to proceed to the normal degree program.

The Center is well-equipped with modern aids to language-learning, including two laboratories, and also provides audio-visual equipment and services to support teaching and research in the other departments. 'Technology-aided education' in general is an area where the Center is expanding and developing its work, particularly in the medium of television. At the moment, there exists a four-camera television studio with editing and other production facilities in both video and audio, as well as complete remote capability. The T-AE section uses these facilities to support the Institute in its various research projects, conferences and educational programs.