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Design, Siting and Construction of Locally Planned Structures to Better Withstand Earthquakes and Wind Storms

Edited by:

William F. Reps

and

Emil Simiu

National Bureau of Standards

Institute of Applied Technology

Center for Building Technology

October 1972

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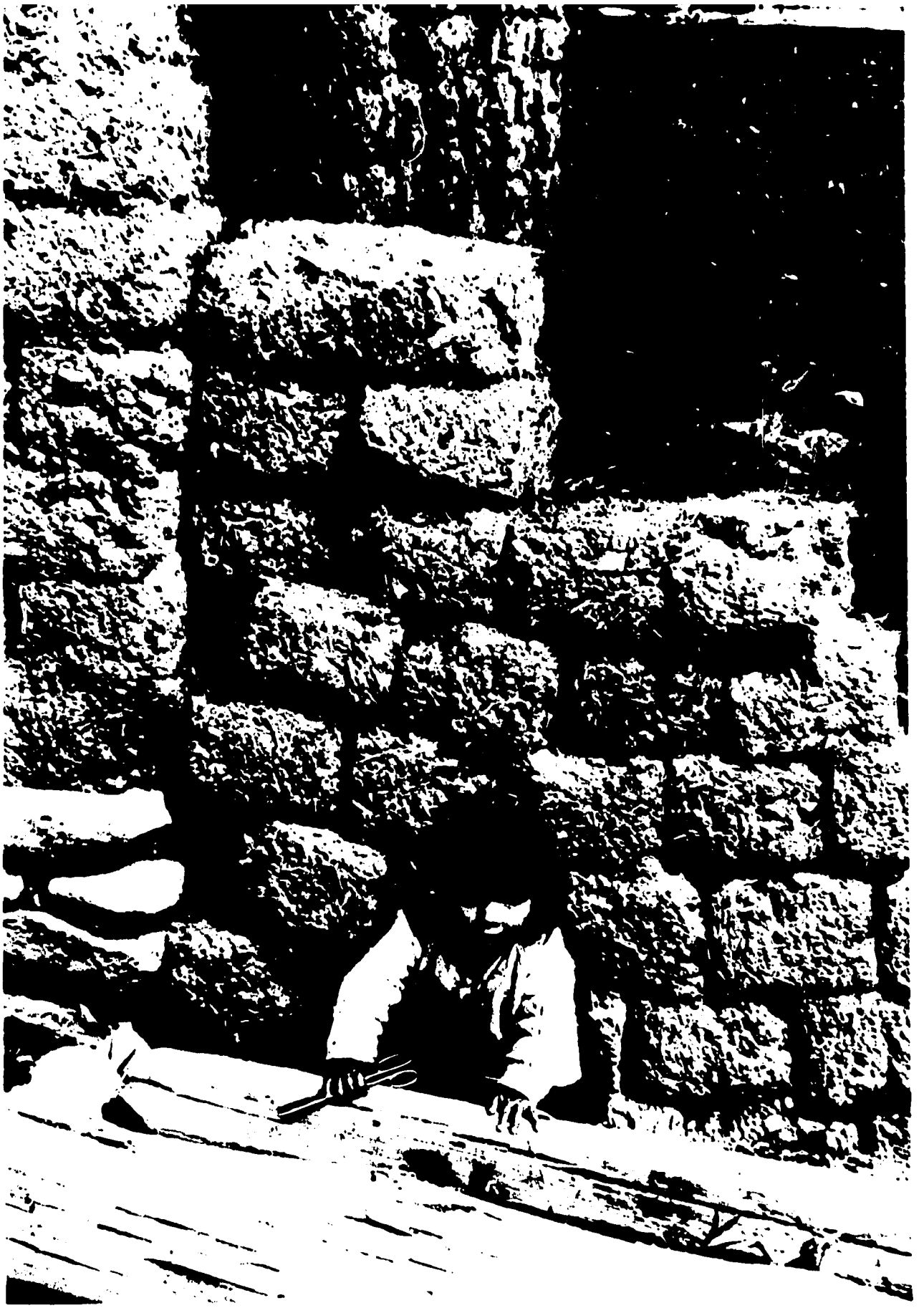

Preface

An agreement was signed on April 13, 1971, between the National Bureau of Standards (NBS) and the Agency for International Development (AID) to conduct a study on the potentials of housing technology to mitigate earthquake and windstorm disasters in developing countries despite their serious socio-economic and cultural constraints. Interim reports of this project were presented at the "Expert Working Group Meeting on the Use of Plastics in the Building Industry", in Vienna, Austria, on September 20-24, 1971, and the "Interregional Seminar on Low-Cost Construction Resistant to Earthquakes and Hurricanes," (sponsored by the UN Centre for Housing, Building and Planning and the Government of Yugoslavia) at Skopje, Yugoslavia, on November 1-19, 1971.

The AID Office of Science and Technology of the Technical Assistance Bureau provided management and monitorship of the project from the AID viewpoint. The Institute of Applied Technology, Center for Building Research, represented NBS responsibilities in conducting the research and study.

The methodology and specific goals agreed upon were as follows:

- Establish a steering committee to serve as an advisory group to the NBS in the execution of the project.
- Examine the body of existing knowledge relevant to the design, siting and construction of earthquake and

windstorm resistant buildings, including recent American technological innovations applicable within the framework of socio-economic and cultural requirements in developing countries.

- Suggest promising technological innovations applicable within this context.
- Evaluate the potential of these innovations through consultations and on-site investigations in Peru, Turkey and the Philippines.
- Identify significant gaps in the technical and socio-economic data concerning construction in earthquake and wind storm areas of developing countries.
- Develop and evaluate alternative approaches to overcome technological and socio-economic barriers against more effective building practices in each of the selected countries.

In order to assess the current state of the art as it relates to low-cost housing technology and to define typical socio-economic constraints in developing countries, field trips were made to Peru, Turkey and the Philippines, representative of countries that suffer frequent devastation from natural disasters such as earthquakes and typhoons.

This report is based on studies which define the general nature of the problems involved and on the results of investigations carried out during the field inspection trips. Tentative conclusions based on these studies and results are

included in this report, which should represent a first step toward a practical solution of the problems posed by the urgent need for earthquake and windstorm resistant dwellings in developing countries.

Acknowledgments

There have been many contributors and reporters who have graciously given of their time and knowledge during the field investigations. Consulting organizations in Peru, Turkey and the Philippines provided timely and appropriate information for the special requirements of the socio-economic study for each country.

A Project Steering Committee comprised of representatives from the National Bureau of Standards, Department of Housing and Urban Development, United States Geological Survey and United States Agency for International Development provided valuable assistance and guidance in the overall investigation.

The author gratefully acknowledges the following individuals and organizations (listed alphabetically) for their interest, collaboration and contributions regarding the building research and development activities described in this report.

Project Steering Committee (1971-1972)

1. Mr. Thomas R. Callaway - Director, Division of Technology and Documentation, Office of International Affairs, Department of Housing and Urban Development.

2. Dr. George E. Erickson - Chief, Branch of Latin American, and African Geology, U.S. Geological Survey, Department of the Interior.

3. Mr. William H. Littlewood - Associate Director, Office of Science and Technology, Technical Assistance Bureau, Agency for International Development, Department of State.

4. Dr. Richard D. Marshall - Structural Research Engineer, Center for Building Technology, Institute of Applied Technology, National Bureau of Standards.

5. Dr. E. O. Pfrang - Manager, Office of Housing Technology, Center for Building Research, Institute of Applied Technology, National Bureau of Standards.

6. Dr. Norman F. Somes - Acting Chief, Structures Section, Center for Building Research, Institute for Applied Technology, National Bureau of Standards.

7. Mr. John H. Street - Deputy Disaster Relief Co-ordinator, Agency for International Development, Department of State.

8. Mr. William N. Womelsdorf - Consulting Architect, Federal Housing Administration, Department of Housing and Urban Development.

9. Dr. Richard N. Wright - Deputy Director (Technical), Center for Building Technology, Institute for Applied Technology, National Bureau of Standards.

In Peru

1. Ing. Edilberto Alarcon - Civil Engineer, U.S.A.I.D., Lima.

2. Dr. Dante E. Brambrilla Picasso - Consultant & Geologist, Miraflores

3. Arq. Francisco Hoyos Jiminez - Inter-American Development Bank, Lima.

4. Mr. Peter Land - Director, Experimental Housing Project, U.N.D.P., Lima.

5. Mr. Guido Nadzo - Housing and Urban Development Advisor U.S.A.I.D., Lima

6. Ing. Carlos Rodriquez Cavero - Inspector General, Ministry of Housing Lima.

7. Eng. Enrique Tola Mendoza - Consultant & Civil Engineer, Miraflores

8. Dr. Ricardo Yamishiro - Head, Structural Department, National University of Engineering, Lima.

In Turkey

1. Mr. Nedret Abbas - Architect, General Directorate of Natural Disaster, Ministry of Reconstruction and Resettlement, Ankara.

2. Mr. Koeksal Anadol - The Building Center, Istanbul.

3. Mr. Ersin Arioglu - The Building Center, Istanbul.

4. Mr. Alkut Aytun - Director, Earthquake Research Institute Ministry of Reconstruction and Resettlement, Ankara.

5. Dr. Harry Buchberg - Professor, School of Engineering and Applied Science, University of California Los Angeles, Currently Fulbright Professor, Department of Mechanical Engineering, Specializing in Environmental Engineering, Bosphorous, University, Bebek, Istanbul.

6. Dr. Erhan Karaesman - Professor, Department of Civil Engineering, Middle East Technical University, Ankara.

7. Dr. Muzaffer Ipek - Professor, Institute of Computer Sciences Istanbul Technical University, Istanbul.

8. Professor Dr. Semih Tezcan - Department of Civil Engineering, Bosphorous, University, Bebek, Istanbul.

9. Mr. Erol Tuncer - General Director of Natural Disaster Affairs, Ministry of Reconstruction and Resettlement, Ankara.

10. Dr. Safak Uzsoy - Head Computer Science Department, Middle East Technical University, Ankara

11. Professor Dr. Rifat Yarar - Chairman of the Civil Engineering School, Istanbul Technical University Istanbul.

12. Dr. Vedat Yerlici - Dean, School of Engineering, Bosphorous University, Bebek, Istanbul

In the Philippines

1. Dean Cesar Concio - Architect, Makati, Rizal.

2. Dr. Roman L. Kintanar - Director, Philippine Weather Bureau, Quezon City.

3. Mr. Roberto V. Ongpin - Managing Partner, Sycip, Gorres, Velayo & Company, Makati, Rizal

4. Dr. Ernesto G. Tabujara - DCCD Engineering Corporation, Makati, Rizal.

5. Mr. Rosalio A. Mallonga - Chief Structural Engineer, Bureau of Public Works, Manila

6. Mr. William Larson - Acting Director, Office of Industrial Development, U.S.A.I.D., Manila.

7. Miss Josefina M. Ramos - Assistant, Senate Technical Staff on Housing, Urban Development and Resettlement Congress, Manila.

International

1. Dr. N. N. Ambraseys - Head of the Engineering Seismology Section Department of Civil Engineering, Imperial College, London, England.

2. Mr. R. G. Gokhale - Director, National Buildings Organization, Government of India, New Dehli.

3. Mr. A. A. Moinfar - Director, Technical Research Bureau, The Plan Organization, Tehran, Iran.

4. Dr. Engineer Khosrow Pakdaman - Deputy Minister, Ministry of Development and Housing, Tehran, Iran.

5. Professor Dr. Hubert N. Rusch - Chairman-Emeritus, Civil Engineering Department, University of Munich, Munich, West Germany.

United States

National Bureau of Standards

1. Mrs. Tarja Cronberg - M.S.C. Lund Institute of Technology Institution for Building Function Analysis, Sweden (Currently National Bureau of Standards, Center for Building Technology, Guest Worker).

2. Dr. Emil Simiu - Postdoctoral Research Associate, Center for Building Technology, Institute of Applied

Technology.

3. Dr. S. George Fattal - Structural Research Engineer, Center for Building Technology, National Bureau of Standards.

4. Mr. Thomas E. Reichard - Physicist, Center for Building Technology, Institute of Applied Technology, National Bureau of Standards.

U.S. Geological Survey

1. Dr. Arthur Grantz - Geologist, National Center for Earthquake Research, Menlo Park, California.

2. Dr. George Plafker - Geologist, U.S.G.S. Menlo Park, California.

Housing and Urban Development

1. Mr. John G. Colby - Chief, Technical Assistance Branch, Division of Technology and Documentation, Office of International Affairs, HUD.

Summary

Purpose of the Report

The purpose of this report is to determine whether technology is available (primarily in the United States) which might be transferred to developing countries, where it could be practical and effective in programs aiming at building structures better resistant to earthquakes and wind storms; to review and study the technical, socio-economic and cultural constraints specific to developing countries and their effects upon the implementation of technological innovations; and to study the feasibility of effectively implementing such innovations within the context of these constraints.

Scope of the Report

The report presents a review of the technical problems related to the structural characteristics of buildings and building materials, to the structural performance of buildings under earthquake and wind storm conditions and to the effect of siting on the safety of buildings. Within the framework of conditions prevailing in developing countries, it discusses methods of housing construction, as well as building codes and regulations and their possible improvement. An analysis is made of the social and economic factors which influence the advancement of housing technology in developing countries. A synthesis of feasible technical improvements is presented, and means of communication and transfer of technology to developing countries are discussed.

Materials and Sources of Information Used

The report includes contributions by experts in the fields of structural engineering, earthquake engineering, engineering geology, wind-resistant design of structures and the social sciences. In addition, it utilizes results of field inspection trips to the Philippines, Peru and Turkey, representative of developing countries suffering frequent devastation from natural disasters such as earthquakes and typhoons. The report incorporates information from various bibliographic sources identified at the end of each chapter and, in particular, from socio-economic studies carried out for this project by consulting organizations in the above mentioned countries.

Socio-Economic Studies

The format of the socio-economic studies referred to above were developed by the National Bureau of Standards in order to facilitate the collation and interpretation of data. Seventeen work items, with appropriate adjustments for each country, were submitted as follows:

1. Review in meaningful and appropriate detail the history of the response of different types of houses to earthquake (or typhoon) disturbances.
2. Identify climatic conditions by region and their effect on the physical requirements for housing and the social and economic patterns of the rural environment.
3. Identify gross national product, its distribution, growth patterns and future potential.

4. Prepare a demographic analysis which shows:

   a) How the people are moving;

   b) Village and urban population ratios;

   c) Method of settlement;

   d) Forecasted population trends through 1980.

5. Determine the average size of the family in different regions, nature of the family as it grows and how they use different parts of the house.

6. Investigate the trends of living space expansion in housing. Determine alternate criteria for expansion in the horizontal or vertical direction and give reasons.

7. Define the need for community and municipal facilities as they relate to existing population centers and to newly planned villages or towns.

8. Determine the range of prices that people can afford for housing measured by their income and geographical location..

9. Prepare a detailed review of the availability of mortgage funds, private and government loans, other capital sources, their terms and interest rates.

10. Determine by category, the availability of raw and fabricated construction materials, building elements or components and their delivered costs in different regions of the country.

11. Determine the availability of oils and asphalt material for adobe (Kerpic) stabilization. Also, determine the availability of urea, formaldehyde and other chemicals used to produce plastics.

12. Determine the scope and capacity of the housing industry, including prefabricated housing, as it exists and as it might be for the period of 1972-1980.

13. Compare labor rate trends in different regions and analyze productivity in the building industry including prefabricated housing.

14. Perform a survey to determine public reaction to the use of new designs and new materials such as plastics as construction materials in housing and suggest a marketing strategy if such innovations were used.

15. Investigate the methods and procedures of housing construction in various regions of the country. Prepare, in an order of preference by region, recommendations defining the most favorable types of construction, which would be both economically feasible and socially acceptable.

16. Identify the effective level of local building codes, code enforcement and building technology. Identify the existence and extent of illegal practices such as bribery and graft at local and national levels and the effect these practices might have on the successful implementation of this program. Determine the flexibility of existing policies and codes to accept new or innovative building technology.

17. Prepare a detailed summary of conclusions and recommendations based on the information and data collected for this study.

The conclusions and recommendations of the socio-economic studies are summarized in Chapter 12.

In the opinion of the consultants, the major obstacles to meeting housing needs in the Philippines are as follows:

1. Shortage of funds.
2. Heavy in-migration of rural population to urban centers which offer better economic opportunities.
3. Population growth.
4. Prefabricated construction markets of insufficient size to achieve economics of scale.
5. An insufficiently developed transportation and distribution system in the eleven major islands, resulting in high costs for prefabricated components.
6. The petro-chemical industry is at this time not sufficiently developed to permit the mass production of plastic building components.
7. Standards of workmanship are often not sufficiently high.
8. Building codes allow little room for technological innovations.

The consultants note, however, that in the Philippines, skilled labor is generally available, productivity of labor is reasonably high, labor appears to adapt to new construction methods with relative ease, and that architects as well as users are receptive to new materials and designs.

In the opinion of the Peruvian consultants the major obstacles to meeting housing needs are:

1. The high cost of housing.
2. The scarcity of skilled labor.
3. Insufficient research leading to the development of new construction materials and new procedures of construction and prefabrication.
4. Resistance to new construction materials on the part of the users.

The consultants note that, in Peru, adobe blocks are widely accepted by users and that their improvement through stabilization would contribute substantially to increasing building safety and quality. They also note that social legislation promulgated by the government may have a favorable effect insofar as the acceptance of new materials, construction systems and designs is concerned. A similarly favorable effect may be achieved by structurally and economically advantageous innovative designs.

A comparison between the two studies reveals that, while problems common to most developing countries exist, constraints and their ordering differ according to local conditions. An ad hoc approach to housing-related problems is therefore required.

Feasible Technical Improvements. Communication and Transfer of Technology

The needs, resources and capabilities in the area of housing vary, sometimes considerably, from country to country. It is therefore not possible to present an exhaustive list of technical improvements applicable to all developed countries. Such improvements may be pertinently discussed only within the framework of the conditions prevailing in a given country and, moreover, with reference to specific projects undertaken in that country.

For example, in the opinion of the Peruvian consultants the shortage of housing in the larger cities of Peru can be alleviated, at least in part, by building high-rise buildings. In rural areas, on the other hand, adobe block buildings are recommended, this material being both inexpensive and widely accepted. In new communities built for industrial employees, buildings using prefabricated components are frequently provided. Dwellings in squatter settlements are most often built using quite rudimentary techniques, while certain dwellings in emergency housing programs are produced by sophisticated industrial processes, as is the case with the "igloo" plastic dome.

Technical improvements resulting in better resistance to earthquakes are feasible in the case of each of the building types or systems enumerated above. This is true of high-rise buildings, with regard to the seismic behavior of which a vast

amount of knowledge and experience is available in the United States; of adobe, whose stabilization considerably improves its qualities and its seismic behavior; of masonry buildings in general, which, if properly designed (with or without reinforcement), exhibit superior aseismic properties and to which the considerable body of experience available, particularly on the United States West Coast, may be successfully adapted; of prefabricated buildings to which techniques used in various European countries or in the United States may be applied; of industrialized dwellings, similar to the "igloos," the design of which would however be more compatible with users' requirements than has been the case with the "igloos."

In addition, new materials are being or may be developed such as materials using jute, reinforced concrete with vezetal or plastic reinforcement, structural sandwich systems to which American research and development or production experience is highly relevant, etc. The production of stabilized adobe flocks, for example, may be considerably increased - while costs would be reduced - if the equipment used in the manufacturing process could be improved.

Communication and transfer of technology is best achieved within the process of interaction between experts of both the assisting agencies and the developing countries involved in specific cooperative programs. In addition, training, educational and fellowship programs, as well as seminars, play a useful role insofar as communication of technology is concerned.

Areas of Cooperation

Areas of cooperation related to design, siting and construction of structures to better resist earthquakes and wind storms include:

- research on the behavior of various types of structures under the action of earthquakes and wind storms (including, for example, wind tunnel and full-scale studies to determine the action of typhoon winds on low-rise buildings)
- development of improved structural systems and designs
- development of improved production and construction methods
- development of seismic maps and of wind intensity maps based on seismological and earthquake engineering, and on climatological studies, respectively. The need for seismic maps was proven, for example, by the disastrous consequences of the Fars earthquake in Iran, which were largely attributed to the fact that buildings had been designed for Tehran, rather than for Fars conditions. The need for wind intensity maps is particularly acute in the Philippines [1].
  development of improved building codes.

The report discusses in detail such technical improvements as the stabilization of composite systems (structural sandwich panels, bamboo reinforced concrete) and of industrialized, prefabricated designs and construction.

A considerable potential for technical improvements leading to structures with superior earthquake and wind storm resistance exists. Decisions as to which areas should be accorded priority should be based on analyses undertaken in close cooperation with the developing countries involved.

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Chapter 1. Introduction

Earthquakes and wind storms are responsible for considerable loss of life and property throughout the world. In the period 1926-1972, for example, earthquakes alone caused almost one million deaths, as well as damages to buildings and public works totaling an estimated fifteen billion dollars [1].

Improved design, siting and construction procedures can contribute significantly to the reduction of such losses. In developing countries, however, severe socio-economic constraints make the adoption and implementation of such procedures particularly difficult, resulting in continued losses on a massive scale.

The purpose of this report is to determine the availability of technology (primarily in the United States) which might be transferred and applied in developing countries, where it could be both practical and effective in programs concerned with the development of building structures better resistant to earthquakes and wind storms; to review and study the technical, socio-economic and cultural constraints specific to developing countries and their effects upon the implementation of technological innovations; and to study the feasibility of effectively implementing such innovations within the context of these constraints.

The report presents a review of the technical problems involved. It examines the constraints which exist in developing countries, in broad terms to offer an overall

perspective, and in detail with reference to specific countries selected as case studies. A review and analysis of available and potential technological improvements which are or would be practical in developing countries is presented, and means of communication and transfer of technology to developing countries are discussed.

The report uses material provided by contributing experts and includes results of investigations made in the course of field trips to Peru, the Philippines and Turkey. The report also includes summary of major conclusions and recommendations submitted by consulting organizations in these countries.

Chapters 2, 3 and 4 provide technical information regarding general characteristics of buildings, building materials and structural performance of buildings subjected to earthquakes and wind forces.

Chapter 5 outlines the importance of siting considerations from the geological, seismic and climatological viewpoint. This chapter was essentially contributed by the U. S. Geological Survey.

Chapters 6 and 7 review methods of housing construction, building codes and regulations. Chapters 8 and 9 summarize the major social and economic factors that influence the advancement of housing technology in developing countries. These chapters drew extensively from the consultants' reports.

Chapter 10 synthesizes feasible technical improvements in construction materials, composite systems and building systems.

Chapter 11 discusses communication and transfer of technology and the role of institutions in this work.

Chapter 12 is a summary of conclusions and recommendations from the Philippines, Turkey and Peru, as prepared by the consulting organizations in each country.

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1. U.N.E.S.C.O., Report on Seismology and Earthquake Engineering, Department of Advancement of Science, January 20, 1965.

Chapter 2 General Structural Characteristics of Buildings and Building Materials

by

Dr. S. G. Fattal

National Bureau of Standards

2.1 Introduction

2.2 Structural Types

2.2.1 Bearing Wall Buildings

2.2.2 Frame Buildings

2.2.3 Shell and Membrane Buildings

2.3 Structural Elements

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2.3.2 Frame Elements

2.3.3 Walls

2.3.4 Roofs and Upper Floors

2.4 Materials and Their Mechanical Properties

2.4.1 Concrete

2.4.2 Masonry

2.4.3 Soil

2.4.4 Wood

2.4.5 Metals

2.4.6 Plastics

References

Chapter 2. General Structural Characteristics of Buildings and Building Materials

by

Dr. S. G. Fattal

National Bureau of Standards

2.1 Introduction

This chapter provides background information for the technical discussions in chapter 3 and 4 regarding structural performance of buildings subjected to wind and earthquakes. In Section 2.2 buildings are described according to structural type and the manner with which they transfer lateral and gravity forces. Section 2.3 describes and classifies building elements according to shape and composition. Construction materials and their mechanical properties are discussed in section 2.4. Special attention is given to types of construction and materials identified with low-cost housing development.

2.2 Structural Types

2.2.1 Bearing Wall Buildings

In buildings of bearing wall construction, the walls are designed to transmit gravity and lateral loads to and from the foundation by functioning as structural elements in compression, shear, tension and bending. Gravity forces consist of the dead load of the structure and vertical live

loads from human occupancy, furnishings, snow, ice, or other transient loads. Vertical forces are also induced by wind suction, uplift and direct pressure on the roof (see chapter 4) and by vertical movements of the ground in an earthquake (see chapter 3). Lateral forces are produced by winds, floods, tidal waves, debris loading and horizontal earthquake movements of the ground.

Figure 2.1 offers a simple illustration of the force transfer mechanism. Vertical loads from the roof assembly produce the compressive forces shown acting on the walls below. Resistance against lateral forces is provided primarily by walls of the same orientation. For instance, in the figure, shearing resistance of walls A and C is mobilized against horizontal forces indicated by solid arrows. Similarly, walls B and D are mobilized against transverse forces indicated by the broken arrows. In addition, walls provide direct tensile resistance against overturning or uplift forces and bending resistance against out-of-plane normal loads induced by lateral forces.

2.2.2 Frame Buildings

The main identifying feature of a framed building is the presence of a substantially complete vertical load-carrying frame consisting of beam and column elements. Where the frame is also called upon to participate in resisting lateral forces, the design usually provides for bracing or for rigid

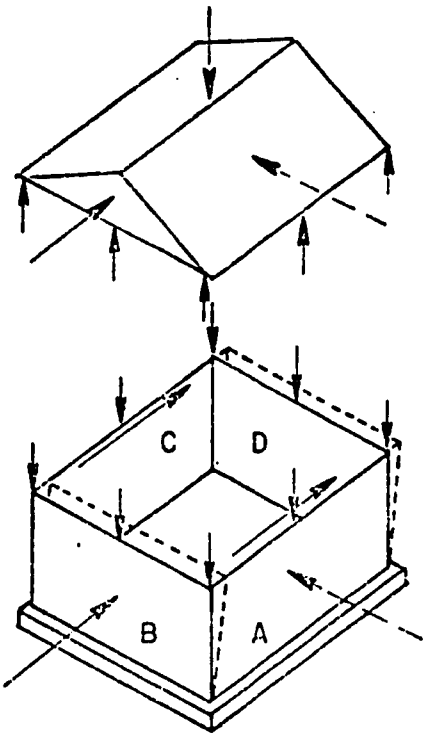

Figure 2.1

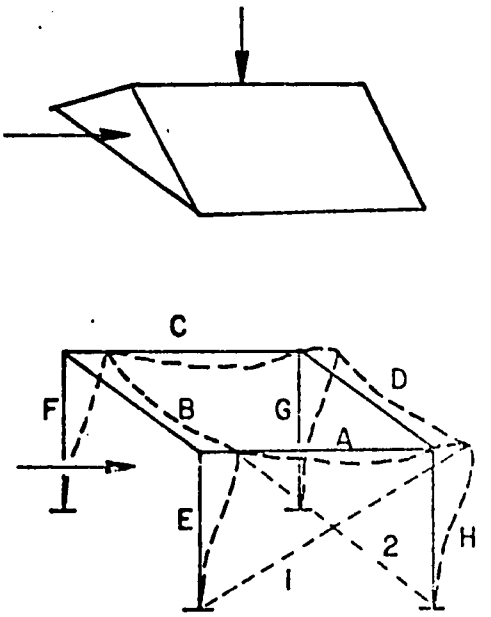

Figure 2.2

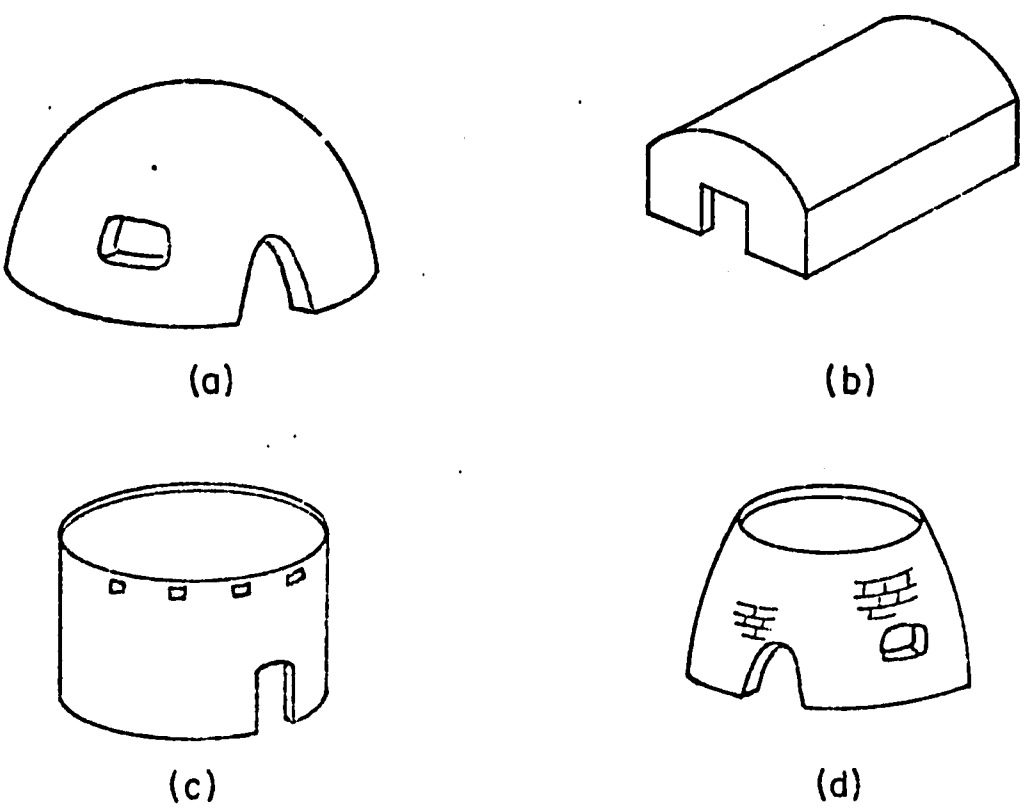

Figure 2.3

connections so that the rotations at any joint are collectively resisted by the elements framing into it in proportion to their bending stiffnesses. For example, in the single-cell space frame of figure 2.2, beams A to D are rigidly attached to columns E to H at the top four joints. The deformed shape of the frame under the simultaneous action of vertical and lateral loads is shown exaggerated by the broken lines for the sake of clarity. Resistance to lateral forces is primarily contributed by the simultaneous mobilization of bending and shear capacity of columns and bending capacity of beams. In addition, beams provide bending and shear resistance against vertical loads transmitted from the roof through floor joists and other attachments, with columns offering resistance against axial loads and any bending moments induced by continuity of joints.

Walls of frame buildings are often constructed for the non-structural purpose of providing enclosure. However, when they are attached to, or built integrally with the rest of the structure, as in the case of infilled frames, most of the lateral forces are carried by the walls in shear since their in-plane stiffness is significantly larger than the combined lateral stiffness of the frame columns.

2.2.3 Shell and Membrane Buildings

Shell type buildings consist primarily of single or double curvature elements. Figure 2.3 illustrates some of

the forms utilized in building construction. The dome shape in (a) provides continuity of roof and wall. The truneated dome in (d) incorporates a flat roof bearing on walls of double curvature (i.e., vertical and horizontal). The structure in (b) uses a cylindrical roof with flat vertical walls and (c) depicts a "silo" shaped structure with flat roof bearing on cylindrical wall enclosure.

The shell is a highly efficient structural form deriving its effectiveness from curvature which, when properly exploited by the designer, gives it the ability to transmit loads through membrane action (i.e., in-plane compression, shear and tension) and minimal amount of bending.

2.3 Structural Elements

2.3.1 Foundations

Building foundations are designed to transmit superstructure loads to the ground below. The type of design is dictated by the bearing capacity of ground material, intensity of loads to be transmitted and allowable levels of tolerance to settlements. These factors become less critical for low-rise dwellings of one-to-two stories. Certain types, such as piles, are seldom encountered except for houses in frequent flood areas built on bamboo stilts driven into the ground to a length sufficient to develop the required load capacity by friction with the surrounding soil. Where flooding is not a major factor, rectangular footings of plain or reinforced concrete or gravel with soil-

cement mortar are quite commonly utilized. Wall footings are usually laid under the entire length of the wall with widths varying from up to twice the wall thickness for load-bearing walls to slightly larger than the wall thickness for nonload-bearing walls and partitions. Depths commonly vary between 30 to 60 cm. Rectangular spread footings, similar to wall footings in composition are used to support individual column loads of frame buildings on rocks or high-grade compact soil. Combined footings or mat foundations are used with less favorable soil conditions.

2.3.2 Frame Elements (Figure 2.2)

A frame is an assembly of beam, column and bracing elements of small sectional dimensions relative to length. The structural behavior of each element identifies it from the other types.

A beam transmits vertical loads horizontally to columns and walls through the combined mechanism of shear and bending. Shearing may be visualized as the tendency of two surfaces, formed by the splitting of a section, to slide off one another in opposite directions. The mechanism is actuated by opposite internal forces developed in the plane of a section. Bending produces curvature in an element causing compression in longitudinal fibers near the concave side and tension in fibers near the opposite side. For this reason, beams made of materials of low tensile strength, such as concrete, require

reinforcing bars near tensile regions for effective action against bending. Beam cross-sections of reinforced concrete or wood construction are usually rectangular while the I shape is more commonly utilized for steel beams.

Columns transmit vertical loads and beam reactions to the foundation. Their structural effectiveness is in compression although in most instances they are also designed to transmit bending induced by continuity of joints or eccentricities of axial loads. Square, circular, rectangular or I-shaped sectional profiles are quite common. Columns are made of reinforced concrete, masonry, wood, metal, or a variety of other materials and combinations thereof.

Bracing elements in frames inhibit lateral deflections and provide resistance against horizontal forces. A common application is the diagonal cross-bracing illustrated in figure (2.2) where the tensile resistance of element no. 1 is mobilized against the lateral force shown. Diagonal no. 2 functions in a similar manner when the direction of the force is reversed. Bracing is also used for columns to increase their resistance against lateral buckling. Non-brittle materials strong in tension are well suited for bracing. Steel, wire, wood, bamboo or even rope are typical examples.

2.3.3 Walls

Structurally a bearing wall is the counterpart of a column in that both are designed to support primarily vertical

loads in compression. In addition, bearing walls develop substantial shear forces from lateral loads which also produce some bending in these elements.

The assembly of a filler wall with a confining frame around it is known as an infilled frame. Under lateral loads, filler walls alter the basic behavior of the frame by inhibiting lateral deflections and assimilating most of the shear away from the columns. Axial loads in filler walls are nominal.

The main function of non-structural walls such as parapets and interior partitions is to provide enclosure in buildings. Therefore, the contribution of these walls to the overall structural resistance should be minimal.

Structural walls of wood, concrete, burnt clay or soil-cement composition are quite common in low-cost housing construction. The walls may be monolythic or of masonry type construction where staggered courses of basic units are laid in beds of mortar. Clay brick and tile, adobe brick and concrete block are conventional masonry units. Masonry mortar of a desired consistency and strength is prepared by using certain proportions of cement-lime-sand or soil-cement mixtures.

2.3.4 Roofs and Upper Floors

Floors above the ground level are designed to develop sufficient capacity in shear and bending to transmit direct

gravity loads to floor joists, frame elements or bearing walls below. They also function as diaphragms distributing lateral forces to supporting elements. Typical examples of floor systems are reinforced concrete slabs supported by joists or at the edges, and joist supported wood floors.

Diverse types of materials and shapes are utilized in roof construction. Pitched roofs are often attached to a wood supporting frame or a truss. Flat roofs are similar to floor slabs in structural behavior although the nature of loads is somewhat different mainly due to the presence of suction and uplift forces. A traditional type of roof construction, consists of wood joists or logs, spanning across opposite walls, overlain first by bamboo, straw or asphalt-impregnated burlap, and then adobe.

2.4 Materials and Their Mechanical Properties

2.4.1 Concrete

Concrete is prepared by mixing certain proportions of sand, cement and gravel with water. At the construction site, the mixture is poured into preassembled wood forms which are removed after setting. Near full strength is usually attained in about a month. Standard size cylindrical samples are removed from different batches during construction for separate testing to determine the compressive strength of the concrete used. This practice is necessary in view of the susceptibility of concrete compressive strength to proportion-

ing and quality of its ingredients, rate of curing and many other factors. Compressive strengths ranging from 1,400 to 3,500 N/cm^2 are typical.

Concrete is weak in tension and therefore, seldom used without reinforcement. The use of steel, fiberglass and other high tensile strength materials for reinforcement, coupled with properties such as durability, fire resistance and mouldability into different shapes, makes concrete a most versatile construction material.

2.4.2 Masonry

The compressive strength of masonry with a specified type of mortar is equal to the test strength of a standard size prism of the same composition modified by a factor. Alternately, the strength is sometimes expressed as a fraction of the strength of its unit for a specified type of mortar. The range of compressive strengths of brick and concrete block masonry used in construction is indicated in the following table.

Type	(N/cm^2) Compressive Strength of Masonry Units	(N/cm^2) Compressive Strength of Masonry
Brick	1,400-10,000	400-3,200
Block	350-2,000	100-6,500

Because of its low tensile strength which is in the order of 5% or less of its compressive value, masonry requires the

use of reinforcement to develop any structurally significant bending resistance.

2.4.3 Soil

In many parts of the world, particularly in developing countries, natural earth is probably the most common material used in building construction. Sun dried adobe bricks containing sand, silt and clay, often untreated against water penetration have been the basic masonry units for traditional low-cost housing construction. The more recently introduced asphalt stabilized adobe brick of high durability and water repellent properties marks a significant breakthrough in improved low-cost construction. With good workmanship, adobe bricks with compressive strengths of 350 to 500 N/sq. cm. may be obtained. Mortars used with adobe units are mixtures of soil and cement, with asphalt added to give it the desired stability.

Several attempts have been made in Turkey to provide stabilization with asphalt. The following is the summary of findings of a study recently conducted by the General Directorate of Building Materials of the Ministry of Reconstruction and Resettlement:

"A laboratory analysis of the adobe material is essential. This will help to decide what kind of asphalt be used and what the optimum amount is. The analysis should cover a sieve test (gradation) and a determination of silt and/or clay amount.

Liquid limit and plastic limit should be determined to know the plasticity index (PI) of the soil. In general soils, with a clay and/or silt ratio of more than 45% are not suitable for asphalt stabilization as silt and clay tend to prevent pulverization.

The kind of asphalt is determined by the kind of soil, as follows:

Cut-back asphalts of RC type and emulsion asphalts, are very suitable for sandy soils, with a small silt and/or clay content. Soils of PI 5 or less are of this kind. As non-plastic soils are cohesionless, the stability of the mixture is a function of the binding power of the asphalt used.

Cut-back asphalts of MC type provide a more homogenous mixture in case they are used with soils of PI 6-10. As the plasticity becomes higher, cohesion is higher. Consequently, the stability of the mixture is determined by both the binding power of asphalt and the cohesion effect of clay. This kind of soil gives satisfactory results with emulsion asphalts.

Asphalts of SC type are good for clayey soils as they are highly penetrative. They can be used with soils of PI higher than 10, and silt and/or clay content higher than 30%. The stability of the mixture does not depend much on the binding property of the asphalt, as the soil itself is highly cohesive.

Soil should contain approximately half of the optimum water content, for cut-back asphalts. In other words, the

asphalt will substitute the remaining one half. In case emulsified asphalts are used, the water content must be 10% or slightly more. This amount of water facilitates the mixing of asphalt.

In the following matrix the average results of two sets of tests (one with 4% and the other with 7% asphalt ratio, with 85-100 penetration rate, in form of an emulsion containing 60% water) were conducted on GM type soils:

	With 4% Asphalt	With 7% Asphalt
Unit Weight	1,879 Kg./dm^3.	1,902 kg./dm^3.
Pressure Strength		
(a) Normal in dry air		
Average	8,647 kg./cm^2	11,181 kg./cm^2
Minimum	7,070 kg./cm^2	10,419 kg./cm^2
(b) Absorbed with water		
Average	-	8,759 kg./cm^2
Minimum	-	7,145 kg./cm^2
(c) After frost	-	Collapsed after 15th repetition.
Capillary water rise		
(a) cm/hour (23 hours)	7 cm.	-
(b) gr/hour (27 hours)	160 gr.	19 gr.
Water absorption	Collapsed	3.64
Cost per adobe block (29 x 14 x 9.5 cm.)	0.387 TL.	0.738 TL.

Availability of Asphalts Used for Adobe Stabilization in Turkey

(a) MC (Medium Cure) Cut-back Asphalt: A mixture of asphalt

cement (AC) and kerosene. Grades 0, 1, 2 of this kind can be produced by Batman Refinery of T.P.A.O. The price in Batman is about 750 TL. ($50.00) per ton.

(b) RC (Rapid Cure) Cut-Back Asphalt: A mixture of asphalt cement (AC) and gasoline. Grades 0-5 of this kind of asphalt can be produced by Batman Refinery. Unit price is about the same as MC type. It is highly flammable and General Directorate of Highways prefers to produce it locally.

(c) SC (Slow Cure) Cut-Back Asphalt: A mixture of asphalt cement (AC) and light oils. Crude oil and fuel oil are of this kind. It is not produced, nor used in large amounts. Can be produced by Batman Refinery. Price in Batman is about 600 TL. per ton.

2.4.4 Wood

The structural uses of fabricated lumber in building construction are diverse and extensive. Wood joists and plywood panels are used for roof and floor systems. Sandwich panels with wood studs and plywood skins are utilized for exterior walls and partitions. However, fabricated lumber may not always be available or be economically feasible for low-cost housing construction. In such cases, non-dimensional lumber, raw timber, cane, bamboo, palm or thatch are used as alternates depending on their local availability.

Generally, wood exhibits good strength in both tension and compression in the direction of its longitudinal fibers. This property makes it adaptable to construction of b nding

resistant elements in a building. Cane, bamboo or split wood may also be utilized to reinforce adobe masonry walls and elements of poured stabilized soil. Exposed wood generally requires special protection against moisture, fire and insect infestation.

2.4.5 Metals

Steel in the form of reinforcing bars for concrete and masonry elements is used quite extensively in housing construction. Individual reinforcing bars of different diameter sizes are usually fabricated with deformed surfaces for better bond. Wire mesh reinforcement is fabricated by welding together two layers of spaced thin bars (usually 1 mm. or less in diameter) in a grid pattern. Poultry netting of hexagonal or triangular pattern is a relatively inexpensive manufactured product which merits exploitation as a reinforcing material for low-cost houses as it may be more readily available locally than other types of reinforcement.

Steel exhibits high strength, stiffness and ductile properties. Stiffness is a measure of resistance against deformations. Ductility is the ability to sustain substantial deformations beyond yielding without rupture. Both strength and ductility provide a measure of the capacity of a material to absorb energy without rupture. Tensile strength of steel reinforcement usually falls within the range of 25,000 to 45,000 N/sq. cm. Mechanical properties of steel begin deteriorating rather rapidly at high temperatures beyond 400°C. Also,

surfaces exposed to moisture are subject to corrosion. In construction, steel is protected against these agents by painting and coating with fire proofing materials.

Other applications of metals in low-cost housing construction includes the use of corrugated sheet metal of galvanized steel or aluminum for roofing and wall siding, use of steel connectors for bolting and anchoring various elements, and use of rods and cables for bracing purposes.

2.4.6 Plastics

Weathering characteristics of plastics in outdoor use and durability in relation to the traditional materials are some of the questions which still remain to be answered satisfactorily, particularly in respect of their use in tropical areas such as the Philippine Islands. It may be of interest to note that some of the leading plastics producing countries in the Far East are South Korea, Taiwan, and the Philippine Islands. A range of plastic products, using indigenous and imported plastics raw materials and processing machinery are manufactured in these countries. Lately, plastic products of interest to the building industry have also been introduced in these and other developing countries. However, Peruvian and Turkish Plastics Industries are only in the very early stages of development and thus will require considerable assistance.

One advantage of plastics, which has been taken into consideration for use in the building industry is adaptability

to mass-production techniques. Their light-weight, corrosion-resistance, and ease of manipulation in manufacturing building components in any specified design are some of the characteristics which have enhanced their acceptance in building applications. Cellular plastics [1] exhibit excellent thermal insulation and thus reduce temperature fluctuations in hot, arid regions with a wide range of temperature cycling. In hot, humid regions there is less thermal advantage to be gained in using plastics, except as part of a lightweight system of construction. In cooler regions there is no doubt that their very effective thermal insulating characteristics are an appreciable advantage.

Being new material, plastics have to find acceptance into the building industry, which generally tends to be conservative in its approach to innovative building materials and techniques.

As a tradition in Turkey for example, solid and durable materials are generally preferred for building construction. However, recently numerous plastic materials emerged in the market, and some of them are used in the newly constructed modern buildings.

Replacement of the traditional materials used in the manufacture of various goods and articles by plastics has resulted in rapid development of the plastic industry in Turkey. This industry mostly depended on imports for raw and auxiliary materials, until the end of 1969. However, in

recent years certain polymers and plasticizers began to be produced locally. Now the plastic industry is in process of improvement.

Of the mentioned amounts [2] of plastic processing production (about 300,000 tons in 1972), only the following items are used in buildings:

(a) Vinyl-asbestos floor tiles: Recently vinyl-asbestos floor tiles became popular in the cities and towns, and are substituted for cement and mosaic tiles. Production is growing rapidly and the rate of acceptance shows that this material may well be adopted in villages too, in near future. It takes an important percentage in total production and has a good potential for export, since it matches established high standards.

(b) Clean and/or Waste Water Installation Pipes: Plastic pipes are already used for irrigation and agricultural purposes, in great extent. It may well be largely adopted in rural dwellings, for it has such advantages as lightness, workability and durability.

(c) Kitchen and Bathroom Fixtures, Water Reservoirs, Wash-Basins, Handrails, Plinthes and Lambris: Use of plastic for such items is constantly increasing.

(d) Flat or Corrugated Plastic Sheets: Although corrugated plastic sheets are widely used as roof covering material in temporary or urban structures (partly for decoration purposes), they are not accepted yet as a major material.

Flat sheets are especially used in signs for decoration and lighting fixtures.

(e) Sheets or Bags of Polyethylene Films: Recently, plastic sheets (films) are widely used on roofs (especially on earth roofs, which provide a good thermal insulation but are very weak against water) for waterproofing, or in hollow gables of roofs for windproofing. Plastic bags are used to hold glass-wool in place, for heat insulation. They are also used on tents or temporary structures as an upper cover (waterproofing).

(f) Plastic Foams for Heat and Acoustic Insulation: Although several kinds of plastic insulation materials (foam, etc.) exist on the market, they are not used yet in dwellings, but are very popular in furniture and industrial use (seats, armchairs, refrigeration, industrial insulation, thermal and acoustic insulation of few modern buildings).

(g) Acrylic Wall and Plaster Covering: This material has not been popularized yet, but seems to be making progress.

(h) Styrofoam Beads and Panels: They are used to provide insulation and lightness in prefabricated houses.

Such materials as electric cables and plastic wall-papers are excluded here because they are considered non-structural.

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Chapter 3 Structural Performance of Buildings Under Earthquakes

by

Dr. S. G. Fattal

National Bureau of Standards

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3.1 Nature of Earthquakes

Major earthquakes are generally believed to be of tectonic origin associated with large strains in the crust of the earth. Tectonic motion, which manifests itself as a random shaking of the ground, is attributed to slip of geologic faults or to rock metamorphosis at greater depths, causing volume changes within the crust. Severe earthquakes may extend over vast geographic areas, releasing large energy, creating fissures, cracking and sudden relative changes in ground elevation causing damage and destruction to surface structures. Aftershocks usually following an earthquake are attributed to ground movements to relieve high stress conditions created by seismic faulting. Tsunamis or seismic sea waves caused by local changes of ocean floor elevation during earthquakes can be particularly destructive to towns along coastal regions. Increased frequency of landslides even long after a major earthquake is attributed to cracking produced during the initial disturbance.

The point from which the first seismic waves propagate is known as the focal point of an earthquake. The epicenter is the point on the earth's surface directly above the focal point.

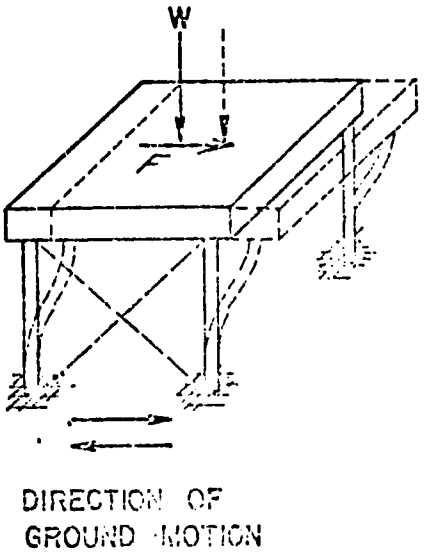

FIGURE (3.1)

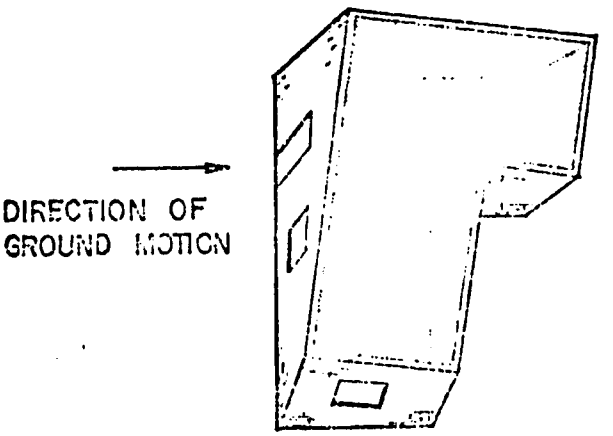

FIGURE (3.2)

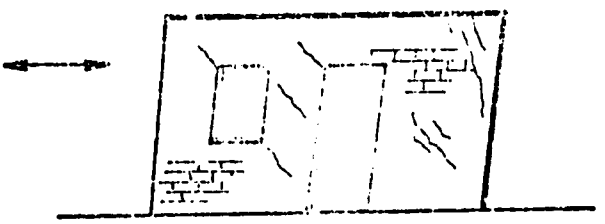

FIGURE (3.3)

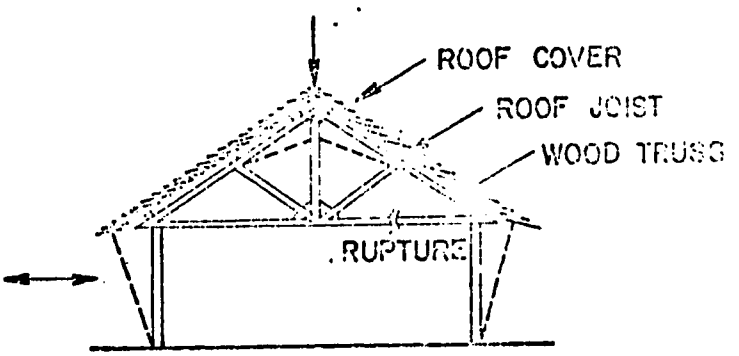

FIGURE (3.4)

Two commonly used indicators of the severity of an earthquake are the Mercalli and Richter scales. The Mercalli scale measures the intensity or the local destructiveness of an earthquake and varies according to the location of the station from the epicenter. The Richter scale measures the magnitude or energy released by an earthquake. Instruments, such as seismometers, installed at various strategic locations are utilized to record amplitudes and frequencies of seismic accelerations and to provide a valuable source of information about the potential severity of earthquakes for these regions. Post earthquake experience is utilized to develop seismic risk maps which are adopted by various codes and building regulatory agencies in prescribing specifications for earthquake design of structures (See Chapter 7).

3.2 Seismic Effects on Buildings

3.2.1 Influence of Structural Configuration

The forces produced in surface structures as a result of ground motions are similar, in nature, to those experienced by the human body in a moving vehicle subjected to sudden manipulations of the driving control mechanisms. The distribution and relative intensities of seismic forces within a structure are influenced, to a large extent, by the type of construction, geometry, mass distribution and stiffness properties.

In general, heavier elements in a building develop greater "direct" forces while stiffer elements receive a larger share

of the forces transmitted between elements. Peak lateral forces tend to concentrate at massive roof and floor levels and propagate to other levels mostly through laterally stiffer vertical elements. For example, in the structure of figure 3.1, the lateral force acting on the roof is transmitted through connections to relatively lightweight columns below, producing critical shear and bending forces in these elements. Additional column bending occurs as a result of gravity load eccentricities created by the lateral drifting of the roof. The introduction of lateral stiffening elements such as cross-bracing (shown dotted on the sketch) or walls in faces parallel to the direction of ground excitation reduced drift and its effects on columns and alters drastically the force distribution pattern (i.e.: the bracing acting in tension, or the walls acting in plane shear, assume most of the lateral forces transmitted from the roof).

The geometry of a building may have a marked effect in distributing seismic forces. For instance, twisting and warping forces are more likely to occur in buildings of irregular shape (figure 3.2) or with non-uniform arrangement of walls and openings. Forces of high intensity will tend to develop at corners of openings (stress concentration points), at the top junctions of abutting walls, near attachments of projecting elements, or, as a result of "hammering" between adjacent walls of detached buildings. In general, buildings marked with sharp transitions in mass and/or geometry tend

to develop structurally unfavorable force distribution patterns.

3.2.2 Foundations

Frequently, structures designed to withstand earthquakes fail as a result of inadequate foundation. In many instances cracking and failure of superstructures are caused not by direct vibrations but rather, by differential settlements of footings caused by conditions leading to liquefaction of sandy soils specially in areas of high groundwater elevation, or, by slope instability and landslides.

Certain types of foundations are more susceptible to earthquake damage than others. For example, foundations of shallow, individual spread footings are likely to be subjected to high differential settlements and "rocking" particularly when the supporting ground consists of different types of soils. Unfavorable conditions may also develop when mixed types of foundations are used for the same structure.

Many houses in coastal areas are built on poles or foundations of treated piles. While this is an excellent practice too often the house is not properly fastened to the poles to give it sufficient stability against lateral earthquake forces.

Shallow foundations deteriorate with age as a result of exposure to freezing and thawing of the surface ground in regions of cold climate and to frequent flooding in tropical regions. In seismic areas some degradation of foundation material occurs as a result of the cumulative effect of past

earthquakes even though they may not create any visible damage to the above-ground structure.

3.2.3 Walls, Frames and Shells

Unreinforced bearing walls of masonry or concrete construction, while most commonly used throughout the world, are highly susceptible to earthquake damage. This weakness is mainly attributed to the fact that in stiffening a building against lateral seismic forces walls develop critical stresses which are likely to exceed their relatively low in-plane shearing capacity. Further significant reductions in wall strength occurs as a result of openings.

Walls commonly fail in racking shear, out-of-plane bending or a combination of both. Racking shear failures are recognized by the cross-diagonal cracking pattern frequently observed in building walls damaged by earthquakes. This type of failure is initiated by cracks which develop at points of high stress concentration (i.e.: corners of openings, centers of wall segments or piers flanking adjacent openings - see figure 3.2) and quickly propagate outward causing complete rupture.

Out-of-plane bending failure occurs mainly as a result of direct seismic forces which develop in a direction transverse to the wall. In general, bending and shearing effects occur simultaneously in an earthquake since the direction of seismic excitation is often inclined with respect to the

orientation of the walls.

Bearing wall failures are characterized by sudden, brittle types of partial or complete collapse of wall segments followed by the collapse of roofs and upper floors. The results are often devastating as was evidenced by the totality of destruction of adobe wall dwellings during the 1972 Fars earthquake in Iran.

Another major contributing factor to bearing wall collapse is failure of connections to roofs and other wall elements and foundation anchorages. This results in a substantial loss of structural integrity of the building and the ability to act as a unit against earthquakes. Tension cracks between abutting walls propagating from the roof downward (see figure 3.3) are indicative of inadequate wall-to-wall connections.

The structural weakness exhibited by bearing walls is also inherent to filler walls confined within load-bearing frames. Due to the effect of frame enclosure, however, filler walls tend to develop increased shear and bending capacity although this is partially offset by the absence of compressive loads, which up to a certain level, increase the capacity of a wall to resist in-plane shear forces.

Rectangular frames of the type shown in figures (2.2) and (3.1) resist lateral forces through the combined bending and shear action of its elements. Collapse of frames under lateral forces may be caused by excessive column bending or by failure of rigid joints between frame elements.

Certain types of shell enclosures such as cylindrical or spherical shapes (see figure 2.3), have found their use in low-cost housing construction in the past. These dwellings are commonly built with traditional materials such as mud or adobe block, without any reinforcement. Under seismic loading conditions failure is likely to be initiated by cracking at corners of openings or near ground or roof attachments where high localized bending stresses are dominant.

3.2.4 Roofs and Upper Floors

One of the major concerns in the mitigation of earthquake disasters is the prevention of roof and floor failures causing loss of human lives. The practice of designing roofs without regard to the seismicity of the region and the use of heavy non-structural roofing materials account for the high incidence of roof failures in low-cost houses in past earthquakes.

Generally, roof failures are attributed to insufficient strength or to lack of adequate connections. Roof collapse may also occur as a result of rupture of supporting walls, columns and other load-bearing elements. The different modes of roof failures are dependent on the structural configuration of the system. For example, the rupture of the bottom chord of a roof truss (see figure 3.4) may trigger a complete structural collapse by forcing the supporting walls outwards as indicated by the dotted lines. On the other hand under a horizontal seismic disturbance, the roof transmits rocking

forces to the supporting walls causing the formation of tensile cracks and separation at the top corners of abutting walls. This mode of failure is also characteristic of massive flat roofs (or floors) supported by beam joists spanning across the width of a building and "resting" on opposite walls.

3.3 Building Improvements to Mitigate Earthquake Effects

3.3.1 Structural Configuration

Usually, the configuration of a building is selected on the basis of requirements other than seismic considerations alone. Further, the possibility of situations with conflicting requirements cannot be ruled out. A case in point is the lightweight roof system which offers certain advantages in a seismic design although it stands a greater chance of being torn off its supports by high wind suction. Another example is the flat roof projecting beyond exterior wall supports. This scheme increases its bending effectiveness against vertical seismic excitation but makes its projections particularly susceptible to wind-induced uplift and suction pressures (see section 4.2.4). However, these situations seldom occur and, in general, it is possible to identify and prescribe certain configurations for improving seismic construction without conflicting requirements. The following is a list of such recommendations.

Low-cost housing construction should be limited to one or at most two story units. This practice permits maximum

exploitation of locally available construction materials and increases the feasibility of producing better seismic-resistant structures.

The weight of roofs and floors should be kept to a minimum. The shape of the building, the arrangement of walls, partitions and openings should be made in a balanced manner to obtain as uniform a stress distribution in the building as possible. Attachments of heavy elements to walls which may be disproportionately stiff relative to their strength should be avoided.

The size and spacing of openings should be governed by requirements of minimum width of piers flanking adjacent openings, maximum permissible length of lintels spanning across the top of openings and uniformity of overall layout. Exterior walls forming a rectangular enclosure may be prevented from separating at the top corners by providing a continuous collar or ring beam having sufficient tensile resistance to forces pulling walls apart at their upper peripheral junctions. Structural damage resulting from hammering of unattached adjacent walls may be avoided by providing connections between these walls for integral action against earthquakes, or, by providing sufficient space between adjacent buildings to avoid impact.

3.3.2 Foundations

For low cost single story housing construction the only type of foundation of reasonable cost in comparison to the

structure is the superficial foundation. In the event when soil conditions require the use of deep or piled foundation, or when the possibility of soil liquefaction exists, serious consideration should be given to the selection of alternate construction sites.

The following factors are necessary attributes of superficial foundations to achieve better earthquake resistant construction:

The base of the foundation should be below superficial or "top soil" level, and below the vegetal root level in all cases, where applicable. In locations subject to general freezing as in Peru, Turkey and Iran, the bottom of the foundation should be below the freezing level of the ground.

Continuous wall footings should extend under the entire length of the wall and sufficient vertical dowel reinforcement should be provided between wall and footing to develop continuity and capacity for integral action. This practice should minimize differential settlements and local damage to the walls and should permit a more uniform distribution of bearing pressures in the soil.

For single story construction the width of the continuous footing should not be less than one and one-half times the thickness of the wall or 35 cm., whichever is larger (4). Depth should not be less than 45 cm.

Foundation materials of gravel mixed with soil stabilized with asphalt or road oil may be used. Stabilization of the

foundation material provides protection against moisture and other deteriorating agents. Split cane, bamboo or wire mesh may be used for vertical reinforcement to provide continuity between walls and footings.

3.3.3 Walls, Frames and Shells

The seismic resistance of walls constructed out of stabilized adobe block and mud can be considerably improved by utilizing locally available reinforcing materials. Results of preliminary tests of several wall sections constructed by traditional methods but utilizing split cane for reinforcement and oil-stabilized adobe block show an increase of over 100% in resistance to static lateral force.*

Unstabilized soil-base materials are not suitable for seismic construction because of the high rate of deterioration and strength degradation resulting from exposure to rain and flood. This situation can be remedied by using oil-stabilized soil or adobe and seismic resistant construction. Besides providing critically needed tensile strength, the use of cane or wire-mesh reinforcement inhibits brittle shattering and rupture of walls and controls the propagation of cracking. The extension of reinforcement into neighboring walls and foundations provides an effective means of achieving continuity and improved seismic-resistant construction.

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*Improved Adobe Construction Program at the National University of Engineering in Lima, Peru.

An effective method of improving the strength of walls is to provide a ring beam around their upper periphery. The purpose of a ring beam is to tie the top of the walls together and to prevent tensile cracking from developing at the upper corners. In order to function in this capacity a ring beam should be continually reinforced with cane, bamboo, wire mesh or other materials of high tensile strength.

The structural resistance of walls is significantly impaired by the location and size of openings. To a certain extent, it is possible to improve the situation by using smaller openings and providing equalized space between openings or between an opening and the vertical edge of the wall. However, in order to reduce the high probability of brittle collapse initiated by the failure of piers flanking adjacent openings it is essential to give special attention to requirements for effective reinforcement around openings.

Tests on frames with infilled walls have indicated a considerable increase in strength of the frame-wall assembly as compared to the individual strengths of frame or wall.* The observation was made on reinforced concrete frames with brick masonry filler walls. Whether this increased capacity can be realized if the infilled frame were made of poured mud, adobe and cane or other reinforcement should be determined in a following project. One concept related to infilled frame

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*Design of Multistory Reinforced Concrete Buildings for Earthquake Motion, by Blume, Newmark and Corning.

construction which would be worthy of study, uses the energy absorption capacity of filler walls. The system is designed in such a way as to permit most of the energy released in a severe seismic disturbance to be dissipated through the process of cracking of filler walls leaving the main load-bearing frame relatively undamaged.

The feasibility of improving the seismic performance of a structure by utilizing curved wall construction cannot be ascertained at this time in view of a lack of documented knowledge of past earthquake history of such buildings.

3.3.4 Roofs and Upper Floors

One of the most effective ways to improve the seismic performance of a building is to reduce the weight of its roof. To a certain extent, this may be achieved without loss of strength by substituting lighter weight materials for roof covering in lieu of heavy materials such as mud or tile which have had widespread use in traditional low-cost dwellings in the past.

Reduction of weight can also be achieved by using shorter spans or by increasing the strength-to-weight ratio of the roof. The first choice requires the use of load-bearing interior partitions. This practice may be justified because of two reasons. First, the addition of load-bearing partitions will increase the lateral resistance of the system. Second, the reduction of weight is greater than the reduction of the

span, often by significant margins. The increase in the strength-to-weight ratio, if it is to be significant, indicates the use of lightweight panel systems which are highly efficient in bending. Some innovative schemes which appear to be promising both from the standpoint of economy and availability of materials have been discussed in Chapter 10.

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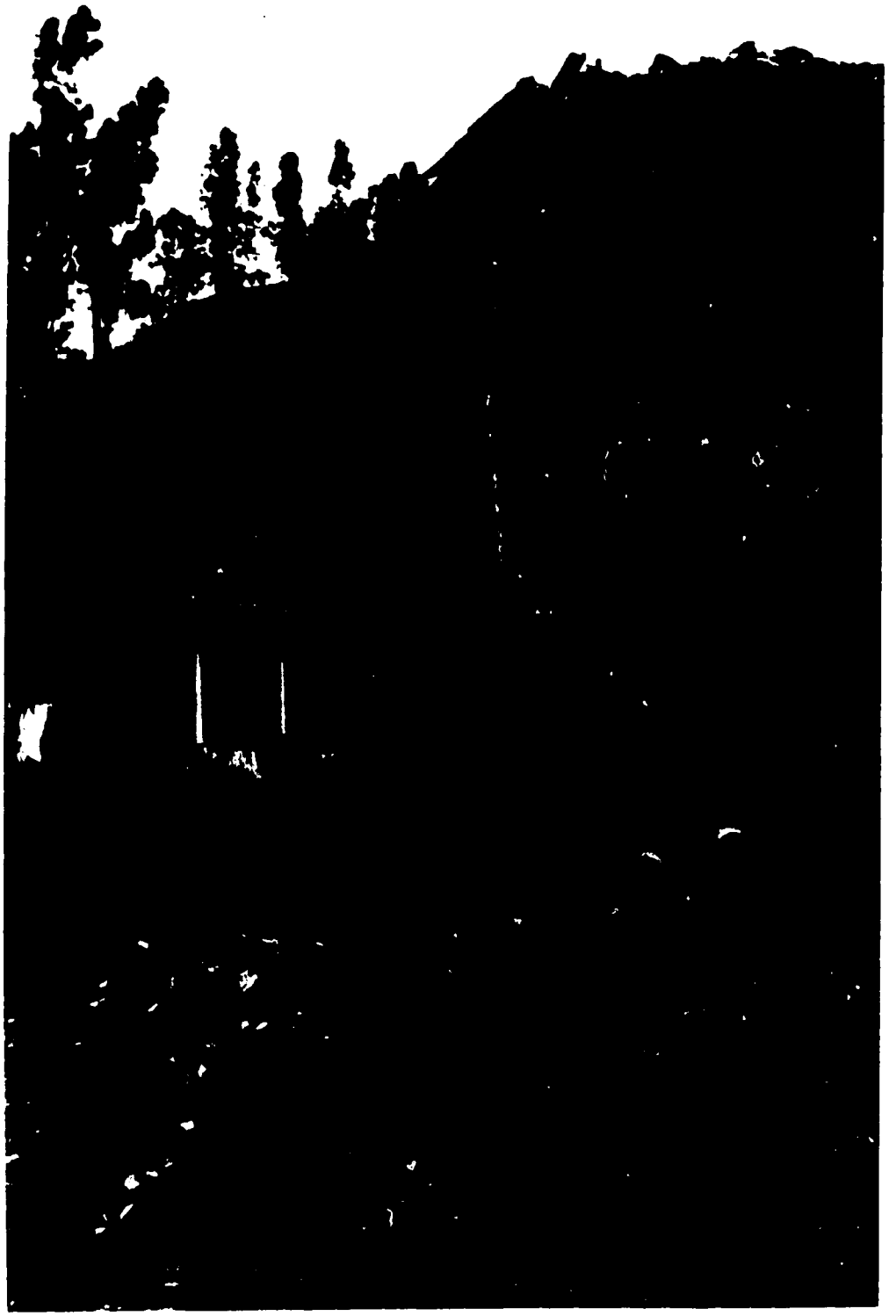
Masonry Buildings After San Fernando Earthquake
(United States, 1971)

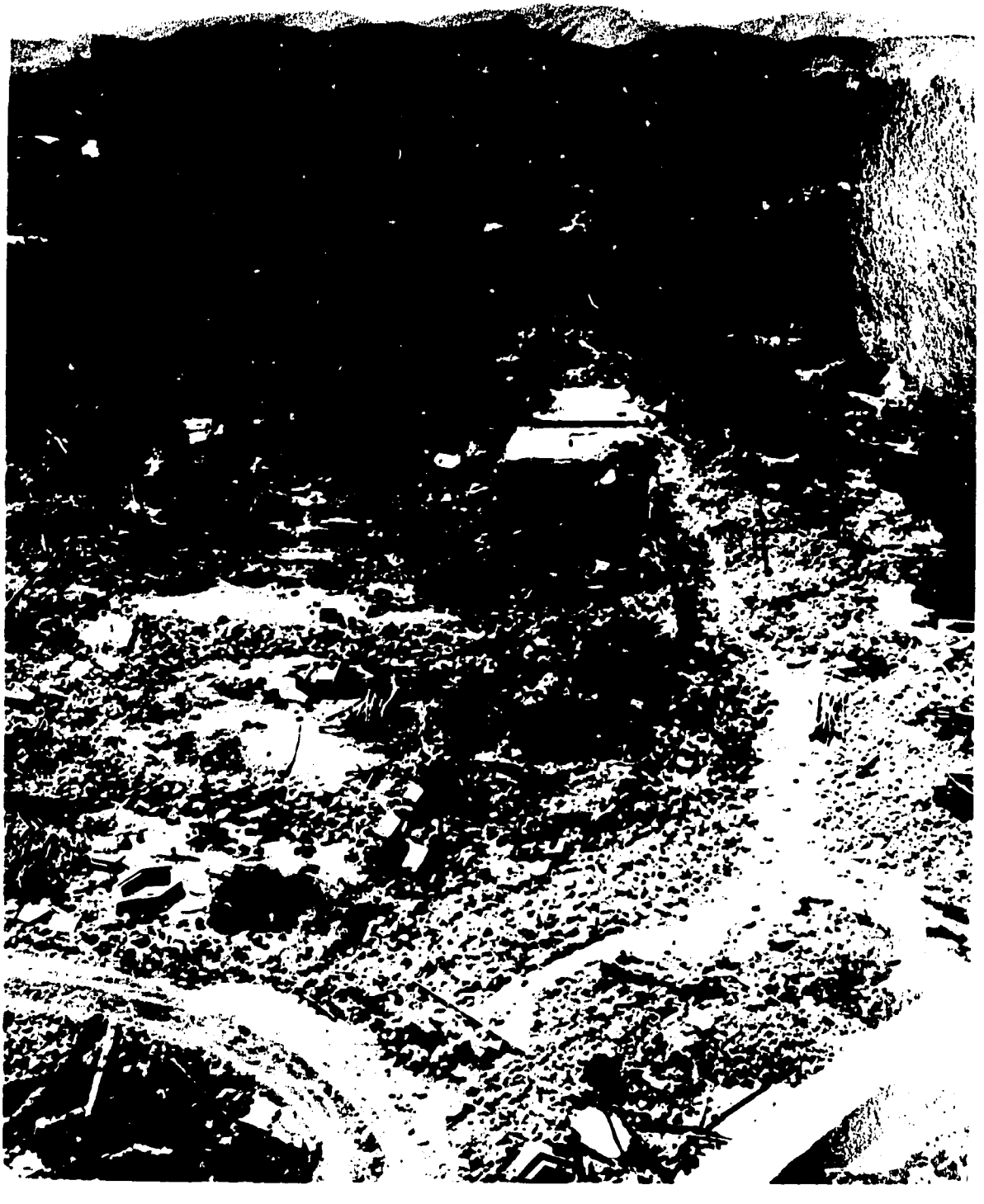
Reinforced Concrete Building After
San Fernando Earthquake
(United States, 1971)



Corner failure of 2-story adobe wall.

Damage sustained by residential units at Chimbote. Stuccoed adobe non-bearing exterior walls have failed in diagonal tension at corners of openings.

A damaged dwelling in Casma, a coastal city in Peru, June 1970.



The town of Ghir after the earthquake
(courtesy of U.S.G.S.)

The structural steel in this new brick building, a malaria control facility was confined to the roof and a bound reinforced concrete beam near the top of the wall. (courtesy of U.S.G.S.)

The partially standing traditional building on the right has walls of sun-dried brick with adobe mortar; the traditional building in the left foreground, which completely collapsed, had walls of rock rubble and adobe. Both types had heavy roofs of logs overlain first by straw or burlap and then adobe. Two-thrids of the people in Ghir perished in the debris of their own homes. (courtesy of U.S.G.S.)

This collapsed house had particularly heavy roof of palur logs, cane and straw, capped by several inches of adobe. The roof rusted on rock rubble and adobe walls of little resistance to lateral earthquake forces (courtesy of U.S.G.S.)

The use of steel to support heavy static loads of the second floor of this rock and adobe building, without increasing the ability of the heavy walls to resist lateral forces did little to protect this building from the strong seismic shaking.

The town of Ghir after the earthquake (courtesy of U.S.G.S.)

Chapter 4 Structural Performance of Buildings Under Wind Storm Conditions

by

Dr. Emil Simiu

National Bureau of Standards

4.1 Characteristics of Wind Storms

4.2 Effects of Wind Storms on Buildings

4.2.1 Influence of Building Shape on Magnitude of Wind Loading

4.2.2 Foundations

4.2.3 Walls, Frames and Shells

4.2.4 Roofs and Upper Floors

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4.3.1 Aerodynamic and Structural Considerations

4.3.2 Foundations

4.3.3 Walls, Frames and Shells

4.3.4 Roofs and Upper Floors

References

Chapter 4 Structural Performance of Buildings Under Wind Storm Conditions

4.1 Characteristics of Wind Storms

Wind storms of sufficient intensity to cause damage to buildings include tropical cyclones, extratropical cyclones, orographic winds and severe local storms.

Tropical cyclones, of which the most destructive are called hurricanes on the North American continent and typhoons in Asia, are most frequent during the summer and autumn of the hemisphere in which they occur. Upon moving to higher latitudes, they tend to assume the characteristics of extratropical storms, i.e., become less symmetrical and are accompanied by lighter rainfall. The damage caused by tropical cyclones is due to the direct action of winds which may reach surface velocities of 150 mph or more, to rainfall and to storm surges, i.e. violent piling up of water by the wind. The damage caused by storm surges is restricted to coastal areas and depends upon the distance from the shore and the elevation above mean tide level. The intensity of storm surge is measured in terms of the surge height which depends upon wind speed and direction, atmospheric pressure, coastline geometry and bottom topography offshore.

The approximate average number of tropical cyclones and hurricanes per year for various geographical areas is given in the following table ("Hurricane" ESSA/PI 670009, 1969) [1]:

	Tropical Cyclones	Hurricanes (Typhoons)
Eastern North Pacific Ocean	8	3
North Atlantic Ocean	8	5
Indian Ocean	15	
South Pacific Ocean	5	
Central & Western North Pacific Ocean	28	20

Extratropical cyclones occur in the middle latitudes and are usually more intense in winter and spring.

Orographic winds are winds intensified by the mechanical action of hills or mountains. Damage from such winds has been reported frequently on the eastern slope of the Rocky Mountains, and has occurred on a considerable scale in Sheffield, England [2].

Severe local storms include thunderstorms and tornadoes.

Thunderstorms are characterized by violent winds of relatively short duration (sometimes on the order of minutes). In certain areas of the world as much as 50% of maximum winds occur in thunderstorms [3].

Tornadoes (tatsumakis in Japan) are funnel-shaped winds attaining speeds estimated at 200 mph or more. The damage they cause is due to the direct action of their high wind speeds as well as to the very rapid drop in ambient pressure as the vortex of the tornado moves over an area. Buildings literally explode because of the intense pressure differentials

imposed on them.

4.2 Effects of Wind Storms on Buildings

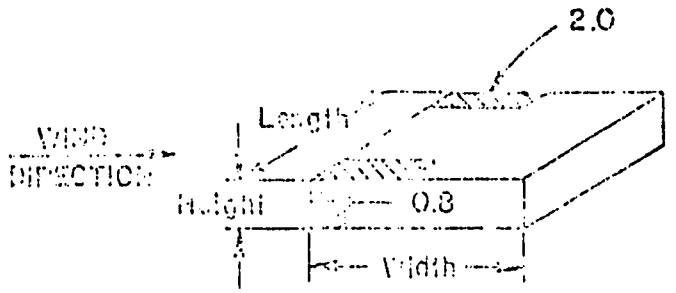
4.2.1 Influence of Building Shape on Magnitude of Wind Loading

The magnitude of the critical wind pressure is dependent, to a large extent, upon the geometric characteristics of a building. A few examples of this dependence are shown in Figure 4.1, in which coefficients proportional to the friction intensities for given wind speeds are shown for various height to width ratios and for various roof slopes. Pressures may also depend upon the relative position of buildings in a group. It follows that the wind resistance of buildings may be improved, sometimes considerably, by avoiding shapes or configurations which cause undesirable aerodynamic effects.

The aerodynamic behavior of a given building or its parts may be determined on the basis of available theoretical and experimental data or by performing a wind tunnel model study. It is noted that most theoretical and wind tunnel studies performed so far are applicable to high rise buildings only. Aerodynamic studies of low-risk buildings especially in tropical regions are therefore needed in the future. These studies should be carried out on both full scale buildings and wind tunnel models.

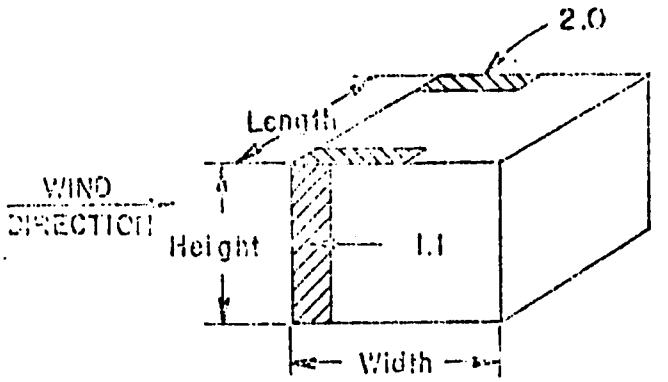
4.2.2 Foundations

The mechanical action of wind forces acting on a building may result in a sliding or in an overturning effect.



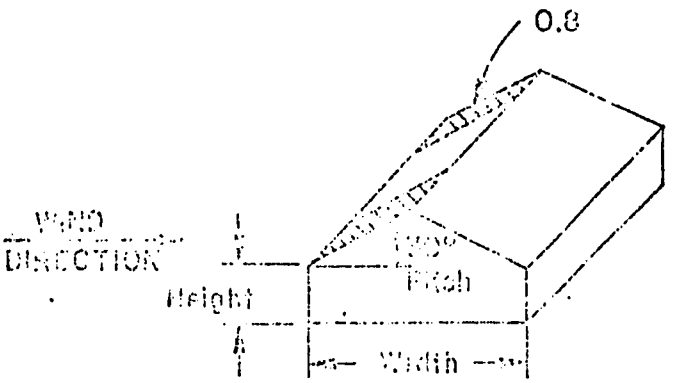
(A)

(Length = Height = 1/2 Width)



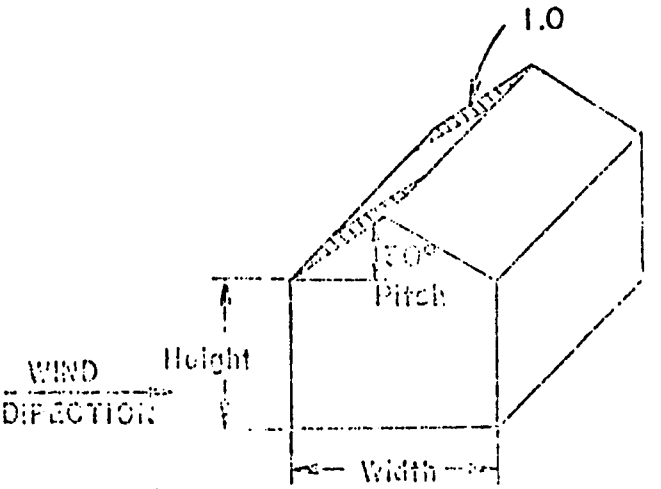
(B)

(Length = Height = Width)



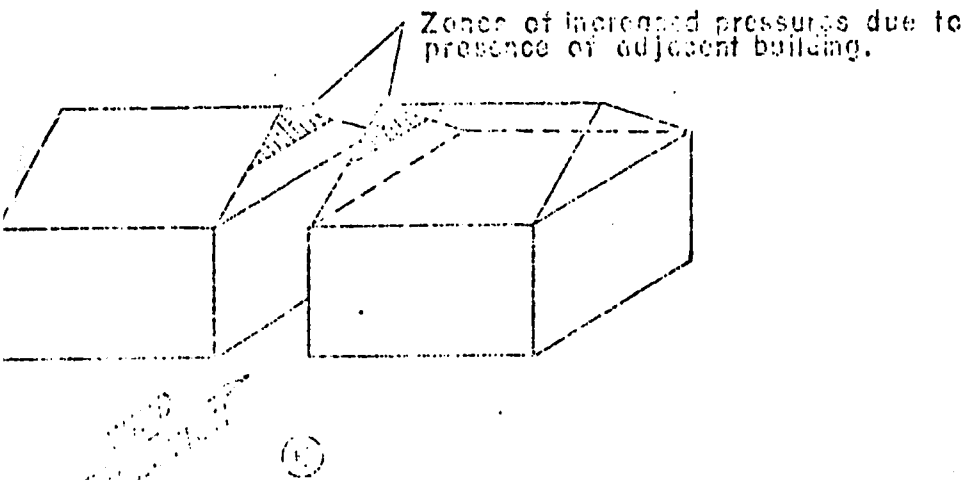
(C)

(Length = Height = 1/2 Width)



(D)

(Length = Height = Width)



(E)

Storm surges and intense rainfalls characteristic of hurricanes and typhoons may result in floods with damaging effects on the foundation soil or on the foundation itself. Among such effects are scouring, landslides, and loss of bearing capacity of the foundation material.

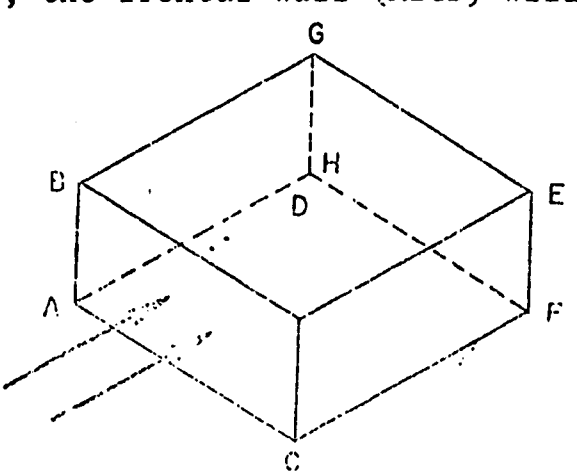
4.2.3 Walls, Frames and Shells

Wind-induced stresses in walls may be classified as either out-of-plane bending or in-plane stresses.

Out-of-plane bending stresses are produced by the direct action of wind pressures or suctions on a wall and become more critical as the wall thickness decreases. Damage caused by tornadoes is largely due to the high bending stresses produced by the explosive action of suctions which develop in the tornado path.

In-plane stresses develop in walls as a result of their action as shear resisting elements within the building structure considered as a whole (see Ch. 2).

For wind acting in the direction indicated by the arrows in Figure 4.2, the frontal wall (ABCD) will be subjected to



out-of-plane bending stresses. The lateral walls (CDEF and ABGH), which prevent the building from racking under the wind action, will be subjected to in-plane stresses.

In Figure 4.3, the effect of wind on wall ABCD is shown. The consequence of the absence of adequate shear walls is illustrated in Figure 3.3.

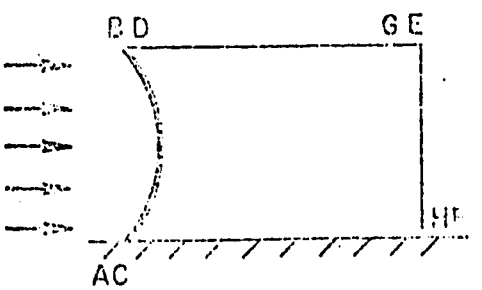


Figure 4.3

Openings in walls create stress concentrations which may be critical, particularly at the opening corners (see Fig. 3.3).

Glass breakage in external walls is known to occur frequently during severe storms.

Connections at the intersection of two walls, or between walls and foundations, floors or roofs may, if not carefully designed or built, be overstressed under the action of wind.

The function of lateral structural walls may be performed by frames, either prefabricated or built on the site. Frame joints are particularly vulnerable to effects of wind. The

attachment of cladding or sheathing to walls or frames also requires special care, especially in areas of high suctions near the corners of the building and near the eaves.

Shell-type elements are sometimes used as walls. Relatively rigid shells have been used in cylindrical-type construction and may present considerable advantages over box-like construction, both structurally and aerodynamically.

4.2.4 Roofs and Upper Floors

The magnitude of wind pressures or suctions on roof surfaces is a function of the roof shape, as was illustrated in Figure 4.1.

The effects of wind on roofs may be direct or indirect. Direct effects may be local or extend over the entire roof.

Direct local effects consist of high pressures or suctions over localized areas of the roof and may result in damage to roofing (shingles, tiles, sheets) or to parts of the roof structure. Overhangs are particularly susceptible to wind damage, as they are subjected to a positive pressure from below and suction from above (Figure 4.4.

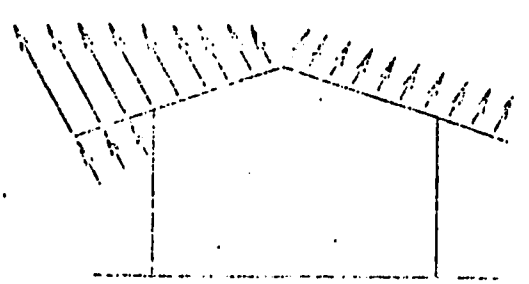


Figure 4.4

If the resultant of the positive pressures on the overhangs and of the suctions on the roof becomes sufficiently large, the capacity of the connections may be exceeded and the roof may be lifted.

Since the roof performs a structural function in the building, in that it acts as a horizontal diaphragm for the transmission of wind loads from the frontal to the lateral shear walls, serious damage to roofs may sometimes result in loss of support at the upper part, and consequent collapse, of frontal or of lateral walls.

4.3 Building Improvements to Mitigate Wind Storm Effects

4.3.1 Aerodynamic and Structural Considerations

Critical pressures resulting from the action of wind may be reduced considerably by proper aerodynamic design. Sharp edges, low roof pitches, large overhangs, and aerodynamically unfavorable shapes or grouping of buildings (see section 4.2.1) should be avoided whenever possible. Improvements in the aerodynamic behavior of buildings or of parts of buildings may be achieved in certain situations by providing rough surfaces or ribs at the exterior side of walls [4]. Grass roofs have been noted to have pressure relieving characteristics. Aerodynamically smooth transitions between planes may also be effective in decreasing pressures or suctions induced by wind.

The shape of the building is important not only for aerodynamic, but also for structural reasons. Therefore, the

selection of a shape which permits as direct a stress path as possible is recommended when the expected wind loads are high. Experience has shown, for example, that cylindrically shaped buildings are particularly well suited for resisting direct tornado action.

4.3.2 Foundations

The structural integrity of a building subjected to wind forces depends largely upon the resistance capacity of the connections and anchorages to the foundations. Such capacity should not be lower than that of any of the building structural elements. Undesirable stress concentrations or stresses should be avoided. For example, anchorage lengths should not be less than determined by tests performed on the materials used.

The damaging effects of storm surges or floods on the foundation itself may be avoided by providing adequate foundation materials whose properties do not deteriorate under the prolonged action of water, and by adding to the materials used if the foundation is constructed of soil, mortar and stone a stabilizing ingredient which will improve their resistance to such action. Inadequate soils should not be utilized or should be improved. In certain cases, the use of inexpensive protective banks or pole-type foundations [5] may be warranted by the severity of storm surges.

4.3.3 Walls, Frames and Shells

Adequate connections must be provided between walls and between walls and foundations, floors and roofs. Horizontal or vertical reinforcement may be required for the strengthening of certain types of walls including adobe walls. Such reinforcement may be provided by inexpensive, locally available materials (for example, split cane, bamboo). Where vertical reinforcement is used, adequate grouting should be provided using methods and mortars appropriate to the type of material available for wall construction. Buttressing of walls, bond beams for lateral support and vertical or horizontal bracing may be required for the purpose of improving the structural capacity of walls, including walls built with such materials as adobe and/or bamboo. Details at corners and openings should result in decreased stress concentrations through elimination of sharp transitions between planes and adequate reinforcement should be provided at critical sections. Wind resistant types of sheathing and appropriate fasteners should be used.

4.3.4 Roofs and Upper Floors

The critical areas of roofs of various types should be identified and connections consistent with the magnitude of the expected loads should be designed. Roofs known to be vulnerable and which for various reasons cannot otherwise be improved should be anchored against a predicted storm, for example, by using wind-storm anchorage kits [6] consisting of

coconut fiber nets in 2 ft. squares thrown over the building and anchored to the ground, or using anchorage ropes or cables. Large overhangs and parapets should be designed so that localized damage in case of overstress is kept from extending to the entire roof. This could be accomplished, for example, by the provision of specially designed pinned connections. It is also possible to design overhangs which allow easy removal and storage of the overhanging roofing sheets. The removal would follow a storm warning and reduce considerably the vulnerability of the roof if the storm actually occurs [6].

Appropriate sizes of washers and thicknesses of roofing should be used in metal sheet roofs to avoid tearing of the roof sheeting.

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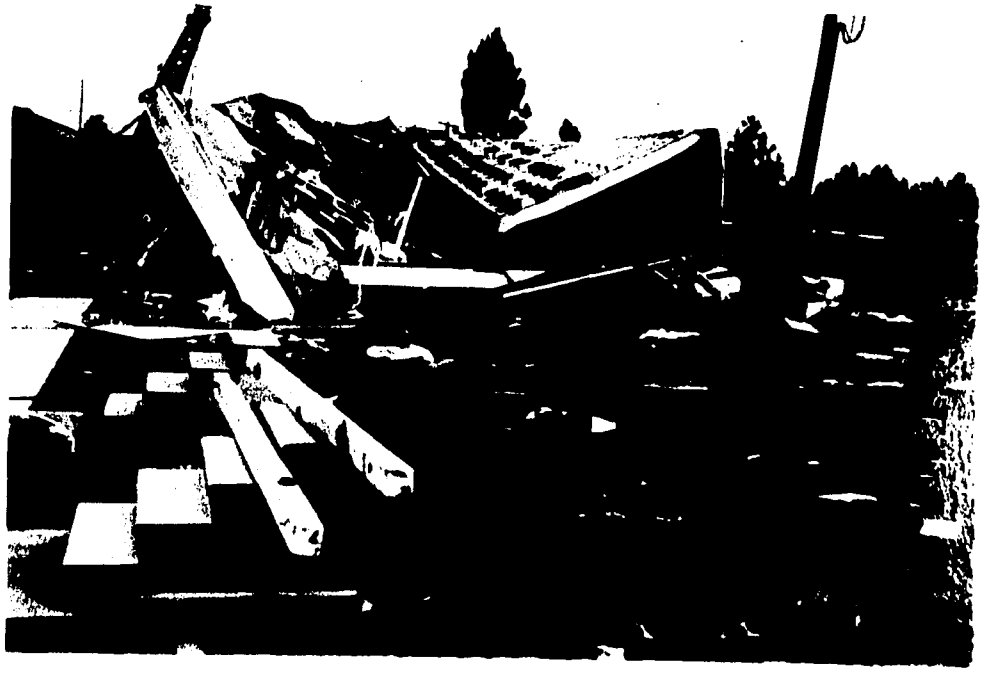
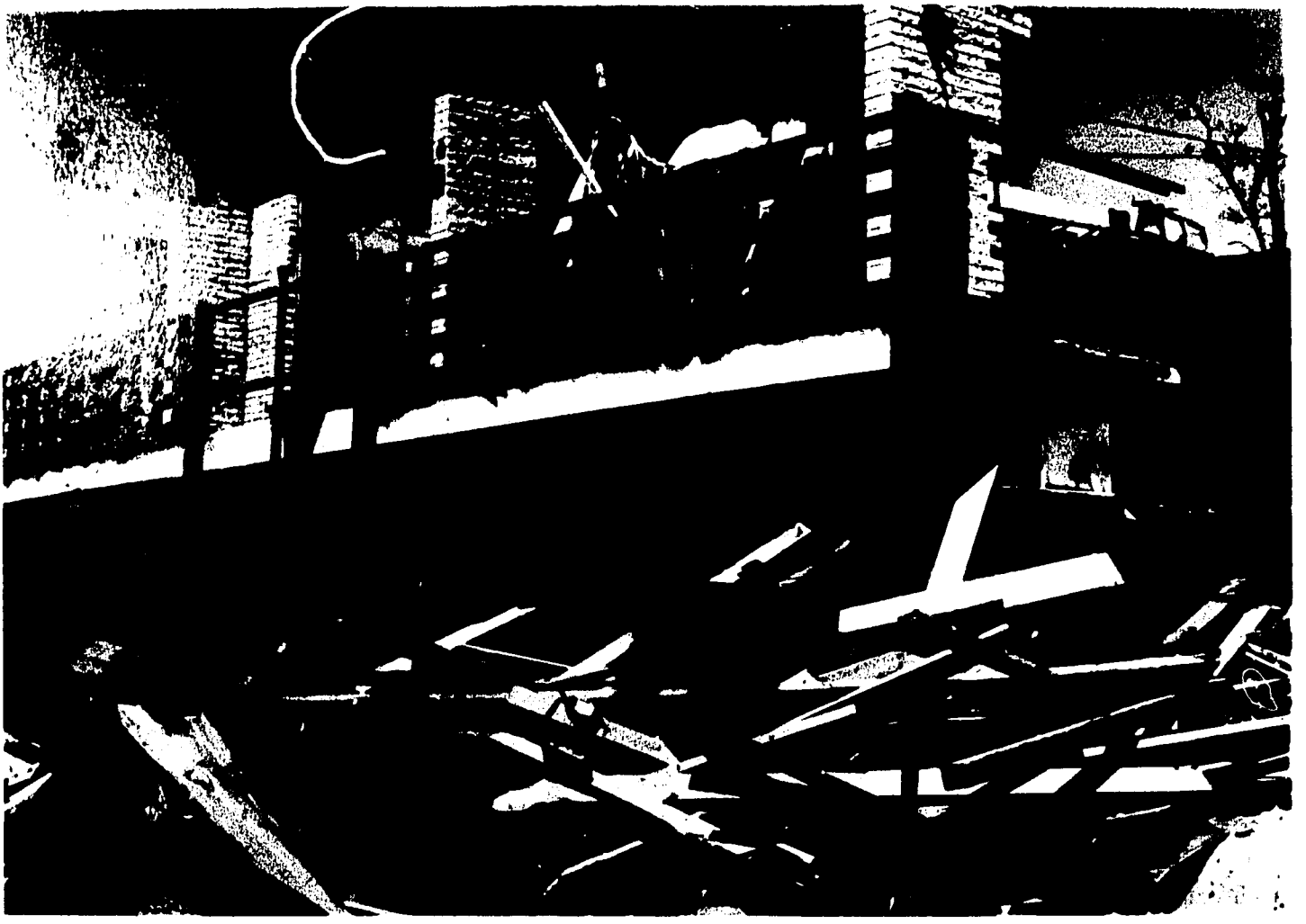
Building Destroyed by Hurricane Camille (United States, 1969)



Buildings Destroyed by Hurricane Camille
(United States, 1969)



Building Destroyed by Hurricane Camille
(United States, 1969)

Buildings Damaged by Hurricane Camille
(United States, 1969)

Chapter 5. Siting Considerations to Reduce the Effects of Earthquakes and Wind Storms

5.1 Introduction

5.2 Identification of Potential Earthquake Hazards

Seismic Risk and Tsunami Hazard Maps. Earthquake Prediction

Tsunami. Public Communication

5.3 Wind Storms

5.4 Siting Considerations for Low-Cost Housing in Turkey

5.4.1 Geologic and Seismic Setting

5.4.2 Seismic and Related Hazards to Low-Cost Housing in Turkey

5.4.3 Foundation Failures

5.4.3.1 Landslides

5.4.3.2 Unconsolidated Deposits

5.4.4 Floods

5.4.5 Recommended Site Investigations for Earthquake-Resistant Low-Cost Housing in Turkey

5.4.6 Methods of Guiding and Controlling Site Selection and Preparation

5.4.7 Proposed Site Investigations

5.4.7.1 Planning-Stage Investigations

5.4.7.2 Site-Intensive Investigations

5.4.7.3 Scope of Investigations

5.4.7.4 Single-Family Rural and Traditional Town Houses

5.4.7.5 Multifamily Houses

5.4.7.6 Improvement of Existing Houses

5.4.8 Technical Supervision

5.5 Case Study: Engineering Geology and Siting Problems Related to the Peru Earthquake of 1970

5.5.1 Introduction

5.5.2 Geologic Environment

5.5.3 Regional Siting Problems

5.5.4 Behavior of Unconsolidated Solids in Flat-Lying Areas

5.5.5 Landslides, Rockfalls and Soil-slips

5.5.6 Debris Avalanches

5.5.7 Conclusions

5.5.8 Recommendations

References

Chapter 5. Siting Considerations to Reduce the Effects of Earthquakes and Wind Storms

5.1 Introduction

This chapter consists chiefly of two studies prepared by the U.S. Geological Survey within the context of the overall objectives of the report. A brief discussion of regional geology, seismic geography and potential hazards attributable to siting of buildings and structures precedes section 5.5, which is a discussion of seismic and related hazards to low-cost housing in Turkey, prepared by Arthur Grantz. Section 5.6, a case study of engineering geology and siting problems related to the Peru Earthquake of May 31, 1970, was prepared by George Ericksen, George Plafker and Juan La Cruz.

Studies of seismological data collected during the past 70 years have shown that earthquakes generally fall within two principal seismic belts: the Circum-Pacific belt, extending from New Zealand to Chile, and the Mediterranean-Alpine belt, extending from Morocco, through the Mediterranean and Middle East into Central and South-East Asia. Other belts of activity are associated with large rift systems, such as the Mid-Atlantic ridge and the East African Rift Valley. An earthquake as a geophysical event is measured in magnitude of energy release, and in duration and intensity of ground shaking. An earthquake as a human event is measured in loss of life and property. The scale of the human event is not always proportional to that of

the seismic event, for casualties and property damage depend on population density, type of structures, stability of geologic foundations, and time of occurrence, as well as on the magnitude duration and distance of the earthquake.

Destructive wind storms include principally tropical storms-hurricanes in the Caribbean Region and typhoons in the western Pacific--and cyclones, which occur most frequently in rather well-defined belts in the temperate climatic zone. On the whole, wind storms cause far greater destruction and loss of life than do earthquakes. Damage may be directly due to gale-force winds, to wave action or wind-generated tides at the sea coast, or to floods caused by heavy rainfall on land.

Considerations of siting to lessen the hazard of destruction are far different for earthquakes than for wind storms. In the case of earthquakes, the total geologic environment must be taken into account--the danger from failure of geologic foundations and from landslides are of paramount importance. On the other hand, damage during wind storms is generally restricted to that caused directly by force of wind or indirectly by flooding. As a consequence, site evaluations for earthquakes are complex, time consuming, and costly, whereas those for wind storms are relatively simple, and deal largely with the climatological characteristics and the topographic configuration of the site and surrounding region.

5.2 Identification of Potential Earthquake Hazards

Seismic Risk Maps and Other Earthquake Hazard Maps

Estimates of seismic risk may be presented in the form of seismic risk maps, which show the maximum intensity of earthquakes likely to occur within the area covered by the map. Such maps are based mainly on a statistical analysis of the number and intensity of earthquakes actually recorded in the area since observations began. Map reliability is a function of the length of the period of observation and of the volume and quality of data collected and is therefore greatest for areas of high seismicity for which much data exists.

Unfortunately, instrumental records, which have been available only for about 70 years, are still an inadequate base for a statistical analysis of earthquake frequency. However, instrumental data can, in many areas, be supplemented by information obtained from historical records. Knowledge of the geology and tectonics furnishes additional information for preparation of seismic risk maps of some areas, as has been done with some success in Turkey and Iran.

A good seismic risk map will contain reliable information on the relative level of risk from damaging earthquakes in an area, i.e. on the probability of occurrence of earthquakes of a given intensity, but it will not tell when such earthquakes will occur. The problem of predicting the time and location of earthquakes, which is of considerable importance, has only recently become the subject of intensive study, chiefly in

Japan and the United States. There is a critical need for extending such studies to other regions. Success in this research would be a major scientific achievement. It must be noted, however, that although the prediction of an earthquake has the potential for saving the lives of people living and working in buildings liable to destruction by earthquakes, it will do nothing to prevent damage to or the destruction of the structures themselves.

At any specific site, earthquake hazard is governed by seismic probability, foundation conditions, topography, local and regional geology, proximity to surface-water bodies (lakes, bays and streams), occupancy, and structural design. All these variables can be shown on maps from which interpretations of level of risk at each point on the ground surface may be made. Such maps may be of great aid in determining appropriate land use. They also may be used to identify specific or potential hazards and thus serve as a guide to engineering design as well as site planning. These types of maps, however, are still in the development stage and it may be many years before standards are established, and still longer before such maps become generally available.

When an earthquake occurs at sea, a segment of the ocean floor may be elevated or depressed owing to faulting or warping of the sea floor, and may cause a complex high-velocity sea wave, or tsunami. Upon approaching land such a wave loses velocity but gains amplitude, and depending upon the local

bathymetry, may produce a high wave that may devastate low-lying coastal regions in its path. To evaluate potential disaster from such waves, special tsunami hazard maps should be prepared for coastal areas, such as those of the Pacific Basin, which are subject to seismic sea waves.

For better decisions at the community level in seismic areas the public needs to be better informed as to the nature of the earthquake as well as the potential local hazards and means of dealing with them. Such information might be introduced into school curricula in earthquake-prone regions. It would be the shared responsibility of officials dealing with environmental hazard and of the professional community of earthquake engineers and scientists to keep community decision makers informed of new knowledge bearing on earthquake hazard and of assessing it and taking the necessary steps to minimize destruction and loss of life during an earthquake.

Although the intrinsic value of geologic site plans and their use in community development are widely recognized, such plans have not been widely used, even in Japan or the United States. Preparation and utilization of meaningful site plans could greatly reduce future earthquake destruction of new communities. Of particular importance are detailed site evaluations, by qualified earth scientists, as a preliminary phase in construction of large buildings such as schools, hospitals, high-rise apartments and offices, and other important public buildings or other works.

A good site plan will consider both short and long-range expansion needs and take account of potential hazards, such as low-lying ground liable to flooding, landslides, tsunamis, and active faults, and water-saturated ground subject to compaction and lateral spreading. As a part of site planning it is desirable to determine soil behavior in response to seismic shaking, especially under load and various degrees of saturation. Laboratory study of behavior of both dry and wet soils under vibrational loading are essential to site planning and for predicting the potential for different soil types for compaction or liquefaction during an earthquake. The behavior of soils under conditions of load and vibration also may be determined by measuring microseismal characteristics and by in-situ soil study.

A microzoning map prepared from these data may greatly aid site-planning. Microzoning maps should give the natural period of the foundation material and portray potential hazards in a manner that is readily understandable to engineers and others who are responsible for construction. A report on "Seismic Microzoning of Chimbote Area in Peru" prepared by the Overseas Technical Cooperation Agency, Government of Japan, March 1971, provides an excellent example of site evaluation. The report provides information about the geologic foundation conditions that allows for planning re-construction of Chimbote as an "anti-seismic" city.

The positioning of a building at a given site may greatly influence its behavior during earthquakes. Earthquake damage to a building resting on two types of geologic foundation material, for example, the interface of deep soil and bedrock, may be much greater than that to adjoining buildings resting entirely on either one or the other of these materials. Structures built on flat areas of deep soils are less subject to damage by foundation failure than similar structures built on slopes subject to incipient sliding or actual landslides.

5.3 Wind Storms

Good site location or orientation, in terms of local topography and natural cover, can be determined to some degree by observing historical wind data, which give the frequency, velocity, and direction of wind. This information can be utilized to locate building sites and position dwelling units to minimize the hazard from wind. Damage due to wind storms may be minimized by proper siting of buildings and by protecting them by hills, embankments, or stands of trees.

Wind intensity maps are required for the rational siting and design of buildings and structures. Such maps, based on wind speed records collected over at least 10-15 years and supplemented by other sources of information, allow for the evaluation of the probability of occurrence of extreme winds of given intensity in a given period of time.

5.4 Siting Considerations for Low-Cost Housing in Turkey[1]

(By Arthur Grantz, U. S. Geological Survey)

5.4.1 Geologic and Seismic Setting

The geologic, seismic, and hydrologic hazards that pose a threat to low-cost housing in Turkey have their roots in the unusual degree of past and present mobility of the earth's crust in the Mediterranean region, and particularly in Turkey. This mobility has persisted, with pauses, for perhaps the last 200 million years of earth history. Although geologic hazards in Turkey are serious and widespread, they can to a considerable degree be antici pated and either avoided or provided for in site preparatio This chapter first reviews the origin and nature of these hazards, and then proposes procedures and programs for coping with them at sites of low-cost housing in Turkey. The work in Turkey, on which this report is based, was undertaken by the author during parts of February and March 1972.

Turkey lies astride the Alpine earthquake belt, one of Earth's two major zones of strong and frequent earthquakes.

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[1]Publication authorized by the Director, U.S. Geological Survey.

This belt is thought to owe its seismicity to continued differential motion between the Eurasian and Afro-Arabian crustal plates, whose collision in early Tertiary time (about 50 to 60 million years ago) produced much of the intense structural deformation that characterizes the present-day geology of Turkey. Recent advances in observational seismology have demonstrated that most earthquakes, worldwide, occur in narrow zones at the boundaries between just such large crustal plates. The stronger shocks are generated where the plates are in direct or oblique collision, or slide past one another under positive normal stress or compression. The weaker shocks are generated where the plates are pulling apart or slide past one another under negative normal stress, or tension. It is Turkey's misfortune that it straddles the suture zone along which the Eurasian and Afro-Arabian plates are in collision. In addition, there are strong earthquake-generating movements between large subsidiary plates along the juncture of the main plates.

Turkey lies almost wholly within a belt of strongly deformed sedimentary rocks that were deposited in a complex seaway that separated Eurasia and Afro-Arabia in pre-early Tertiary time. Intense compression of the rocks laid down in this seaway was caused by the progressive drift of Eurasia and Afro-Arabia toward each other during the last 200 million years of earth history. This compression produced a generally east-trending belt of strongly folded, faulted, and locally

intensely sheared and broken rocks, to which the name Alpine orogenic belt has been applied. In many places, large volumes of submarine volcanic and intrusive igneous rocks were added to (and churned into) the sedimentary rocks of the Alpine belt. When the collision of Eurasia and Afro-Arabia closed the intervening seaway about 50 to 60 million years ago, what is now Turkey became a complex of mountains, seaways, and lowlands. The seaways and lowlands received locally thick accumulations of marine, lagoonal, and terrestrial sediments, part of which are still poorly consolidated, and volcanic rocks. Continued uplift and locally intense Alpine structural deformation during subsequent Tertiary time contributed further to the folding, dismemberment, and crushing of the pre-Tertiary rocks, and locally produced complex structures in the Tertiary rocks themselves.

The uplift, folding, and shearing have continued into modern times, producing the mountainous terrain that dominates much of the Turkish landscape. Other manifestations of this young crustal mobility are repeated fault displacements, with associated earthquakes and tsunamis, and volcanic activity.

5.4.2 Seismic and Related Hazards to Low-Cost Housing in Turkey

Building sites in the seismic zones of Turkey are subject to four types of seismic and related hazards. Estimates of the relative level of risk for damage to housing posed by each

Table 1.--Relative hazard to housing in four seismic zones of Turkey.

Seismic hazard to low-cost housing in Turkey	Seismic zones				
	Aegean-Marmara	North Anatolian	Central Anatolian	Southeastern Anatolia	Other areas
Direct effects of seismic shaking	2 and 3 [1/]	2 and 3	Mostly 0 and 1, locally 2	2 and 3	Mostly 0 and 1, locally 2
Foundation failures (failures in underlying or upslope soil and rock produced by seismic shaking in areas with slopes exceeding 15°)	B and C [2/]	B and C	Mostly 0 and A, locally B	B and C	Mostly 0 and A, locally B
Fault displacements	High risk near faults of Holocene activity, significant risk near faults of pre-Holocene-Quaternary activity	High risk along North Anatolian fault	High risk near faults of Holocene activity, significant risk near faults of pre-Holocene Quaternary activity	High risk near faults of the Dead Sea fault zone	Mostly negligible risk
Tsunamis (applies only to most susceptible sites in each zone)	2 or 3 along Marmara, Aegean and Mediterranean coasts	0	0 inland, 1 or 2 along coast	0 inland, 1 or 2 along coast	0 inland, 1 along coast

1/ Risk categories for direct effects of seismic shaking and tsunamis:

0 - Negligible risk of damage

1 - Significant risk of minor damage; small risk of moderate or major damage

2 - Significant risk of moderate damage; small risk of major damage

3 - Significant risk of major damage

2/ Risk categories for foundation failures during earthquakes:

0 - Negligible risk

A - Small risk

B - Moderate risk

C - High risk

hazard in the four seismic zones shown in Figure 7 are given in table 1. The seismic risk categories used in the table are analogous to those adoped by Algermissen (1969) for the Seismic Risk Map of the United States. They are based, however, on judgments derived from a comparison of recent faulting and seismicity of Turkey and the United States, rather than on a detailed analysis of Turkish seismicity. These relative ratings are presented only as a guide to the application of the lateral force requirements of the 1970, Uniform Building Code (U.B.C.) of the International Conference of Building Officials, to the design of low-cost housing in Turkey, and not as a substitute for a carefully considered seismic risk map of that country. The U.B.C. uses the Seismic Risk Map of the United States as the basis for its lateral force requirements.

In table 1, the same risk categories also are applied to tsunamis. The risk categories for tsunamis cannot, of course, be applied to building design in terms of lateral force requirements. For foundation failures, the categories refer to the risk of numerous or widespread failures, and are analogous to the risks from seismic shaking. Other potential siting hazards, such as volcanism, shallow ground water, and swelling soils are not considered here.

Future multistory-multifamily low-cost housing plans, if designed for Turkey, should strive for lateral force requirements at least as stringent as those specified by the U.B.C.

Such requirements must be supported by a modern seismic risk map of Turkey. Such a map does not now exist, although one is in preparation by the Earthquake Research Institute of the Ministry of Reconstruction and Resettlement. To be realistic, this map will have to be based upon geologic and tectonic criteria of recent seismic events, on the long historic record of Turkish earthquakes, and on modern seismographic records and field investigations of earthquakes.

It may not be economically and culturally feasible to design single-family, low-cost rural and traditional town and village housing for Turkey that will meet the lateral force requirements of the U.B.C. The greatest challenge (and the greatest potential for a major contribution) that the project faces is its ability to approach, and perhaps meet, U.B.C. requirements for such housing.

With respect to siting of low-cost housing near active faults, it is recommended that: (1) New low-cost housing in Turkey be sited at least 50 and preferably 100 meters from main faults, fault strands, and branches that can be observed or inferred to have displaced geologic formations or deposits of Holocene age (the last 10,000 years). (2) All high-population-density (multistory-multifamily) low-cost housing be sited at least 100 meters, and preferably 150 meters from faults, fault strands, and branches that can be observed or inferred to have displaced geologic formations or desposits of Holocene age, and at least 50 meters from faults that can

be observed or inferred to have displaced deposits of pre-Holocene Quaternary age (the last 2 or 2 1/2 million years). (3) All critical structures (those with many people per unit area, such as schools, auditoriums, and hospitals, and those that provide essential services, such as power plants or water treatment plants) should, in addition to the requirements in category 2, be sited at least 50 meters from any fault that cannot be proven to have been inactive (i.e., has not undergone displacement) since the beginning of Quaternary time. The difference between categories 2 and 3 lies in the character of the evidence required for judgment. In category 3, definite evidence of lack of Quaternary activity is required; in category 2, lack of evidence for Quaternary activity is accepted in lieu of definite evidence of lack of such activity. The distinction is necessary because bedrock in Turkey is broken by so many faults that application of category 3 to all multistory buildings would be unrealistically restrictive.

The width of the setback zones along faults of Holocene or Quaternary displacement is adequate for most, although not all, faults or fault zones. It is rather conservative, however, for faults that show repeated surface rupture in the same location during past displacement episodes. Therefore, the setbacks could properly be considerably reduced where detailed site studies, which should include the excavation of trenches across the fault zone, showed that smaller setbacks would be safe. In no case, however, should the setbacks be less than 20 meters.

Detailed investigations will undoubtedly also show that in some places setbacks should be even larger than those specified above.

The relative hazard from tsunamis given in the tabulation applies only to the most susceptible parts of the coastal areas categorized. Tsunami hazard is not uniform along susceptible coasts because the severity of impinging tsunami wave trains varies markedly with the local configuration of the shoreline and near-shore bathymetry. Bold headlands and coasts having deep water near shore are generally slightly affected by tsunamis, which generally build up large and destructive wave trains only in narrowing or shoaling inlets. Thus, some sites on low ground at the head of narrow, shoaling inlets in the Aegean-Marmara zone may be exposed to a significant risk from tsunamis.

During some earthquakes around the world, large rockfalls or landslides falling into deep water have created surge waves that have devastated adjacent shorelines to recorded heights of at least 565 m. Subaqueous slides in deep water have also set in motion local surges that have destroyed entire communities on adjacent shores. In Turkey, such surge waves may present a significant risk in a few areas where bold topography underlain by poorly consolidated or intensely sheared rocks abut deep tidal inlets, reservoirs, or lakes.

5.4.3 Failure of Geologic Foundations

Landslides (slumps, mudflows and rockfalls), landspreading, and differential compaction of weakly or irregularly consolidated alluvium and other surficial deposits locally pose serious siting problems for structures of all sizes in Turkey, even in the absence of earthquakes. Such failures are especially common, however, under the dynamic stresses induced by strong earthquakes. The physiography and climate of Turkey and the character of many of its geologic formations make large areas of the country susceptible to landslides, and it is not surprising that field reports of the effects of strong earthquakes in Turkey commonly mention landslides, soil slumps, and lurching (cracking of soft ground induced by lateral movement) as important, and often damaging secondary geologic effects. The hazard from landslides, mudflows, and rockfalls is not, of course, limited to site disruption, but includes both slow and extremely rapid modes of site inundation.

5.4.3.1 Landslides

The distribution and relative abundance of landslides is controlled most strongly by slope, precipitation, character of underlying soils and rocks, and cuts and fills and other perturbations created by the activities of man. Studies in California and elsewhere (summarized by Radbruch, 1970) show that most landslides form on slopes of 15° to 35°; a lesser, but still appreciable percentage form on slopes of 5° to 15°

and greater than 35°. Very few form on slopes less than 5°, and these are commonly caused by liquefaction or landspreading during earthquakes. In California, landslides are also rare in areas receiving less than 250 mm of mean annual precipitation. The absolute amount of precipitation above 250 mm per year does not, however, seem to be as important as the character of the underlying soil and rock in determining the abundance of landslides in specific areas. The character of the underlying soil and rock is the dominant control on the distribution and abundance of landslides in areas having slopes greater than 5° and more than 250 mm of mean annual precipitation. Soft, water-saturated poorly consolidated formations, or intensely sheared or fractured rocks, and rocks containing minerals that swell or decay readily in the presence of ground water, are especially susceptible to sliding and slumping. The activities of man in undermining slopes by cuts and excavations, or in overloading slopes by excessive or inappropriately placed fills, commonly induce sliding and slumping in otherwise stable slopes. The addition of water to certain slopes by irrigation, and by seepage from pipes, septic systems, springs, or other sources is a common cause of sliding because the water increases the weight of the ground while simultaneously decreasing its resistance to shearing stresses.

Landsliding is a significant problem in Turkey because large areas of the country have slopes that exceed 5°, and slopes of 15° to 35° are common; mean annual precipitation in

almost all Turkey exceeds 250 mm per year; many of the rocks that underlie Turkey are poorly consolidated or intensely sheared; and swelling clays are probably widespread and abundant in the rocks and soils. The extensive tracts of steep topography that are underlain by 1) soft sedimentary rocks of Tertiary, and especially of late Tertiary age, 2) crushed and sheared rocks that are found along many of the numerous fault zones in Turkey, and 3) ophiolite melanges, (chaotic mixtures of diverse rock types that are characterized by widespread intensely sheared rocks and by serpentine), are all especially susceptible to sliding. The gross distribution of two of these broad categories of especially landslide prone rocks (the Tertiary rocks and ophiolite melanges), and the stability of potential building sites on such rocks, particularly where slopes exceed 15°, should be examined with special care.

Turkey owes many of its extensive areas of landslide-prone rocks to its long history of tectonic mobility and instability. The relatively small proportion of lowlands in large areas of Turkey will inevitably lead to more construction of houses, roads, and a variety of other engineered works on hills and mountainsides where the risk of damage due to landsliding is significantly greater, particularly during strong earthquakes.

5.4.3.2 Unconsolidated Deposits

The distribution and intensity of shaking damage from a given earthquake has been observed by many workers to be strongly influenced by the local character and thickness of the underlying soils and unconsolidated deposits, and by the position of the water table. The relationship between these properties of the substrata at a site, and the nature and intensity of damage is complex, however, and one that is strongly influenced by the amplitude, frequency content, and duration of the seismic wave train at the site. Thus, dominantly short period shaking from nearby shocks may produce very different amplitudes and periods of shaking, and adversely affect very different kinds of structures than the long period shaking that dominates the wave trains from more distant earthquakes. The study of the relation of the local distribution of earthquake damage to local soil and rock conditions is called earthquake "microzoning." As discussed in a following section, such studies should be made before extensive, low-cost housing developments are sited.

Patterns of damage from strong earthquakes, particularly to multi-story buildings sited on unconsolidated deposits, are closely related to lateral variations in the thickness, composition, and water-saturation of the underlying soils. Variations in these factors can, for example, cause the horizontal velocity of ground motion from a moderate earthquake to vary by a factor of 2 to 10 with respect to nearby sites on

bedrock (Borchardt, 1970), and the response to given types of structures to vary by factors ranging from 3 to 6 (Seed and Idriss, 1969). Liquefaction, differential settlement and landspreading of unconsolidated deposits, and block glides and slumps on gentle to steep slopes are also common geologic foundation failures that have created extensive damage during moderate and large earthquakes.

Methods to predict the dominant period and relative amplitude of earthquake-induced shaking at a particular building site are currently under study by many workers, and steady progress is being made toward widely applicable analytical procedures (for example, see Seed and Idriss, 1969; Seed and others, 1970). Such predictions, however, require fairly detailed knowledge of the thickness and physical properties of the soils and poorly consolidated rocks of the site, and a realistic assessment of the seismicity of the area (Seed and others, 1968). Some of the analytical procedures are moderately sophisticated, but estimates can be made from relatively simple formulas. Modern practice requires that, in areas of significant seismic risk, large buildings should be designed to have a different fundamental frequency of vibration from that of the poorly consolidated foundation material.

Unconsolidated deposits containing liquefiable (noncohesive) materials and having abrupt lateral variations in density and compactibility, and which therefore are susceptible to flowage, differential compaction, lurching, and landspreading

during earthquakes, can be recognized by sufficiently detailed surface and subsurface site exploration. Areas in Turkey that are especially susceptible to failure of geologic foundations, particularly where the water table is shallow, are those underlain by fine-grained, noncohesive or very soft cohesive sediments of alluvial, pluvial, or estuarine origin. Many of these areas have been the sites of failures and damage in past earthquakes in Turkey, and will be subject to failure in the future.

5.4.4 Floods

The high mountains and narrow alluvial valleys that characterize much of Turkey have created a significant hazard from local, but sometimes destructive floods. Unusually heavy snow accumulations on high mountains may in some years melt at rates that exceed the capacity of the river channels, resulting in overflow and flood damage to settlements. The magnitude of the problem is difficult to gauge from the literature available to the writer, but the Menderes and Seyhan River systems, for example, which drain high mountains in southern Turkey have periodically been the scene of destructive floods. Accordingly, dikes and other flood-control structures have been built on at least some rivers in Turkey.

5.4.5 Recommended Site Investigations for Earthquake-Resistant Low-Cost Housing in Turkey

In Turkey, the significant risk to low-cost housing from the seismic and other geologic hazards outlined above can be substantially reduced by using geologic, hydrologic, and soils engineering principles in selecting and preparing building sites. Furthermore, it is certain that rapid advances now being made in these disciplines will result in more effective guidance in future selection of building sites. Accordingly, it is recommended that any large-scale program to construct low-cost housing in Turkey include investigations to guide in the selection and preparation of building sites. The program of such investigations proposed below envisions more than a pilot study, because the usefulness and practicability of such investigations appear to be demonstrated. On the other hand, it is not offered as a national program of land-use analysis, although it contains elements that would be included in a national program.

5.4.6 Methods of Guiding and Controlling Site Selection and Preparation

Two methods exist for insuring application of scientific and engineering knowledge to the selection and preparation of building sites to reduce seismic and other hazards. One uses regional geologic, soils engineering, hydrologic, and other studies to guide the initial selection of sites. The

second consists of inspection and approval of site preparation and building plans by a building official or inspector after a builder (private or governmental) has selected a site and prepared plans for its development. The two methods are quite compatible, and can be used in sequence.

The first method controls siting during, and as part of, the planning stage of a low-cost housing program. Its advantages are that the effort devoted to siting control is utilized to help find the best building sites in an area from all points of view, including safety, and does this in advance of costly site and building plan preparation. As part of the planning process, the method emphasizes regional studies that can be made by a relatively small number of teams of specialists. It thus requires fewer well-trained professionals than the second method, which is based on individual inspection of all sites or projects. The principal disadvantages of siting control at the planning stage are that it is too expensive for isolated single houses or small developments, and insufficiently detailed to control site selection and preparation for large buildings.

The second method typically relies upon a building code for guidance, is administered by local offices of national or regional agencies, or by local governments, and usually requires intensive site investigations for problem areas. If based upon a well-prepared building code, this method has the advantages of uniformity and clarity in its requirements. It has the drawbacks, however, of being unable to efficiently fit local

conditions and exceptions without becoming unworkably complex, of exercising review and control only after a considerable effort has been expended on site selection, planning, and design, and of requiring greater numbers of adequately trained technical people to review site selection and planning than will be available in Turkey for many years. In any case, at best, the method condemns hazardous sites only after the expense of selection and planning, and does not provide any direct help in choosing the best sites.

The building code approach to assuring the safety of foundation is exemplified by chapters 29 and 70 of the 1970 edition of the Uniform Building Code. Chapter 70 deals with grading practices and makes specific recommendations on the dimensions, slope, drainage, and erosion control of cuts and fills. Chapter 29 relates building foundation requirements to the character of the soil and geologic formation beneath a building site. These chapters serve as general guides to site preparation. Adherence to at least these minimum recommended grading practices is especially desirable for earthquake-resistant construction because geologic foundation failures are a common cause of building damage and loss during earthquakes. However, the U.B.C. does not provide specific guidelines for treating such seismic and related hazards as active faults, off-site landslides, mudflows, and liquefaction. Neither does it provide adequately for hazardous conditions due to local geology, soil, ground and surface-water, macro- and micro-

climate, and topography. As is true of all general-purpose codes, the grading requirements specified by the U.B.C. are too restrictive for some sites and insufficiently restrictive for others. Recognizing this, the U.B.C. specifies that soils engineering and engineering geologic investigations for cuts and fills be made at the option of the responsible building official. Of necessity, the code neglects local customs and local technical and administrative capacity for adequate inspection and control of building sites. Indeed, such inspection and control is rarely available for single-family and small multifamily dwellings in smaller cities, villages, and the countryside anywhere in the world. Thus, adherence to the U.B.C. or similar codes is a helpful, but insufficient guide to site selection and construction in Turkey.

5.4.7 Proposed Site Investigations

It is recommended that planning-stage studies be the basis for selecting and preparing sites for all earthquake-resistant housing for which more than one or two alternative sites are available. Site-insensive investigations (detailed studies of foundation conditions at a building site and its environs) should be made of all sites proposed for large engineered buildings, whether the sites were selected on the basis of planning-stage studies or for other reasons.

A practical program to guide site selection and preparation for low-cost housing in Turkey must deal realistically

with the following:

1) The recognition of many siting problems is difficult, and the assessment of the risk presented by these problems, even after they are recognized, requires a high level of technical competence.

2) The level of risk varies widely, commonly even between adjacent sites.

3) Several disciplines (principally geology, soil engineering, and hydrology) are required to recognize and evaluate even the most common siting problems and hazards.

4) The number of competent professionals in these disciplines is in short supply in most countries.

5) The relevant technologies are now in a period of rapid evolution towards better insight and more complex diagnostic procedures and solutions to siting problems and hazards.

Accordingly, a program of site investigations in Turkey should: 1) rely on active site investigations by multidisciplinary teams of professionals, rather than on the enforcement of detailed codes by local or regional building officials; 2) concentrate on housing units or projects that are large enough or extensive enough to warrant the application of necessarily expensive site investigations; 3) propose regional reconnaissance studies as an alternative to site-intensive studies for

some types of low-cost housing projects; and 4) incorporate a review board to provide for continuing review and updating of site evaluation and selection procedures and criteria, and to guide continuing training of the site evaluation and selection teams.

5.4.7.1 Planning-stage Investigations

Effective planning-stage studies require that the entire region under consideration for low-cost earthquake-resistant housing be evaluated for suitable building sites. Experience in California and elsewhere has shown that specialists able to extend or detail existing soil, geologic, and hydrologic data by the extensive use of aerial photographs as well as by standard field methods can study areas exceeding a few square kilometers at much less cost than by standard field methods alone. Such studies are primarily geologic, but include soil engineering, hydrologic, and at times botanical study. Mapping scales for planning-stage investigations ordinarily range from 1:10,000 to 1:250,000.

5.4.7.2 Site-intensive Investigations

Site-intensive investigations consist of standard engineering geology, and soils engineering field and laboratory investigations of selected sites and their relevant environs. "Relevant environs" refers to the minimum area surrounding a site that must be studied to evaluate its seismic and related

hazards. This area most commonly ranges from one or two to a few tens of hectares in extent, but in special cases it may be much larger. This is necessary because the critical evidence for many siting hazards, such as landslides, is commonly difficult to find within a small site. Subsurface investigation by drilling, trenching, and geophysical surveys would ordinarily be conducted at and near the site, particularly for large structures. Mapping scales will ordinarily range from 1:100 to 1:1,000. The evaluation of the soil-engineering and geologic data must take into account the seismic zone in which the site occurs. For sites on flood plains, or those having shallow ground water, poor drainage, or other water-related problems, hydrologic expertise may be required.

5.4.7.3 Scope of Investigations

Both planning-stage and site-intensive investigations should include consideration of the following possible foundation problems and siting hazards, but a complete list for any site will require study of the site itself by qualified experts.

Geologic: 1) Active faults at and near the site; 2) Landslides or other slope failures beneath or upslope from the site; 3) Liquefiable or easily compactable materials beneath the site; 4) Lateral innomogenities in compactable materials beneath the site; and 5) Expansive and/or creeping soils.

Hydrologic: 1) Anomalous drainage or foundation condition

due to permanent or seasonally shallow ground water, springs, or seeps; 2) Eroding shorelines of seas, lakes, reservoirs or rivers; 3) Floods, mudflows, tsunamis, and surge waves.

Seismic: 1) Magnitude, distance, duration, and frequency of damaging earthquakes; and 2) Estimation of the base motion of the most damaging credible earthquake at a building site.

Soil Engineering: 1) Natural period of vibration of building sites; 2) Bearing strengths of the surface and substrata; 3) Effect that soils and poorly consolidated geologic materials beneath a site have on the character of shaking caused by the most damaging credible earthquakes (can vary within wide limits, depending on both the character and distance of the earthquake and the physical properties and thickness of the substrata); 3) Slope stability; and 4) Liquefaction potential.

Economic and cultural factors: Rural and village populations apply a variety of economic and cultural factors in siting their houses, factors that will commonly be equivalent or greater in importance than the seismic, geologic, and hydrologic considerations. Serious conflicts and economic hardship may befall the occupants of low-cost housing that is sited without regard to such economic and cultural factors.

Accordingly, the planning-stage site-selection teams should include a person or persons knowledgeable about the life style and economic pursuits of the relevant populations. Interviews with the people to determine their needs and wishes are important so that the technical studies can concentrate on finding safe sites that are also economically and culturally acceptable and satisfying to the people.

5.4.7.4 Single-family Rural and Traditional Town Houses

Site control for single-family and small multifamily housing is practical only by planning-stage investigations; the cost of site-intensive studies is too great for such buildings. Planning-stage investigations, however, are in turn only practical for large housing projects. Siting control for isolated individual units (or small groups of units) of low-cost earthquake-resistant housing should be limited to existing procedures, if any, until suitable regional studies are made on behalf of larger housing projects, or for other purposes.

5.4.7.5 Multifamily Houses

Site investigations for large, engineered multifamily-multistory low-cost housing should follow two patterns. Where the choice of sites is limited or predetermined, site-intensive investigations of the geology, soils engineering, and hydrologic conditions at the site and the relevant contiguous

terrain should be made. Where there are alternative sites, selection should be based on a regional environmental (planning-stage) study followed by the site-intensive investigations recommended above of the most suitable site or sites. The cost of many of the site-intensive investigations will be significantly reduced if the site is selected through a regional study.

5.4.7.6 Improvement of Existing Houses

Site studies can be of assistance in preparing proposals to improve the earthquake resistance of existing housing by structural or foundation modifications. Where extensive housing tracts or large buildings are involved, regional planning-stage and site-intensive studies can be used to guide expenditures for modification to those houses located at suitable sites. Unsuitable sites might then be designated for eventual conversion to parks or other low-risk uses.

5.4.8 Technical Supervision

The site-selection program should strive for technical excellence through the establishment of an independent review board composed of scientists and engineers from university faculties, private consulting firms, and governments at home and perhaps abroad. International financial assistance for obtaining foreign technical participation might be obtained. The most important task of the review board would be the

establishment and continual improvement of a set of recommended investigations and site standards that are realistic to the specific area or region of the country at each stage in its development, and commensurate with available budgets and professional staff. The board should also provide the site-selection teams with consultation on difficult or special problems, assist in the recruitment and selection of personnel for study teams, and administer a program of continuing training of team members in the newest technical developments in their various disciplines.

5.5 Case Study: Engineering Geology and Siting Problems Related to the Peru Earthquake of May 31, 1970[1] by George E. Erickson and George Plafker, U.S. Geological Survey and Juan La Cruz L, CRYRZA[2].

5.5.1 Introduction

The Peru earthquake of May 31, 1970 offers a model for examining the effects of the geologic environment on destruction, for the earthquake caused a wide variety of geologic foundation and slope failures that were major contributors to the extensive destruction and death toll. In the affected region, principally the Department of Ancash (figure 1), the rugged topography, extreme variation in relief, proximity to the sea, and great climatic variation have given rise to most

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[1] Publication authorized by the Director, U.S. Geological Survey.

[2] Comisión de Reconstrucción y Rehabilitación de la Zona Afectada por el Terremoto del 31 de Mayo de 1970.

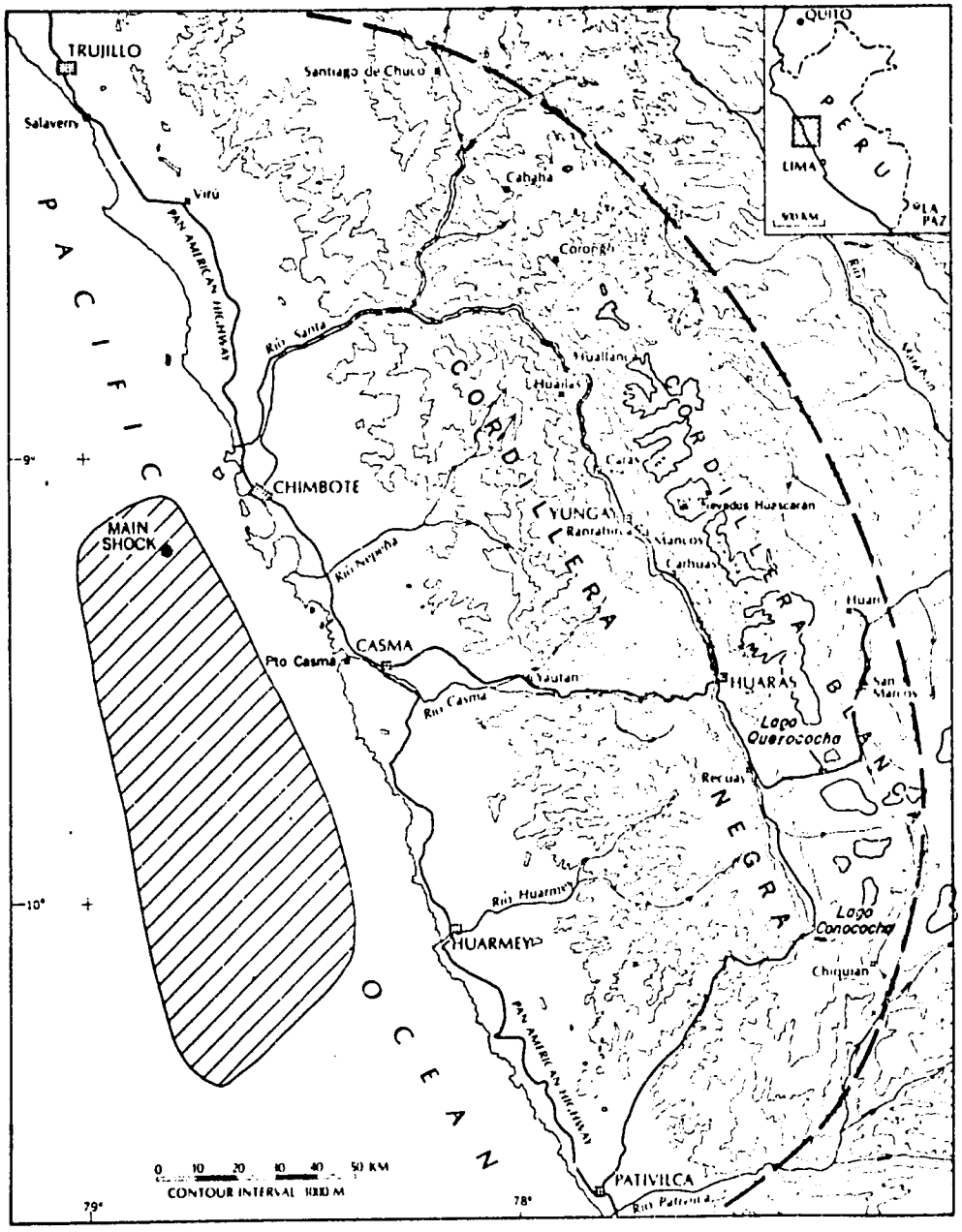

Figure 1.--Region of northern Peru affected by the May 31, 1970, earthquake. The epicenter of the main shock and the region of principal aftershocks (diagonal line pattern) are from the U. S. Coast and Geodetic Survey P.D.E. listings. Heavy dashed line shows the approximate limit of compaction and fissuring of unconsolidated sediments, of landslides, and of widespread damage of buildings.

geologic hazards that might be found in any earthquake-prone region, all within a relatively small area. This earthquake was probably the most catastrophic natural disaster in the history of the Western Hemisphere and ranks high among the world's greatest natural disasters. The extent of destruction--roughly 49,000 people killed and 184,000 buildings destroyed--was largely due to unstable terrain and to adobe construction that had little resistance to seismic shaking. Destruction was far out of proportion to the magnitude of the earthquake (Ms = 7.7), which in terms of seismic energy release does not place it among the truly great earthquakes of historical times.

The initial shock occurred on May 31, 1970, at 3:23 p.m., Peruvian time, according to the U.S. Coast and Geodetic Survey (P.D.E. card, June 1, 1970). The epicenter was at lat. 9.2° S., long. 78.8° W., at sea 25 km west of the port city of Chimbote in the northwestern part of the Department of Ancash. The hypocenter, or focus, was determined by the Coast and Geodetic Survey to be at a depth of 56 km. Most of the aftershocks having magnitudes between 4 and 6-1/4 and hypocentral depths of 44-66 km, occurred in a well-defined zone 25-50 km wide that extends about 140 km southward from the main shock epicenter (figure 1).

The area of moderate to severe structural damage and pronounced ground effects extends along the coast from near Trujillo to Pativilca, and inland for a maximum distance of about 135 km (figure 1). A maximum intensity of shaking of

VIII on the Modified Mercalli scale is indicated in the Coastal region between Casma and Chimbote and at Huaraz in the Andean region.

This report is based on information in our earlier reports (Erickson, Plafker, and Fernandez Concha, 1970; Plafker, Erickson, and Fernandez Concha, 1971), upon field work carried out by Juan La Cruz and other geologists of CRYRZA, and upon fieldwork by Erickson and Plafker during June and July 1971, carried out as part of an international project of earthquake siting and construction problems sponsored by the Agency for International Development (AID), U.S. Department of State.

5.5.2 Geologic Environment

The Andean region of Ancash has extremely rugged topography and great relief; oversteepened slopes tend to be extremely unstable and subject to development of destructive landslides and rockfalls during earthquakes. In the high glacier-covered Cordillera Blanca (figure 2), rock and ice avalanches are an extreme hazard, as are the more than 200 glacial lakes, which may burst during an earthquake to cause devastating floods and debris flows. Volcanic and granitic rocks on steep slopes of the Cordillera Negra (figure 1) are locally deeply weathered or strongly fractured and consequently are subject to sliding during the rainy season, or during a seismic event. Many thousands of landslides developed in both these ranges during the 1970 earthquake, causing extensive damage to farm lands and rural

composition. Fortunately, none of the glacial lakes ruptured during the earthquake.

The valley of the Rio Santa (figure 1) is partly filled with deposits of streams, debris avalanches, debris flows, and moraines. The behavior of these sediments, which are the principal foundation materials of the communities in the valley varied greatly in response to seismic shaking. The oldest sediments, constituting the earliest valley fill, are well cemented and relatively stable, whereas younger terrace gravels, glacial moraines, and alluvium are poorly cemented and subject to epicenter failure by sliding. Fine-grained water-saturated sediments and soil tended to fail by differential compaction, liquefaction, and lateral spreading during the earthquake.

Most of the coastal communities are built on the alluvial deposits of flood plains of the major streams draining westward from the Cordillera Negra. Stream valleys for distances of 5-10 km inland from the coast are generally flat bottomed and have valuable agricultural lands and many rural settlements. Towns and cities along the coast, Chimbote, for example, have extensive areas underlain by lagoonal and beach deposits, commonly with a shallow water table. These fine-grained water-saturated deposits, which tend to be very unstable under seismic shaking, occur in most areas where geologic foundation failure contributed to extensive structural damage.

No detectable vertical coastal uplift was associated with the earthquake, nor does there appear to have been a significant

Figure 2.--View southward along crest of the Cordillera Blanca showing scars on north and west sides (arrows) of north peak of Nevados Huascarán, the sources of two major debris avalanches during the May 31, 1970 earthquake.

seismic sea wave (tsunami or maremoto) of the type that has accompanied some great coastal earthquakes in Peru, and elsewhere around the Pacific margin. This suggests a probable absence of shallow dip-slip faulting on the sea floor during the earthquake, and is compatible with the seismologic data indicating that the earthquake was of subcrustal origin.

Surface faulting was not observed anywhere in the earthquake-affected region, and, to judge from the location of the epicenter and major aftershocks offshore from the coast, major faulting would not be expected onshore. Nevertheless, recent faults are widespread in the region; the most prominent comprise a system of en echelon normal faults along the west flank of the Cordillera Blanca. The faults are marked by well-defined scarps as much as 20 m high that displace Holocene glacial moraines and beds of streams cutting these moraines. Undoubtedly, movement has taken place on some of these faults during the past few hundred years, but evidently there was none during the 1970 earthquake.

5.5.3 Regional Siting Problems

Throughout the area affected by the Peru earthquake of May 31, 1970, the degree of destruction in any one community was determined largely by the type and age of buildings, by the type of geologic foundation material, and by relative stability of slopes of nearby hills. In general, old 2- and 3-story adobe buildings, such as those of Huaraz (many having

supporting timbers weakened by age and termites), or buildings constructed of very poor quality adobe, such as those of Casma (figure 3), were more heavily damaged than well-constructed adobe buildings. Other types of buildings showed various degrees of damage, but modern reinforced-concrete buildings, or buildings with reinforced-concrete frames and brick filler walls, generally sustained little or no damage.

Extensive damage due to failure of geologic foundations resulted from differential compaction, slumping, and lateral spreading of water-saturated fine-grained sediments such as lagoonal sediments, beach deposits, and manmade fill. The most notable example of foundation failure in deposits of these types was in Chimbote. To a far lesser degree, similar foundation failures took place in several other communities on the coast and in the Andes. Furthermore, buildings constructed on dry dune sand and on mudflow material associated with piedmont aprons and slope-debris accumulations in the extremely arid coastal region, showed greater damage than buildings of similar construction on compact stream gravels and bedrock.

There seems to be no obvious correlation between the intensity of structural damage and foundation materials in many areas where foundation failure did not occur. Adobe structures failed on foundations as diverse as granodiorite and saturated alluvium or thick soils. Some villages were almost totally destroyed, whereas nearby villages of apparently similar construction and geologic foundation were only moderately

Figure 3.--Residential street in Casma, Peru, where all adobe-block houses collapsed during the earthquake of May 31, 1970. Adobe used in construction here was of extremely poor quality, containing a high-percentage of silt and sand, with little or no straw binder. It crumbles easily in the hand. Casma, a town of about 15,000 inhabitants before the earthquake, was almost totally destroyed during the earthquake.

damaged. Similarly, in the towns, one could find adobe houses that had collapsed next to houses of similar age and construction that were either moderately damaged or undamaged. The reason for these striking variations in degree of damage is unclear. Subtle differences in composition and (or) water content of the foundation material could be an important factor, but slight differences in construction and the pattern of seismic-wave propagation may be equally important.

The most widespread damage due to earthquake shaking was to residences made of adobe blocks, which constitute the overwhelming majority of smaller buildings. Significantly, good adobe construction, such as the 3-story Hotel Chimu in Chimbote, survived the shake with little or no structural damage. Unreinforced brick or concrete-block buildings generally withstood shaking better than adobe, but in some areas buildings of this type were extensively damaged (figure 4). Well-constructed houses and most small buildings of reinforced concrete generally showed little or no damage in most towns, even where they were entirely surrounded by demolished adobe-block structures. Damage to large reinforced concrete and brick structures ranged from negligible to total collapse, depending upon the design and quality of construction.

5.5.4 Behavior of Unconsolidated Sediments in Flat-lying Areas

Failure of unconsolidated sediments in flatlying areas

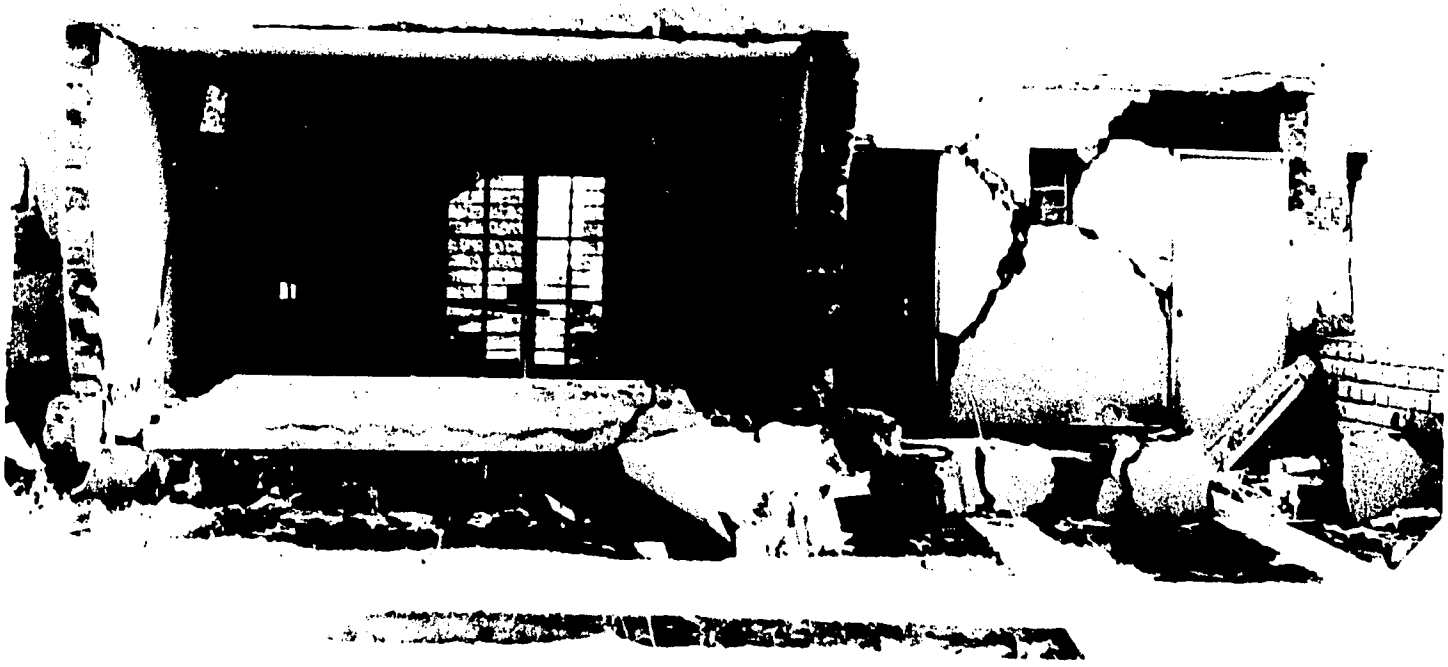

Figure 4.--Typical destruction of new homes of unreinforced brick construction in the Buenos Aires suburb of Chimbote; all buildings in this suburb were damaged beyond repair. None of the homes collapsed, probably because of the reinforced concrete stairway that connected concrete floor slabs.

caused extensive damage to structures during the May 31, 1970 earthquake. The most serious damage was due to compaction and spreading of fine-grained water-saturated sediments. Coarse unconsolidated sediments, such as stream gravel and glacial moraine, were subjected to little or no compaction during the earthquake, and consequently caused little damage. Dry unconsolidated sediments were comparatively stable but some dry sediments, such as desert soils of coastal Peru containing highly porous mudflow material or manmade fill, failed by differential compaction and slumping. Such failure, which was commonly accompanied by fissuring at the surface, caused some damage to roads and buildings. Differential compaction of dry slope debris containing mudflow material and manmade fill caused widespread damage to the steel plant in Chimbote, chiefly by breaking of heavy concrete floors and misalignment of heavy equipment. The observed settlement at the steel plant ranged from a few centimeters to about 30 cm.

Although compaction of unconsolidated sediments probabily occurred to some degree throughout the earthquake-affected region, its effects were most noticeable in the Chimbote and Casma areas and along those segments of the coastal transportation routes that cross alluvium-filled valleys. Compaction of water-saturated materials was locally accompanied by ejection of water or water-sediment mixtures and the formation of sand boils. Near-horizontal movement of mobilized, or "liquefied," water-saturated sandy deposits toward free faces occurred at

Figure 5.--Compaction of foundation material and destruction of adobe, brick, and concrete block houses in low-lying area near the coast in southern Chimbote. Before the earthquake the ground surface was dry, and the water table was reportedly at a depth of about 50 cm.

a number of coastal localities. This process has been termed "landspreading" (McCulloch and Conilla, 1970) to differentiate it from landsliding, which connotes downslope movement.

The most spectacular examples of compaction and landspreading of water-saturated sediments in Chimbote include: 1) settling and flooding of a residential area in the southern part of the city (figure 5), where there was almost total destruction of unreinforced buildings; 2) differential compaction in the downtown business district (figure 6); 3) compaction and landspreading near the steel plant dock, which caused subsidence of about a meter (figure 7), and damaged roads and buildings; and 4) spreading of liquefied sand on a beach berm resulted in opening of a fracture more than a block long, along which masonry houses were ripped apart (figure 8).

The near-total destruction of central Huaraz (figure 9) was the result of collapse of old, relatively unstable adobe buildings owing to a combination of shaking and probable incipient compaction and landspreading of water-saturated foundation material. This foundation consists of a layer of silty and clayey sediment, at least 2 m thick, resting on gravelly material of an alluvial fan.

Compaction of water-saturated sediments, fissuring, and landspreading at many other localities in the Santa Valley, particularly in fields along old terraces or flood plains of the Rio Santa, caused local damage to roads and buildings. A notable area of slumping and landspreading occurred in a

Figure 6.--Street in downtown Chimbote where differential compaction of water-saturated beach deposits and manmade fill caused settling of buildings and cracking of concrete sidewalks. Here, 2, 3, and 4-story buildings on slab foundations settled 20-30 cm into the underlying material.

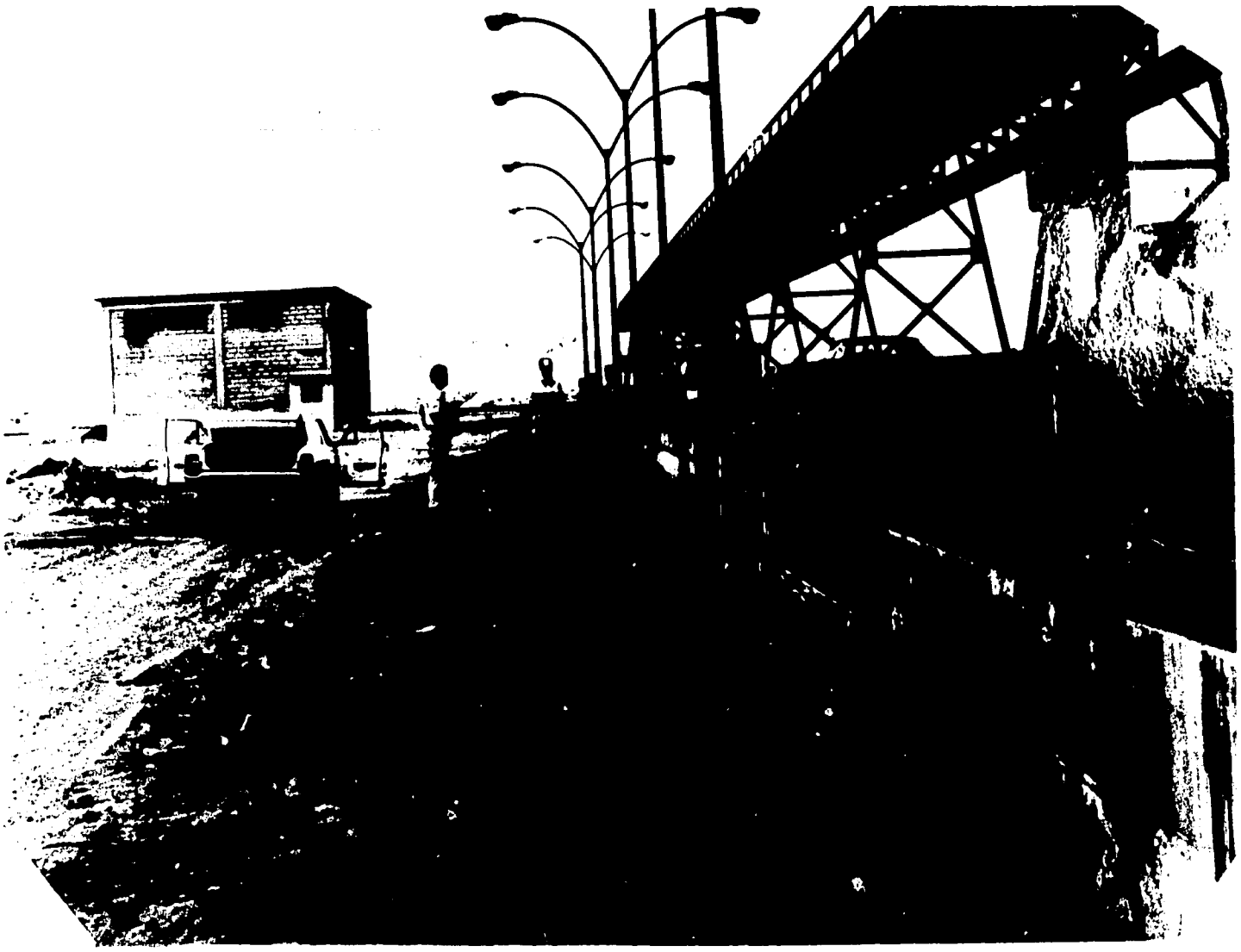

Figure 7.--Subsidence of roadway fill at side of steel plant [illegible] northwestern Chimbote, due to compaction and seaward spre[illegible] of underlying water-saturated sediments. Roadway settled ab[illegible] 1.2 m here. The dock, which is on deep concrete piles, did [illegible] subside.

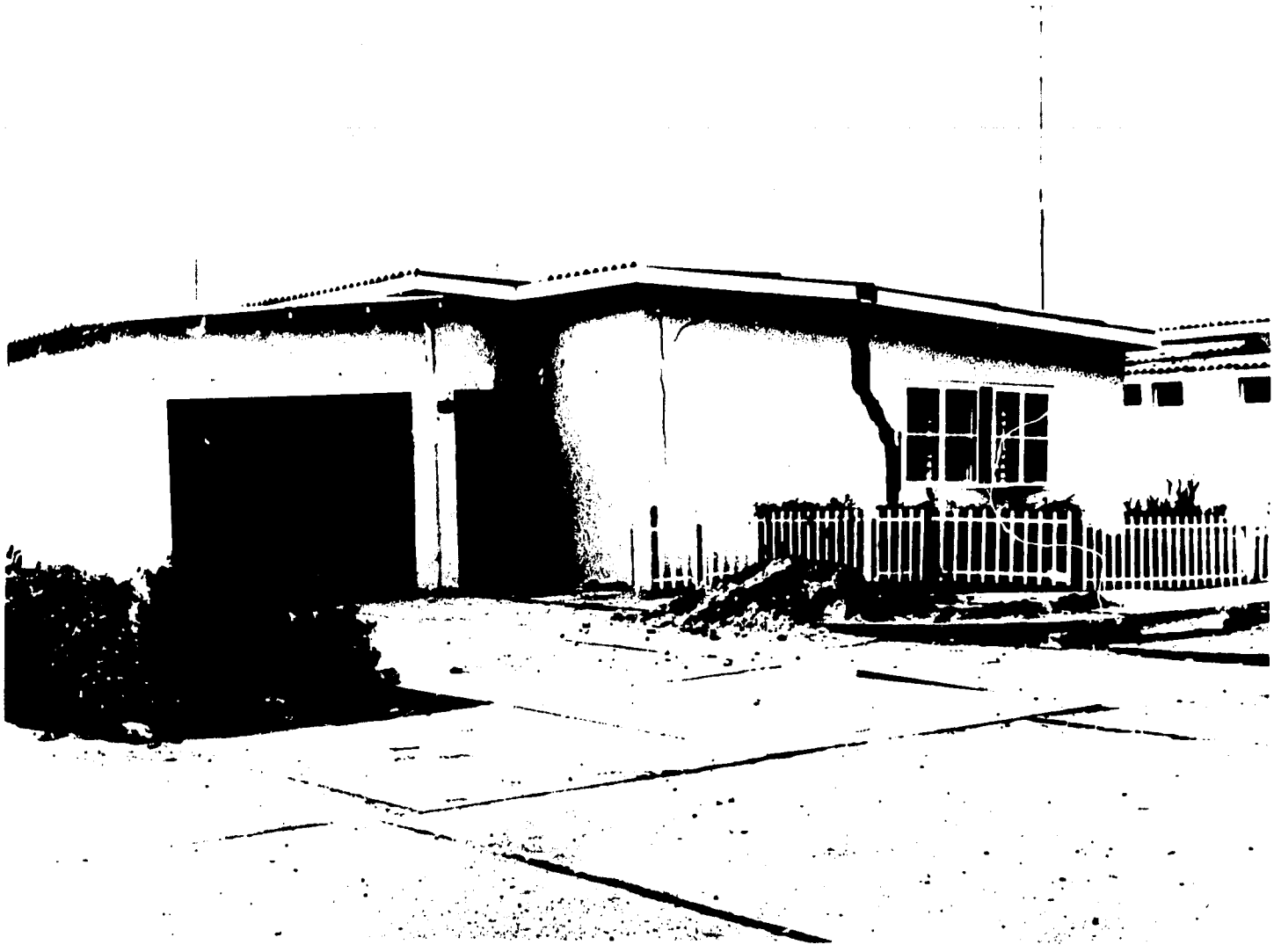

Figure 8.--Concrete block house at the Corporacion Peruana del Santa housing development, northwestern Chimbote, torn apart by seaward spreading of the underlying beach sands that became liquefied during the earthquake.

Figure 9.--Typical street scene in a 100-block area of central where nearly all adobe-block buildings were destroyed. Most were 2 or 3 stories high and had heavy tile roofs, and streets narrow; thousands of people were buried both in the narrow streets and collapsed houses.

gently sloping field just south of Caraz. Here, an area 50-75 meters in diameter spread downslope, with development of fissures and tilted blocks in the soil at the head of the slump area and a surficial flow of liquified soil at the toe.

Many earth flows formed by liquefaction of water-saturated muds and sands associated with extensive glacial outwash and morainal deposits in the southern part of the Santa Valley. This is a grassy area of subdued topography, and the flows took place on gentle to moderately steep slopes. Because these flows developed in a sparsely populated area, the only damage they caused was to roads and trails.

5.5.5 Landslides, Rockfalls, and Soil-slips

The earthquake triggered thousands of landslides and avalanches throughout the area of about 65,000 km^2 outlined on figure 1. The landslides included a wide variety of falls, slides, and flows involving bedrock, unconsolidated sediments, and snow and ice in varying proportions. The overwhelming majority of the slides occurred on the steeper slopes of the Cordillera Blanca and Cordillera Negra, within the area outlined in figure 9, and in the region of deeply incised drainage along the western flank of the Cordillera Negra, just west of the outlined area. The largest and most destructive slide was the Huascaran debris avalanche. At least five of the slides blocked stream drainage, thereby forming landslide-dammed lakes. Many small rockfalls occurred along the steeper natural slopes

and in roadcuts in the relatively low lying arid coastal region, but none is known to have resulted in noteworthy damage. The total volume of material moved downslope during the earthquake is conservatively estimated to be between 100 and 200 million m^3--perhaps a quarter to half of which was in the great Huascaran debris avalanche.

The overwhelming majority of landslides involved falls or slides of rock and slides of poorly consolidated debris and soil along steep valley walls, stream banks, and roadcuts. Thousands, or possibly tens of thousands, of landslides of this type were triggered by the May 31, 1970, earthquake. The largest slides, which could be discerned on vertical airphotos, are plotted on figure 10. Some of these are so closely spaced that a single symbol on the figure may represent many slides. In general, the larger slides were mainly in the Cordillera Blanca whereas most of the smaller ones occurred in the Cordillera Negra, particularly near the north end of the range and in deeply incised canyons elsewhere. Most of the individual landslides are rockfalls and rockslides that involve at least several thousand cubic meters of material. Rockfalls and slides are so numerous in and near the Canon del Pato downstream from Caraz that it is virtually impossible to delineate individual slides.

Shallow soil slips of unconsolidated materials were observed throughout the area, but were especially common on slopes mantled with water-saturated glacial till, volcanic ash,

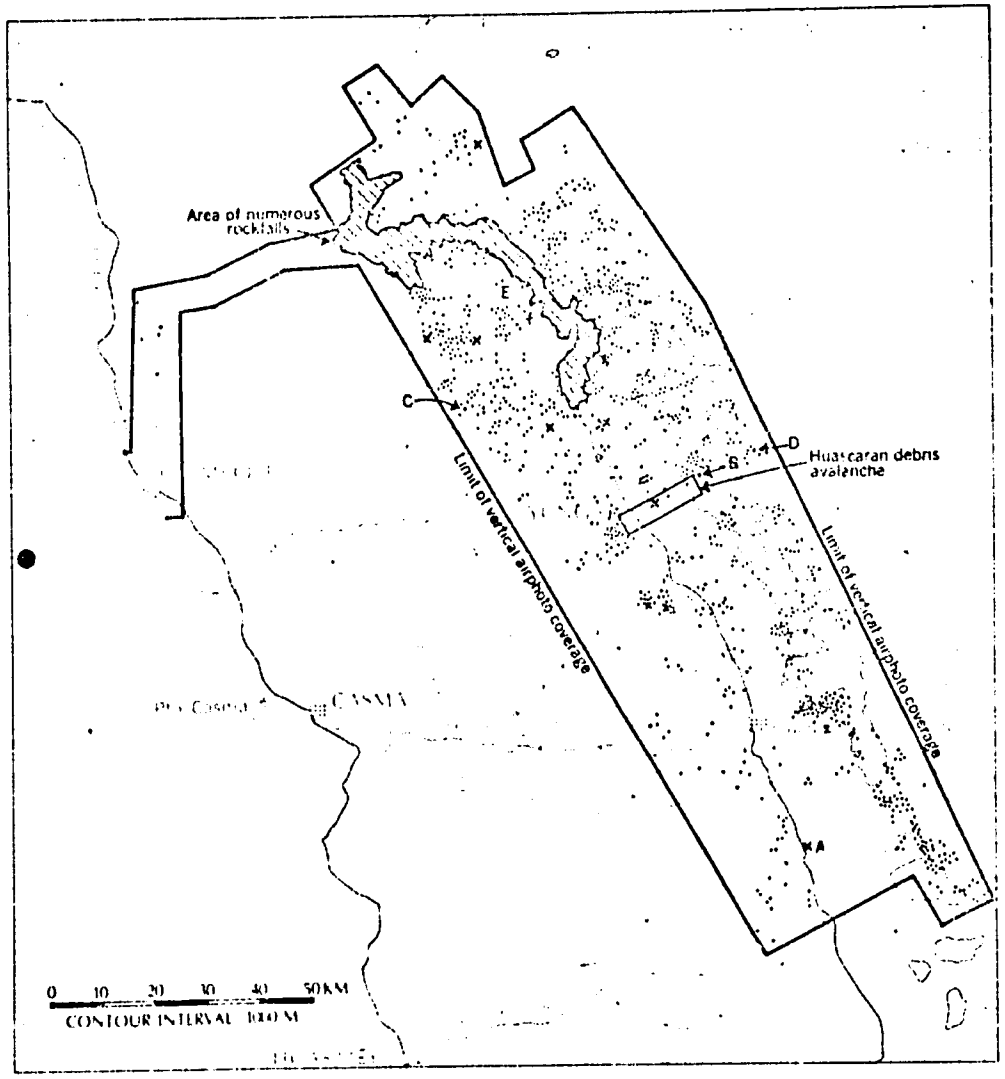

Figure 10.- Map showing distribution of landslides triggered by the earthquake of May 31, 1970. Lots- rockfalls, rockslides, and debris slides; crosses- block slides and rotational slides; [illegible] landslides-[illegible].

and colluvium. The soil slips are characterized by a series of irregular transverse open fissures as shown in figure 11 and by areas where thin slab-like soil masses have broken away and slid or tumbled downslope. Although they are subtle features, soil slips caused extensive damage because they commonly developed on cultivated hillsides where they disrupted irrigation canals, trails, and fences, as well as destroyed fields and buildings. In some very steep areas on the west side of the Cordillera Negra the thin soil of steeply inclined fields (many having slope angles of 30° or more) slipped away, leaving bare rock. In this same area, soil slips destroyed trails that were the only access to many fields. Many of these fields still were not accessible a year after the earthquake because of the difficulty and expense of blasting new trails across newly exposed steep rocky slopes.

Only 11 landslides involving slumps and rotational slumps of large masses of coherent materials could be identified within the area outlined in figure 10, the area for which post-earthquake aerial photographs were available. It is estimated that each of these slides contained more than a million cubic meters of material. These slides appear to have occurred in poorly consolidated fluvial-glacial deposits, pyroclastic volcanic rocks, and thin-bedded shaly sedimentary rocks. The largest rotational slide block, located at Recuay (figure 12), involved at least 8 million cubic meters of material, and perhaps as much as 20 million cubic meters, depending upon

Figure 11.--Surficial slips in thin grass-covered soil and slope debris along trail on east side of Cordillera Blanca, from Catac-San Marcos road about 2 km north of pass across range.

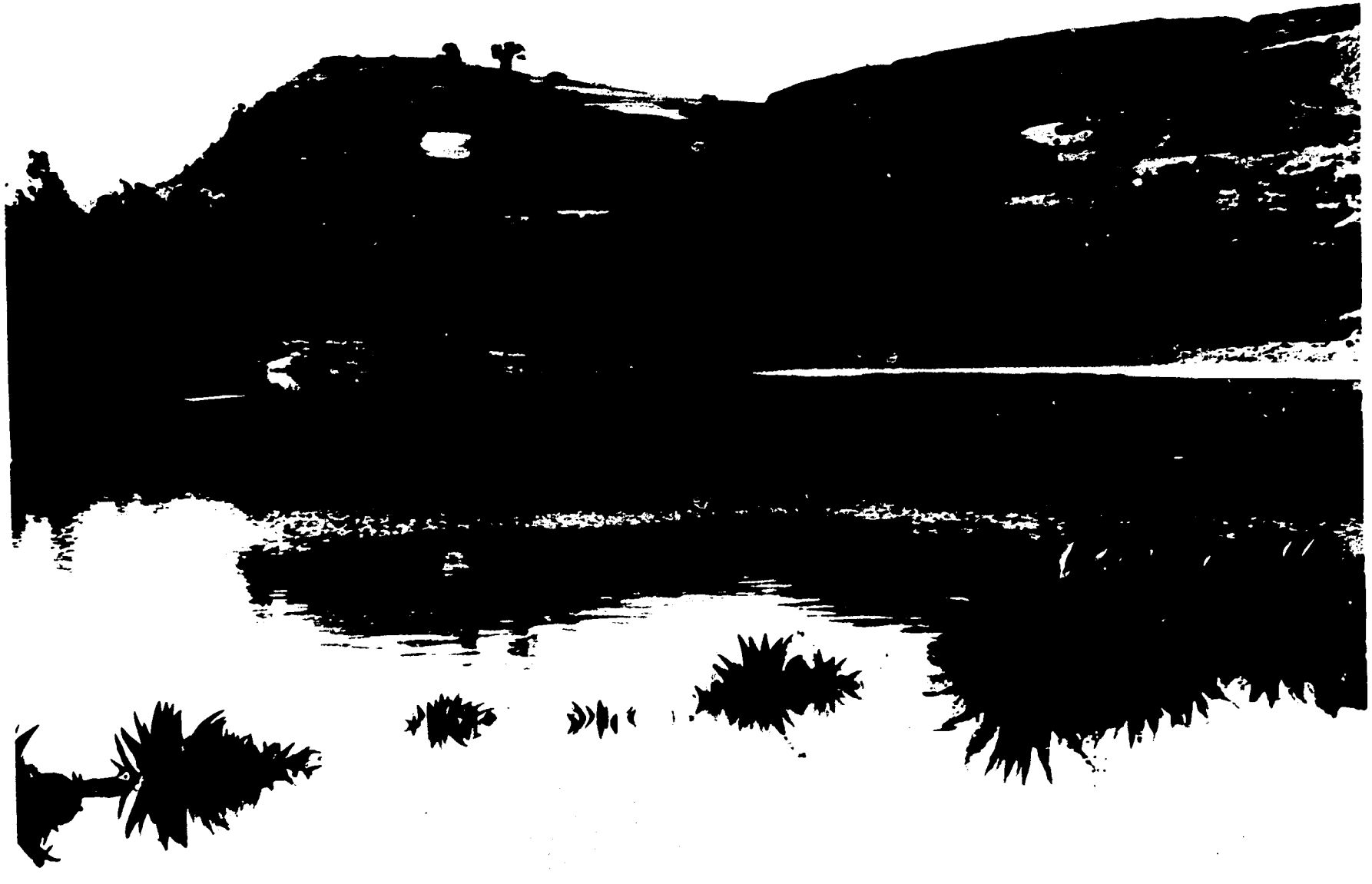

Figure 12.--Rotational slide in glacial outwash and underlying thin-bedded sedimentary rocks at Recuay. Maximum height of headwall (arrows) is about 7 meters. The toe (arrows) is a 5-meter high ridge that blocked the Rio Santa and formed the small lake in foreground of photograph.

Figure 13.--Oblique aerial view of Nevados Huascarán and the Huascarán debris avalanche that destroyed Yungay, part of Ranrahirca, and other nearby communities. Vertical relief between the avalanche source and the Rio Santa averages 3,500 m (11,500 ft.). Photo courtesy of the Servicio Aerofotográfico Nacional de Perú.

curvature and depth of the failure surface. The headwall scarp is as much as 7 meters high, and the upthrust toe is a ridge as much as 5 meters high, that formed a dam across the Rio Santa. At least 5 of the other rotational slides also impounded drainage.

5.5.6 Debris Avalanches

By far the most destructive and geologically fascinating aspect of the earthquake was the cataclysmic avalanche of rock and ice from the glacier-covered north peak of Nevados Huascarán (figure 13). This avalanche appears to be an event that, in terms of destructiveness, height of fall, velocity, and probably volume, far exceeds any avalanche known to have occurred during historic time.

The debris avalanche originated as a rock and ice fall from the sheer west face of the north peak of Huascarán, between the altitudes of 5,500 and 6,400 meters. The original slide mass, in which the amount of rock apparently far exceeded the amount of ice, probably involved a volume of rock and ice of at least 50 million cubic meters. This mass gained velocity as it slid over Glacier 511 (figure 14) for a slope distance of 2.4 km and vertical drop of nearly 1 km. Below this glacier, part of the debris was funnelled along the valley of Quebrada Armapampa, and the remainder broke out of the valley and sped across major topographic irregularities on a more direct course toward Quebrada Ingayoc. Below the confluence of

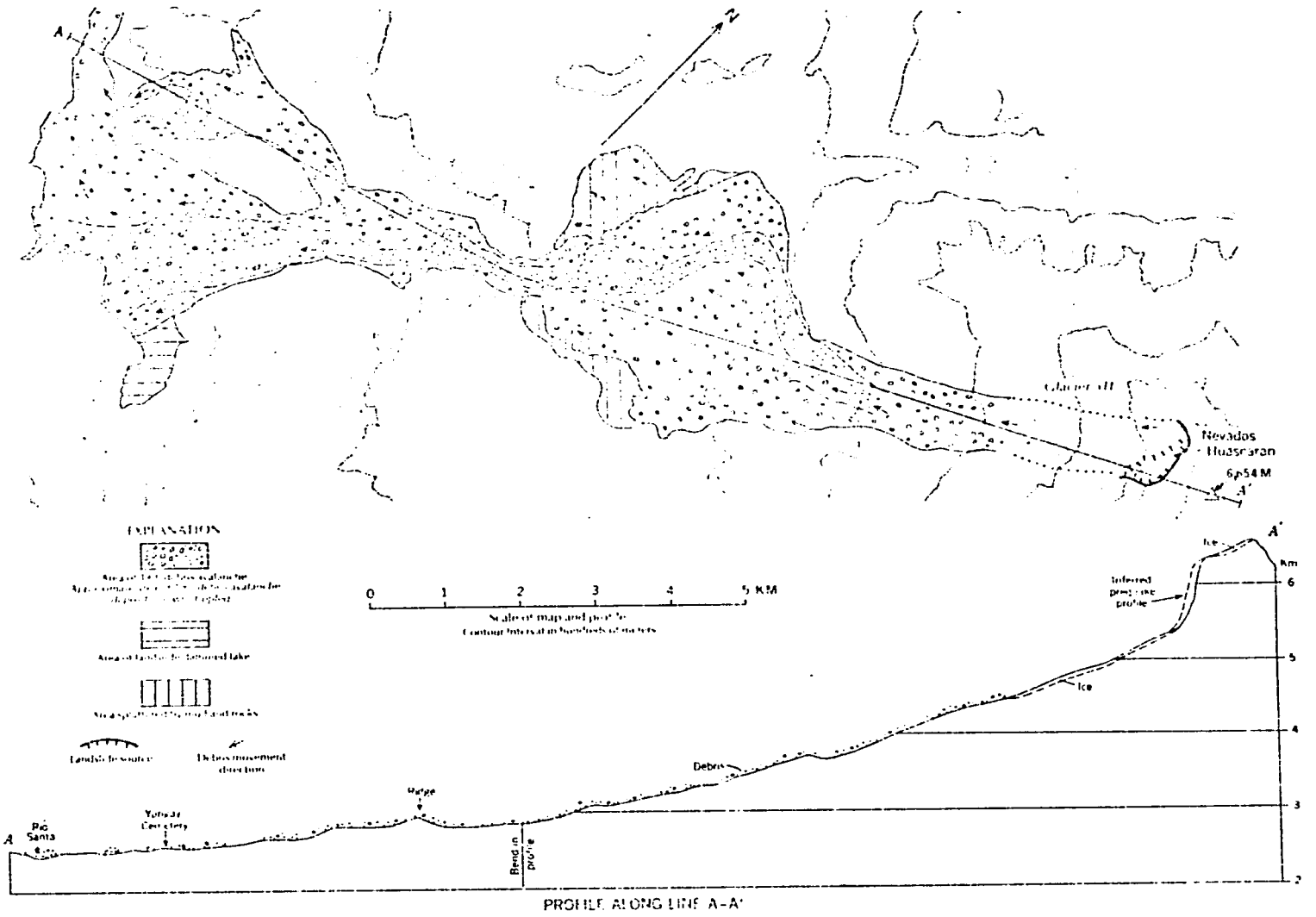

Figure 11.—Sketch map and profile of the Huascaran debris avalanche. Profile is from a point in Yungay, which is based map of the American Alpha atlas (Lamb 1964, 1968), which also shows the local debris avalanche.

Quebradas Arnapampa and Incayoc, the main tongue of the avalanche was channelled down the Rio Shacsha Valley to the Rio Santa. Within a few minutes after the first tremors of the earthquake were felt, the avalanche had sped 16 kilometers from Huascarán to the Rio Santa. The debris blocked the Rio Santa, temporarily causing it to back upstream for a distance of about 1 kilometer; it also lapped up onto the west bank of the river, reaching and destroying part of the town of Matacoto and flowed downstream. Yungay was buried by a relatively small tongue of debris that swept over the ridge between the city and the valley of Rio Shacsha. In overtopping this ridge, the avalanche climbed as much as 230 m above the adjacent valley floor.

According to eyewitnesses, the Huascarán debris avalanche was triggered within a few seconds after strong earthquake tremors were first felt. It moved downslope at high velocity with a deafening noise, and was accompanied by a strong turbulent blast of air. An eyewitness account indicates that the debris avalanche travelled the 14.5 km distance from its source to the vicinity of the cemetery at Yungay in less than 3 minutes and possibly as little as 2-1/2 minutes--an average velocity of between 280 and 335 km/hr (Mateo Casaverde, oral commun., July 3, 1970). Extremely high instantaneous velocities are indicated by the distances that boulders were hurled across the Rio Shacsha valley. For a vacuum ballistic range of 1,600 m, the estimated maximum horizontal distance

that boulders were thrown, the initial projectile velocity had to be at least 450 km/hr. The effects of air drag would increase this initial velocity by some 25-50 percent, suggesting an initial velocity of as much as 600 km/hr.

5.5.7 Conclusions

The extensive destruction and loss of life in the Peru earthquake of May 31, 1970 was due largely to 1) poor construction of buildings, chiefly adobe, which had little resistance to lateral forces imposed by earthquake shock, and 2) the Huascaran debris avalanche that buried Yungay and parts or all of several smaller communities, and destroyed extensive areas of farm lands. To a lesser, but significant degree, destruction was caused by the widespread landslides and by differential compaction, landspreading, and fissuring in unconsolidated geologic foundation materials. Geologic conditions influenced the distribution of the landslides and foundation failures during this earthquake, and will undoubtedly do so in future earthquakes in the Ancash region and in other earthquake-prone regions of the world. Although neither lake break-outs, surface faults, nor a destructive tsunami accompanied the earthquake, they remain potential earthquake hazards in this part of Peru.

Large landslides and debris avalanches and flows constitute the major geologic hazard in the mountainous regions of Peru. Steep slopes are extremely unstable and are periodically subject

to sliding, particularly when the ground becomes water saturated during the annual rainy season. Earthquakes often cause widespread downslope movement of unconsolidated material, and may trigger some larger slides than those that would normally be expected to occur sporadically in mountainous regions. Failure of unstable dams of moraine, alluvium, and landslide debris that impound lakes in steep-walled glacial valleys may result in disastrous floods and debris flows during earthquakes. Such a debris flow, triggered by the January 6, 1725 earthquake, buried the colonial town of Ancash, which is located in the Santa valley about 3 km downstream from Yungay (figure 1).

Differential compaction, landspreading, and fissuring may cause extensive destruction during large earthquakes, particularly to structures that are built on water-saturated fine-grained unconsolidated deposits or on poorly compacted natural or artificial dry materials. In Peru, these materials are generally most widespread in valleys of coastal regions, which commonly are also areas of highest population density.

Surface faulting was associated only with the 1946 Ancash and 1969 Pariahuanca earthquakes in Peru (Silgado, 1968; Ernesto H. Deza and Daniel Huaco, oral commun., June 1970), and because most known active faults in Peru occur in remote, sparsely populated areas, damage by direct fault displacement does not appear to be a major hazard. However, active faults are serious hazards in most earthquake-prone regions, and movement of them can cause extensive destruction to works of

man.

A major earthquake-related hazard in coastal regions is from destructive sea waves or tsunamis that could be generated by sudden large-scale vertical displacement of the sea floor at the continental shelf or slope. No such waves were generated during the 1970 Peru earthquake, presumably because the causative fault displacement was relatively deep seated. Nevertheless, many large destructive tsunamis have accompanied previous major earthquakes along the Peruvian coast during historic time (Silgado; 1968; Berninghausen, 1962), and will undoubtedly occur in the future. Both distant and near-source tsunamis could cause widespread inundation of lowlying parts of Peru, as well as of other coastal settlements of the Pacific basin. The danger from tsunamis cannot be minimized, and it should be taken into consideration in all construction in coastal areas of earthquake-prone regions.

5.5.8 Recommendations

The investigation of the Peru earthquake of May 31, 1970 has shown the need for systematic geologic and seismologic studies in Peru in order to better select sites for construction that will avoid potential geological hazards. Such studies are needed in all regions subject to frequent strong earthquakes, but actually are being carried out in relatively few countries. The following studies and facilities should be emphasized in Peru:

1. The Instituto Geofisico del Peru should be designated as the principal governmental agency to undertake seismological and geological engineering studies related to earthquakes. A section of this organization should be devoted wholly to earthquake studies, and in addition to direct investigations should act as coordinator of the several other agencies in Peru that are currently involved in earthquake studies. These agencies include CRYRZA, Escuela de Ingeneria del Peru, Servicio de Geologia y Mineria, and CERESIS. The staff need not be large, perhaps 5 or 6 scientists, and should include seismologists and engineering and structural geologists. The Instituto now has some seismological equipment, but needs more, particularly strong-motion and portable seismographs. Also needed are portable seismometers of high sensitivity for micro-tremor observations.

2. CRYRZA, the agency for reconstruction and development of the area affected by the May 31, 1970, Peru earthquake, should continue diversified studies in geology in this area. The geologic staff at CRYRZA not only should continue engineering geology studies, but should also initiate systematic investigations of mineral resources, the exploitation of which could contribute materially to the economy of the region. Such mine development could lead to opening of new areas by mine access roads, and formation of local mineral-dependent industries.

3. The following systematic seismologic and geologic studies should be carried out in Peru as a means of identifying

hazards and corrective measures to minimize destruction and loss of life in future earthquakes: a) Preparation of a seismic risk map of Peru; preparation of a tsunami-hazard map of the Peruvian coast; c) preparation of geologic foundation maps of the principal cities of Peru; investigations should include bore-hole and trenching tests and study of micro-tremor characteristics; d) monitoring of glacial lakes of Peru in order to evaluate the potential for breaking of morainal dams that could result in disastrous debris flows; and e) identification of areas or regions that are particularly susceptible to major landslides or rockfalls.

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Chapter 6 Methods of Housing Construction

6.1 Introduction

6.2 Traditional Construction Methods

6.2.1 Basic Materials

6.2.2 Aided Self-Help

6.3 Industrialized Construction Methods

6.3.1 Labor Intensive Industrialization

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Chapter 6. Methods of Housing Construction

6.1 Introduction

Viable technologies capable of responding to the urgent need for large numbers of inexpensive earthquake and storm resistant dwellings in developing countries can only be achieved if the resources available in the area of housing construction are properly utilized. One such resource, of considerable importance in view of its availability on a relatively large scale, are traditional methods and skills. In order that such methods and skills be used effectively, it is necessary that they be improved by the injection of appropriate innovative technologies requiring limited investments and training programs. The resulting improved methods would achieve considerably higher standards of quality and productivity while being compatible with local conditions and needs.

In recent years, industrialized methods of construction have been introduced and used in various developing countries, often with encouraging results. Such methods represent an extremely promising technical solution to the problem of providing safe, inexpensive construction on a large scale. Progressive technologies compatible with local capabilities and needs should therefore be used in an effort to develop and improve industrialized methods of construction.

This chapter contains a brief review and discussion of traditional and industrialized methods of construction in three

developing countries selected as case studies: Peru, Turkey and the Philippines.

6.2 Traditional Construction Methods

6.2.1 Basic Materials

Stone masonry was used in Peru by the Incas for fortifications which are still standing today. In the rural areas of the country adobe blocks have been for centuries and still are the construction material most widely used.

Due to the relative scarcity of wood, rural dwellings in Turkey are often built with adobe blocks and rubble stone. Thick earth roofs are frequently used.

A large variety of materials is available in the Philippines. Among these, woven thatch is used extensively.

6.2.2 Aided Self-Help

Self-help construction projected on a large scale can provide the development of cooperative enterprises, skilled labor and social organization. Self-help construction systems can also generate employment. The community is usually capable of building its own housing, whereas the installation of public utilities and municipal facilities requires skilled labor and supervision.

The Philippines have developed an interesting custom called "Bayanihan" which means "all working together." The custom is usually observed on the local village scene where a number of men will help construct a house for a family or a municipal facility such as a school building. Many of the

Marcos school buildings, for which materials are supplied by the Japanese Government as postwar reparations, are constructed in the custom of "Bayanihan" under government supervision.

Technical assistance for aided self-help programs is important and is considered essential to all future construction systems employing this method and practice. Supervised and technically controlled production of basic building components is also essential to quality, reliability of structural performance, and timely completion of housing units.

6.3 Industrialized Construction Methods

6.3.1 Labor-Intensive Industrialization

Within the context of the need to promote a better combination of scarce resources of capital and skills with an abundant supply of labor, it is natural to develop labor-intensive industrialization, as the first phase of a transitional technology that will evolve with, and stimulate, the economy. There exists at the present time a shortage of new techniques which lend themselves to labor-intensive methods. For example, foam plastics appear to offer significant promise for light-weight roof insulation and wall in-fill. Honeycomb and corrugated cardboards show potential in sandwich panel configurations using gypsum, jute fabrics and foam insulation. The production of adobe blocks or bricks also lends itself to labor-intensive industrialization.

Prior to the actual initiation of a local production set-up, a determination of economic feasibility is of course

necessary. While quality and quantity are important, cost of production is clearly the most critical factor in evaluating the feasibility of such a program. In marketing the product, in addition to considerations of design, construction and site planning, the individual user's requirements, including choice and control of dwelling environment, must be taken into account.

6.3.2 Prefabricated Housing in Turkey

Prefabrication of housing in Turkey was first used in 1957 when a Turkish construction firm built a housing complex consisting of one, two and three-story units, using the Danish Larsen Nielsen procedure in the Eregli region. Since little progress in prefabrication of housing was achieved subsequently, the Turkish Government became involved in this field during the last few years.

Prefabrication in Turkey uses the following combinations of materials for frame and wall units:

(i) Steel skeleton and timber partition walls

(ii) Reinforced concrete panels

(iii) Lightweight, reinforced concrete panels

(iv) Plastered panels

(v) Steel frames and walls filled with lightweight concrete

(vi) Timber panels

(vii) Prestressed concrete units

(viii) Plastic dome elements

All systems used are based on the "partial" and "open" prefabricated concept.

Prefabricated housing efforts have increased considerably since 1967. This is mainly due to the successive natural disasters occurring in Turkey since this date. The Varto, Sakarya, Demirci, Gediz, etc. earthquakes, the Mersin flood and several landslides produced an urgent need for housing. The government awarded initial contracts to private firms for the construction of partially precast dwellings. Later the fabrication of construction components was started in the workhouses of the MKE (State Mechanical and Chemical Industry Institution) and in the plants of the Land Resettlement Directorate.

In 1968, the housing effort was focused on the establishment of a new plant with half private ownership. Later two plants depending on the General Directorate of Natural Disasters were established.

At the present time prefabricated units for housing purposes are mainly produced by three plants. Two of them belonged initially to the Ministry of Reconstruction in Ankara while the third is owned by the "YTONG" firm in Istanbul. The three plants are described below.

1. The Lodumnu plant in Ankara was founded in 1968 and is exclusively reserved to the preparation of timber housing components. Initially, the plant produced 6 dwellings a day for the disaster regions of Kigi, Igdir, Amasra and Bartin. After the Gediz earthquake in 1970, the production was nearly tripled and reached a capacity of 16 dwellings a day. At present, 7 dwellings are produced in a normal shift and 16 a day in emergencies.

On a modular size of 1.20 m., several types of timber panels are prepared. They can be divided mainly into two groups: outside panels and inside panels. Outside panels are 10 cm. thick of which 5 cm. consist of insulating glass-wool. They are covered by hard board of 19 mm. thickness on the inner face and by 8 mm. thick asbestos on the outer face. Inside panels are 6.0 cm thick and are covered by thin hard board on two faces. The units are prepared to constitute panels with and without openings.

The panels are mostly used in construction of one story, single dwelling units of 48 sq. m. clear surface for urban types and 43 sq. m. for rural types, in accordance with prototype architectural plans.

The timber roof system consists of 37 panels, 7 roof trusses, and additional miscellaneous items, and is also manufactured and delivered by the plant.

Timber prefabricated components are also used in the construction of mosques. Minarets are built by prefabricated circular timber components.

The thermal insulation provided by the glass-wool is satisfactory. It has been concluded after laboratory tests, that the external walls consisting of 10 cm. thick panels are equivalent to 60 cm. thick brick walls as far as heat transfer is concerned.

The earthquake resistance of the panels has not been tested in the laboratory, but it is estimated that the earthquake

hazard risk of these is less than for brick masonry dwellings of the same size.

The prices of these panel units vary between 140 and 167 TL. (1972 prices) for inside panels and between 194 TL. and 233 TL. for outside panels.

The components and miscellaneous items required for the construction of a dwelling are sold by the plant at a price of 13,000 TL. With foundation, erection, roffing in place and installation of sanitary and electrical equipment, the price rises to 21,000 TL.

For a total construction area of 51.8 sq. m. (a clear surface of 48 sq. m.) this corresponds to a unit price of approximately 400 TL./sq. m., or 2.5 times less than for similar dwellings made by private firms.

5.5 cu. m. of timber is used in the construction of such a dwelling.

2. The Etlik plant, near Ankara, was founded in 1970 and produces prefabricated light-weight concrete panels. The aggregate used in the lightweight concrete is imported Styropor a product of the German BASF firm. Styropor will soon be produced in Turkey in the PETKIM (State Petrochemical Industry) plants. Concrete obtained using styropor as a light filler material has a compressive rupture cube strength of not less than 40 kg/sq.cm.

The panel components are also based on a 1.20 m. modular size. The most typical panels measure 1.20 m. x 2.40 m. The

thickness of panels is 6 cm. for inside walls and 8 cm. for outside walls. The panels are covered by 1.5 cm. thick concrete at outer faces and by 0.2 cm. thick concrete at inner faces. The typical disaster region dwellings built with these panels have a prototype plan of 6.08 m. x 7.28 m. (fig. 10). Prices of panels vary from 136 TL. to 179 TL.

A typical dwelling is constructed using 39 panels and 47 additional elements, including timber roofing elements. The price of all the items is 11,500 TL. Including erection costs, the total price of one dwelling is 17,200 TL. or 400 TL./sq.m.

For roofing and door window details, 3.5 cu.m. timber is used in this type of construction, and 9 cu.m. of concrete without counting the concrete in the strip foundation.

The heat insulation capacity of those panels is equivalent to that of a 50 cm thick brick wall. The earthquake resistance is estimated to be good although no tests have been conducted.

The production of the two plants of the General Directorate of Natural Disasters is now being used for the construction of school buildings, and of dormitory buildings used for the Turkish Army.

3. The "Ytong" Firm of Turkey, founded in 1966, utilizes a Swedish process which consists of using limestone instead of coarse aggregate and of using alumina powder as an additive to portland cement.

Hydrogen is released in the chemical reaction which takes place after the contact of the dry mixture with water. Within

two hours after the chemical reaction, the material reaches a sufficient degree of strength. It is then cut out in blocks which are sent to autoclaves where steam circulates under pressure. The forced curing and drying process takes about 10-11 hours.

The material can be cut in the shape of bricks, panel wall units, panel slab units, etc.

The "Ytong" products used in the partial precasting can be listed as follows:

(i) Panel Slab Units are the rectangular prismatic blocks with standard width of 50 cm. Their length can vary from 1.0 m. to 6.0 m, in increments of 0.25 m. Their thicknesses vary from 7.5 cm. to 25 cm., in increments of 2.5 cm.

The slab panels are also used as precast concrete joists. Empty spaces left between the panels are filled with reinforced concrete joist beams.

(ii) Panel Wall Units: The width of the panels is 50 cm. while the lengths vary from 0.50 m. to 3.00 m., in increments of 25 cm. The thicknesses vary from 15 to 25 cm.

6.3.3 Prefabricated Housing in the Philippines

Only two companies are presently involved in the manufacture of prefabricated houses, a private firm using an extruded aluminim frame wall system and a government owned enterprise producing light-weight concrete panels. Technical difficulties in the activity of the government owned enterprese have been reported.

6.3.4 Prefabricated Housing in Peru

Wood Construction.

According to the official registers of the Ministry of Industry and Commerce, there are two plants for the production of prefabricated wood houses, one located in Lima and the other in Pucallpa in the jungle region: In 1955 these companies produced 123 units at a total value of S/6,912,000, i.e. an average value of S/56,195 per unit. In 1968 they produced 190 units at a total value of S/25,075,785 and an average unit value of S/131,978. The available statistics include as units not only houses but also temporary sheds erected at the beginning of civil construction projects.

An estimate of the construction capacity for prefabricated wood houses shows that between 1965 and 1968 only 30% of the installed capacity was used.

In the city of Lima there are 50 or 60 carpentry shops producing wood houses, of which 5 or 10 account for about 70% of the production. It is estimated that the present installed capacity, working two shifts, can deliver between 500,000 and 600,000 units a year, provided there is a sufficient supply of the appropriate wood, cedar, caoba and "madera compensada" of "tri-ply" type.

It is noted that the comsumption of lumber and plywood was only 8.5 bdft per capita in 1970, lower than in most Latin American countries. It was estimated that resources available in the natural forests of the eastern slopes of the Andes and

of the upper Amazon basin amount to approximately 500 bdft per capita yearly. Their present under-utilization is due to rudimentary exploitation techniques, to transportation difficulties and to the presence of heavy mixes of various species, of which it is estimated that over 1,500 exist (only 300 species exist in Europe, and only 25 are exploited commercially in Peru.)

Concrete Construction.

At Chimbote, where cement is available from the plant at Pacasmayo, large concrete panel and modular systems are competing with conventional permanent construction.

The "Unicreto" plant, located south of the city, produces a variety of "U" shaped modules averaging 3 meters in width, 2-1/2 meters in height and 1-3/4 meters in depth. Concrete slab thickness is 7-1/2 cm. and units are placed in an inverted position forming walls and roof. In this fashion three inverted "U's" shipped to the site with trimmed window and floor openings form a space of approximately 160 square feet. The present output of this plant is approximately 60 modules per day. An average house consists of 9 basic units. Concrete mix is 1:1.5:3.0 yielding concrete with a strength of 210 kg./sq. cm.

Presently the "Unicreto" plant is producing 328 complete houses and 872 basic units under a contract with the B.I.D. which will probably be extended to include an additional 2,000 units. In addition, the national plan of Peru calls for an additional 6,000 units by the end of 1973. The cost of the

B.I.D. units currently being built average 70,000 Soles, or $1,630 for a 46 square meter complete home ex-factory. Land and service add an additional 50,000 Soles, or $1,160. This averages $6.10 per square foot complete with land and service. For a basic unit of 29 square meters these figures are 31,000 Soles, or $740 ex-factory, and an additional 32,000 Soles for the site and utilities. This averages $5.10 per square foot complete. Lot sizes average 150 square meters.

The plant as it now exists is a most efficient operation occupying 40,000 square meters and employing 150 persons, of whom four are skilled. Delivery problems cause difficulties because the number of special vehicles available to deliver modules to the site is inadequate at the present moment. Since production is on schedule a large number of units are accumulating at the plant awaiting delivery. Additional delivery vehicles are being adapted from conventional dump trucks. (See photographs in Appendix.)

At the Listos plant, also located south of Chimbote, columns and panels are manufactured under a process patented in Peru. Four basic units are produced: a hollow wall panel of 3 m. x 3 m. x 20 cm., a solid wall panel of 3 m. x 30 cm. x 12 cm., a column fifteen centimeters square notched to receive the solid wall panels, and a narrow hollow roof panel similar to the hollow wall panels. It is estimated that at least two crews of seven men each and a time of 3 to 4 days would be needed per housing unit.

The manufacturers of "Listos" have their own large clientele in the private sector and also have won the public bidding for the construction of 200 dwellings in Chimbote (in the area of the coast affected by the 1970 earthquake). They are also negotiating to export their technique to Mexico, where they have apparently won a public bidding. The Lima factory is being enlarged in order to reach a production of between 50 and 100 dwellings per month.

The cost of construction of houses of this type is up to S/. 1,600 per square meter for low-cost types of housing. Although it is expensive, this system does have the advantage of a short construction time.

The experimental manufacture of complex modules of reinforced concrete for construction of houses and retaining walls was started in 1966. The method used has been registered under the name "Unicreto" and covers the basic module which is a reinforced concrete structure in the form of an inverted "U" covering an area of 2 by 3 or 2 by 4 meters and with a height of 2.40 meters. The wall thickness is 6 centimeters. The modules can be placed side by side or one above the other. The open ends - either 3 or 4 meters long - are closed by brick walls. The units are erected on a concrete platform. The walls are finished with a special concrete wall paint.

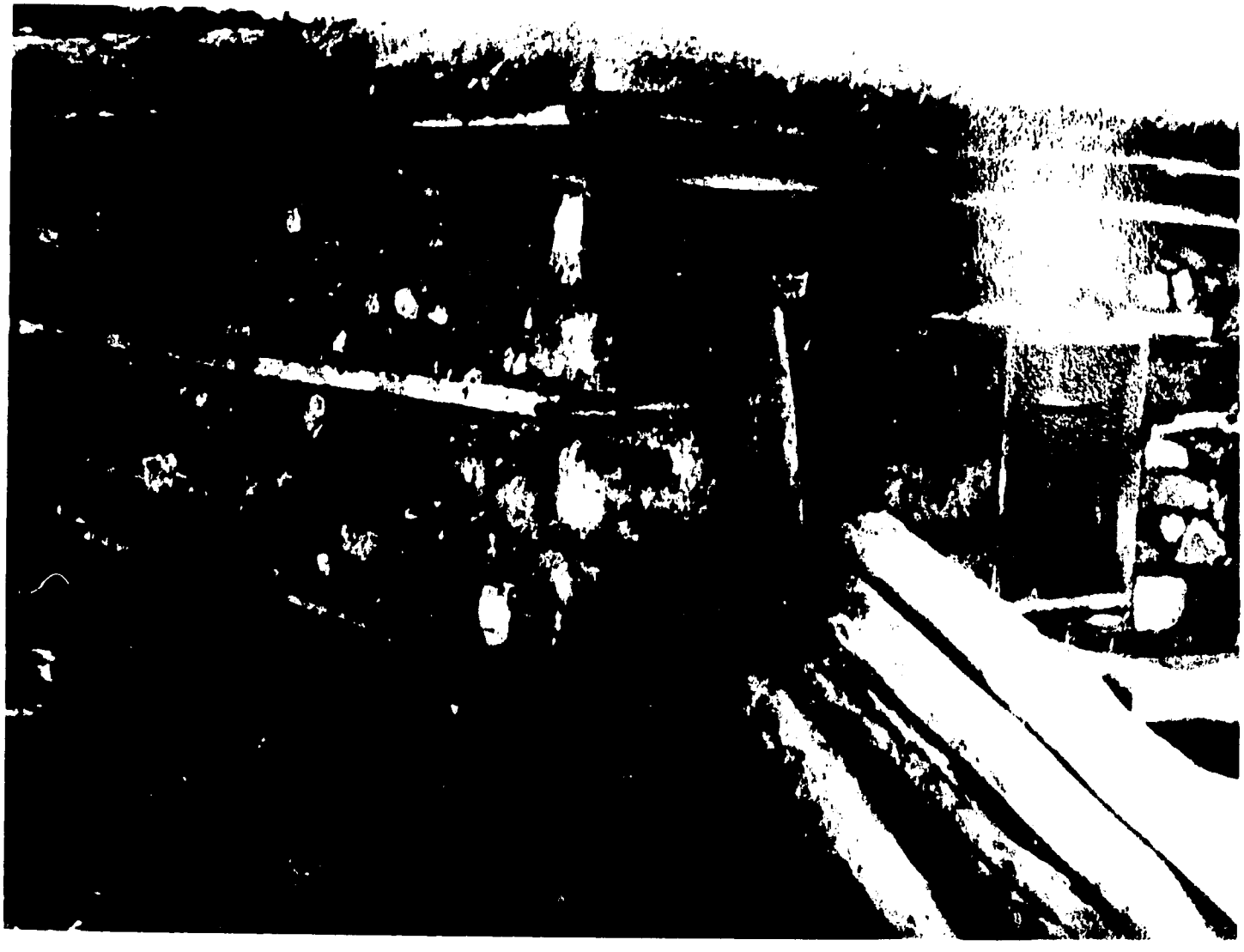
This system is quite flexible and for this reason has been well accepted. Nevertheless, transportation of the modules is difficult which results in high transport costs. Assembly

is fairly simple but requires special machinery for moving the modules.

This system won a public bidding in Chimbote for the construction of 500 houses which have been difficult to sell because of their high price. Recently, it won another bidding in Chimbote for the construction of 200 basic housing units at an average cost of about S/. 60,000 per unit. These houses have a constructed area of 40 square meters, including a patio with a simple roof of corrugated asbestos-cement sheeting. Electric wiring is external with PVC insulation.

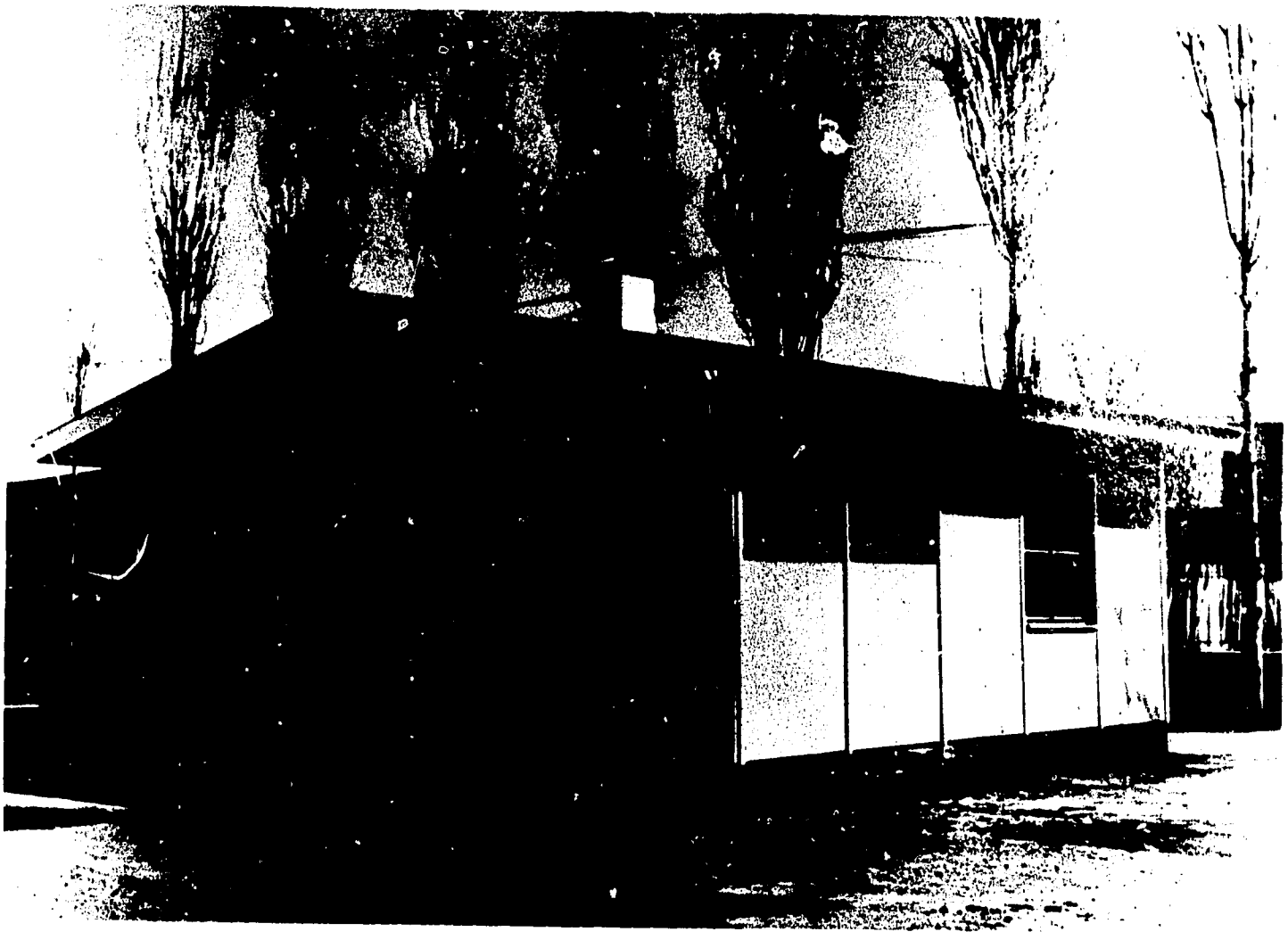
Miscellaneous Systems.

Other systems use wood or steel frames, and panels made of asbestos-cement, fiber-cement, plywood, "maderita", "mapresa", reinforced expanded polyurethane, etc. Systems in which wall panels are assembled on a cast in-situ concrete floor are also used. Extensive studies of roof panels, first developed in India, using thick cloth as both forms and reinforcement for light air-entrained concrete with pumice stone aggregate were carried out at the National University of Engineering between 1957 and 1972.

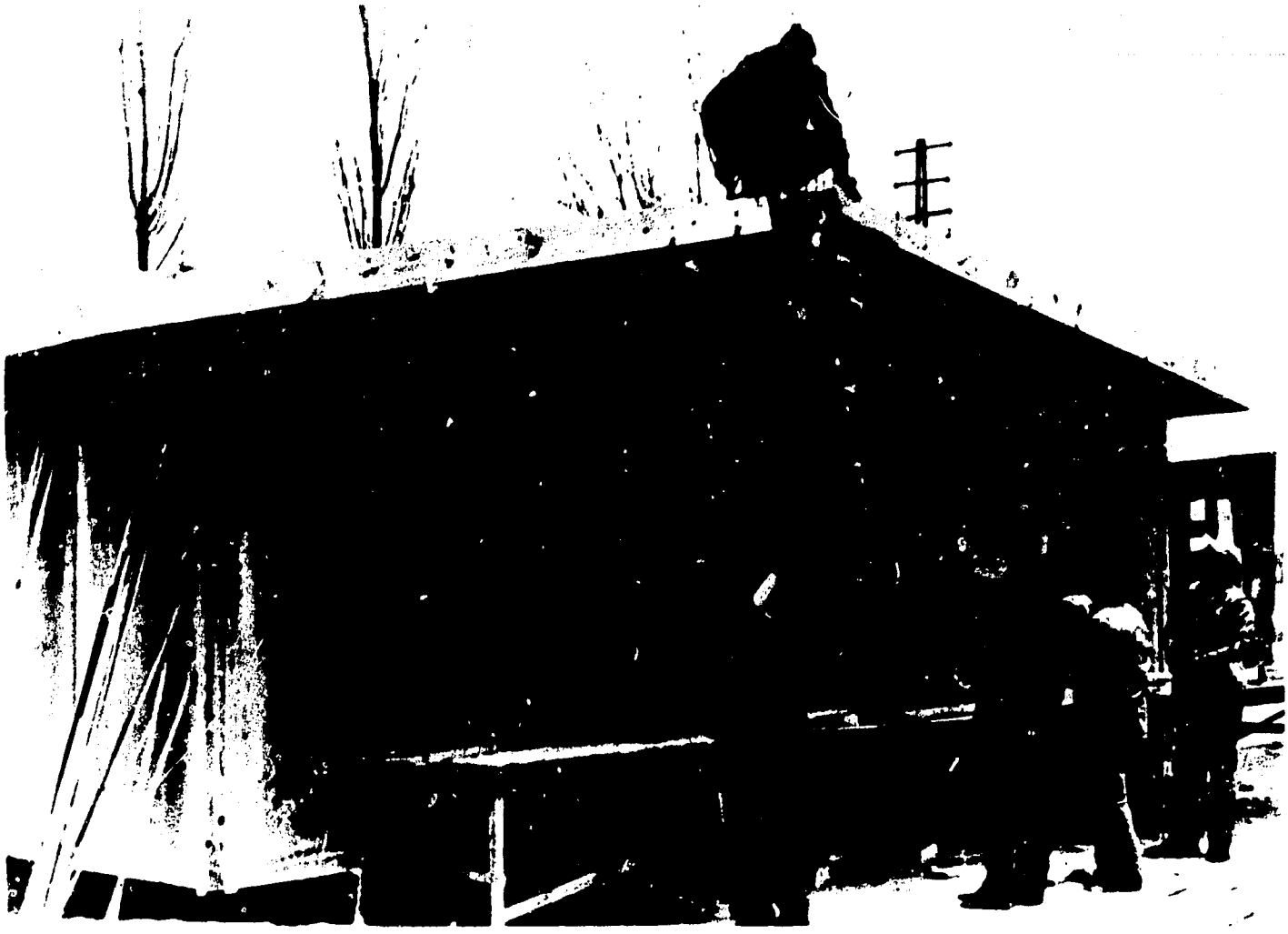


Suburb of Bingol, Turkey, 1971 Repaired Rural Type House - Home made. Note the heavy, flat roof typical for East Anatolia region of Turkey.

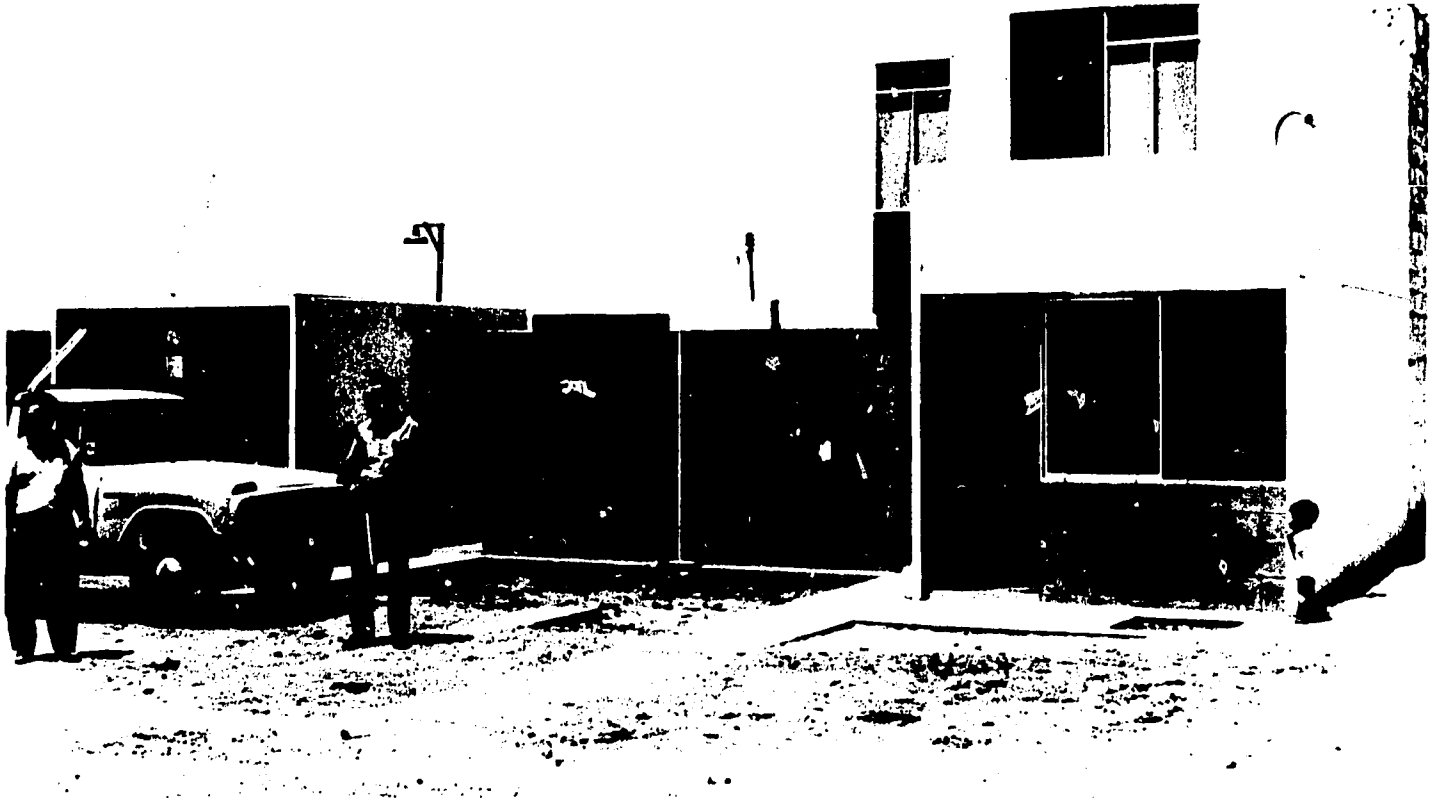
Bingol, Turkey, 1971, Three story reinforced concrete, filled cinder block walls made under control of general directorate of disaster affairs.



"IGDIR" House, prefabricated near Ankara, Turkey, 1971. Principal components; plywood, asbestos,cement, wood frame and floor, glass insulation and corrugated metal roofing.

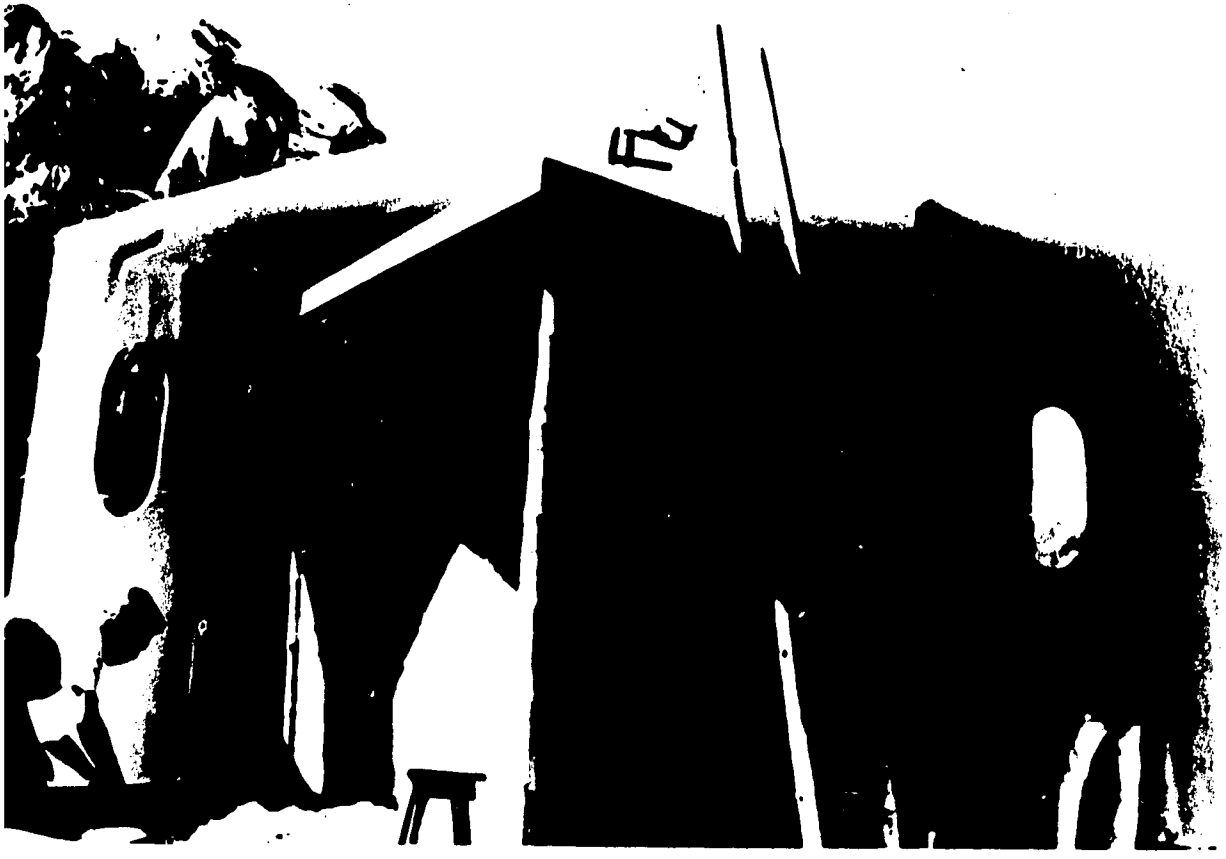


"IGDIR" House assembled on plant site near
Ankara Turkey, 1971.

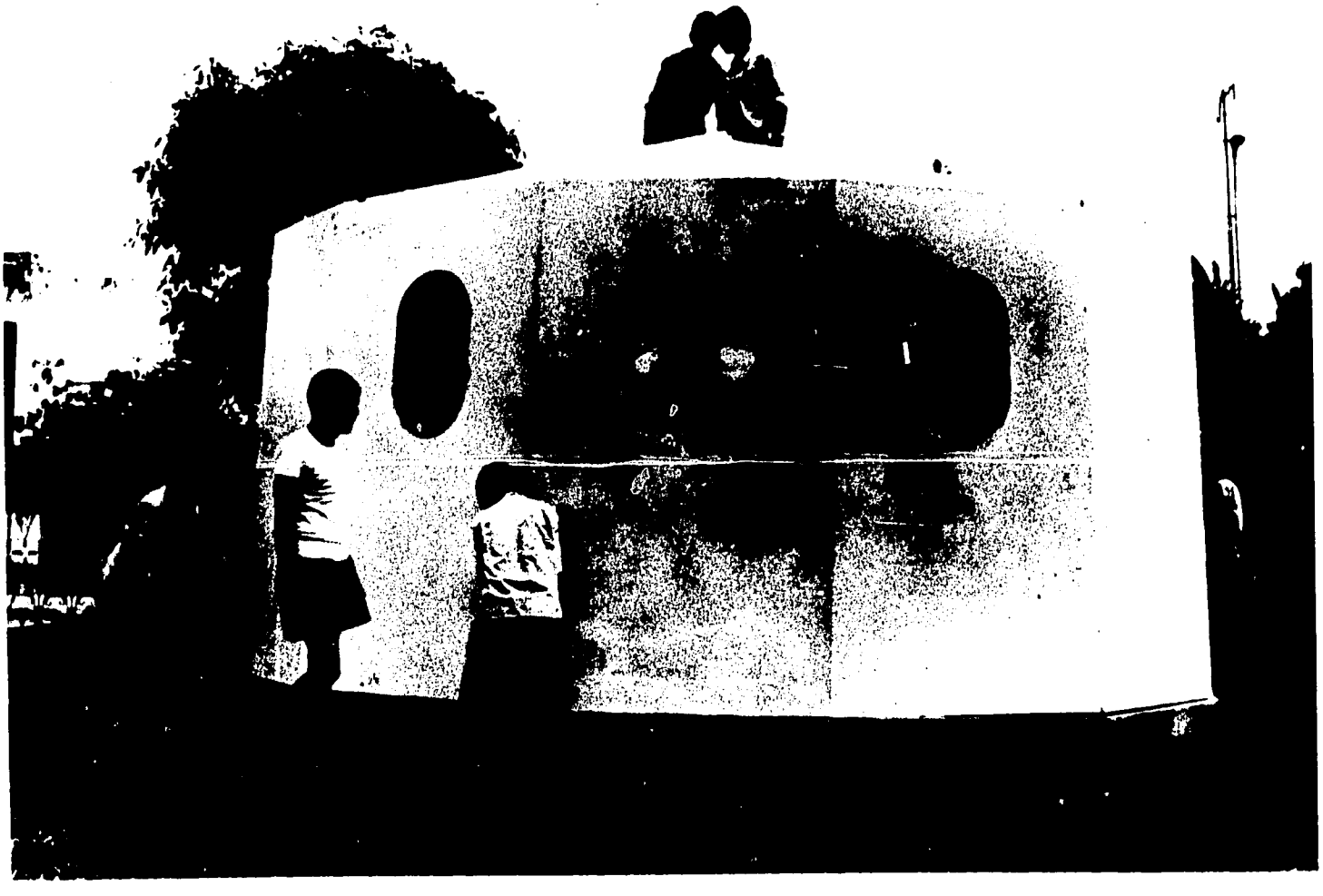


Unicrete precast concrete plant at Chimbote. Construction of demonstration homes.

Unicrete precast concrete plant at Chimbote.
General view showing transport of precast
module from plant to site.



Bangladesh - Care, Inc. "Plastic Prototype House." (1971) Interior view of three segments in place. Note variation in segments, one at extreme left does not use jute husk laminate but pure fibre glass with the necessary gusseting for this type of configuration. The other two sections are jute hust laminate each with some experimental variations.



Aligning the individual sections of the plaster dwelling in Bangladesh, 1971

House under construction in Bangladesh using cinva- ram cement-stabilized soil block masonry (courtesy of CARE, Inc.)

Chapter 7 Building Codes and Regulations

7.1 Introduction

7.2 Building Codes in the Philippines

7.3 Building Codes in Peru

7.4 Building Codes in Turkey

7.5 Difficulties Encountered in the Promulgation and Enforcement of Codes and Regulations

7.6 Building Codes, Local Conditions, and Innovative Technology

Chapter 7 Building Codes and Regulations

7.1 Introduction

Building Codes and Regulations contain mandatory requirements, one of the main purposes of which is to prevent the design and construction of structures deemed to be unsafe. In a seismic region, for example, building codes should specify the intensity of the minimum seismic loads that structures must sustain, the quality of materials and workmanship consistent with an adequate aseismic behavior of structures, etc.

In order that effective building programs be undertaken, it is necessary that building codes be developed which take into account local conditions and needs. The compilation of national seismic codes published in 1960 by the Organizing Committee of the Second World Congress on Earthquake Engineering reveals that more than half of the 70 countries which lie within the main seismic zones of the world, do not have building code provisions for aseismic construction or design. The use of inadequate building codes may have serious, and sometimes disastrous technical, economic, and social consequences. Improvement of existing building codes is therefore a required phase of any effort to provide safe, low-cost housing on a major scale.

7.2 Building Codes in the Philippines

Most municipal codes used in the various regions of the Philippines provide the basic minimum specifications--mechanical,

electrical, and plumbing--for the construction of housing units.

Code improvements which would contribute to solving the problem of providing safe and inexpensive housing on a massive scale include:

a. more strict provisions on items frequently associated with typhoon-caused damage. Such items include anchorages of roof trusses, purlins and roofing materials, and are described in detail in Chapter 4.

b. more flexibility to allow the introduction and use of appropriate innovative designs, especially those related to prefabricated structures.

Enforcement of code requirements is generally satisfactory as far as the review of plans and design is concerned. In many cases, however, code enforcement in the construction stage is not sufficiently reliable, according to local and UNESCO reports.

7.3 Building Codes in Peru

Until 1971, the planning and building of projects was handled by municipalities or district councils whose inspectors were responsible for checking and approving plans presented by engineers, architects, or contractors registered in the former Ministry of Development. The same inspectors verified the conformity of construction with the plans previously approved. In a few major municipalities, professional help was available to the inspector. In most municipalities, however, this was not the case.

Since the creation in 1962 of the College of Engineers of Peru, only engineers and architects graduated from, or associated with, the College can present construction plans.

The regulations utilized were, depending upon the type of construction or the judgement of the engineer, selected from German, North American, French, or Japaneses sources. American Concrete Institute norms were introduced by the Catholic University of Peru and later by the National University of Engineering.

In 1967 the government named a commission to formulate a unified construction code. After the 1970 earthquake the commission accelerated its work and in that same year approved the National Construction Regulations which are now in force in all parts of the country.

The National Construction Regulations of Peru are a very detailed document which represents a significant technical advance. It is believed, however, that further progress is possible in the area of aseismic design. In addition, progress can be made in the areas of standardization of adobe block manufacture and construction, of construction elements, etc.

With respect to the application of the codes, it must be kept in mind that there are still few municipalities staffed with the professional experts required for verifying the compliance of projects and of construction with the established regulations.

7.4 Building Codes in Turkey

The Turkish Association for Bridge and Structural Engineering is an unofficial professional organization established to supply technical assistance for Turkish engineers working in the fields of bridge and structural engineering. One of the main tasks of this Association has been to publish recommendations for design and construction in areas such as the following:

(i) Design loads

(ii) Reinforced concrete

(iii) Reinforced brick floors

(iv) Steel structures

These recommendations proved to be of great assistance to the Turkish engineers until the early sixties, when specifications were published by the Ministry of Public Works and standards were prepared by the Turkish Standards Institution

The control of construction of buildings in the cities and towns is governed by the Municipal Construction Offices.

The architectural design and construction project of each private building are examined in accordance with the master city plan and also with the current building codes. If the projects are found to be adequate, a construction license is issued by the Municipal Construction Office.

During the construction period and after the completion of the building, municipal engineers check the building for

compliance with the approved projects. If the building is found to be adequate, a license for occupancy is issued.

The above mentioned system for controlling constructions appears not to be always working efficiently in practice because of shortcomings existing in the current Municipal Regulation. For this reason, a more strict Municipal Regulation for controlling private construction is being prepared by the Government.

Building Code for Natural Hazards Regions: This code is composed of nine sections. The titles of the principal sections are listed below.

Section I - Limitations of the Scope of the Code: Not within the scope of the code are dams, bridges, minarets, mosques, high chimneys, transmission towers, etc.

Section II - Land on which Structures cannot be built.

Section III - Protection against Floods.

Section IV - Protection against Fire.

Section V - General Regulations for Material and Workmanship.

Section VI - Protection against Earthquakes.

(This section will be discussed in detail below.)

Section VII - Repairs

(Under this section it is required that the structures damaged by an earthquake be repaired in such a manner that they will resist a future earthquake. The section also contains regulations concerning size and location of chimneys.)

Section VIII - Earthquake Resistant Design for Building Structures.

(This section will be discussed in detail below.)

Outline of Section VI - Protection Against Earthquakes

In this Section five different types of construction are considered. These are reinforced concrete, masonry, semi-masonry, wooden frame and adobe.

(a) Reinforced Concrete Building Structures:

Specific requirements are given for the design of structural elements of reinforced concrete buildings, such as foundations, foundation connections, columns, beams, slabs, and walls. Recommendations on the design of a structure considered as a whole are also made.

(b) Masonry:

The maximum number of stories (excluding basement) that masonry buildings can have is three in seismic Zone I, and four in Zones II and III. Regulations for foundations and footings are given according to the seismic zones. Minimum wall thicknesses are also given according to seismic zones, number of stories and type of material. Three types of material are specified for walls; these are stone or concrete, brick and solid concrete brick.

(c) Semi-masonry:

These structures can have a maximum of two stories, exluding the basement. Foundation design is the same as for masonry. Minimum thicknesses are specified as a function of the number of stories and of the material used.

(d) Wooden Frames:

The code requires that wooden frame structures have a maximum of two stories excluding the basement and that each story have a maximum height of three meters. Foundations are to be designed using the regulations for masonry structures.

(e) Adobe:

For foundation and basement, uncut stones (moloz tasi) may be used. It is required that bearing walls be made of clay soil. Organic soil cannot be used for walls. In seismic Zone 1, the building may not have a flat earth roof.

7.5 Difficulties Encountered in the Promulgation and Enforcement of Codes and Regulations

The promulgation and enforcement of building codes and seismic resistant structures presents problems of particular difficulty in developing countries. For example:

(a) Many local materials have not yet been studied scientifically. Their technical design parameters are therefore not known.

(b) In many regions local geology and soil conditions have not been investigated.

(c) In many regions seismic or extreme wind records are not available.

(d) In many areas a reliable system of inspection and enforcement does not exist and is difficult to establish.

7.6 Building Codes, Local Conditions, and Innovative Technology

In order to effectively perform their function, building codes must be compatible with local conditions. This is true not only in the sense that codes in developing countries cannot be based on conditions prevailing in countries with a highly developed technical base. It is in addition necessary that, within the same country, local conditions which may vary from region to region or even within the same region, be properly taken into account. For example, modern buildings located in the Fars region of Iran were designed by Tehran engineers using criteria which did not take into account the geologic characteristics of that region. In the recent earthquake which devasted southern Fars, over 60 percent of the victims perished as a result of the collapse of such buildings, which in turn was the result of enforcing a building code in a region to which its provisions were not warranted by local conditions.

Building codes must also be compatible with local capabilities. If this is not the case, systematic evasion of unrealistic requirements occurs, and the protection offered by the codes becomes illusory.

The relationship between codes and the development of innovative technologies must also be mentioned. In order that the protection of the public provided by properly enforced building codes not be achieved at the expense of prohibitively high construction costs, innovative technical solutions,

compatible with local conditions must be sought. Rigid formulation of the codes may have the effect of hindering the development and use of progressive technologies. Properly formulated codes should therefore exhibit sufficient flexibility with regard to the adoption of new techniques.

Chapter 8. Social Factors Which Influence the Advancement of Housing Technology

8.1 Introduction

8.2 User Requirements for Basic Housing

8.2.1 General Outline of Requirements

8.2.2 Case Study: User Requirements for Basic Housing in Peru

8.2.3 Summary & Recommendations

8.3 Acceptance of Innovative Designs and of New Materials

8.4 Population Growth and Consequences for Housing

8.4.1 Population Growth

8.4.2 Family Planning

8.4.3 Urban Growth

8.4.4 Infrastructure, Municipal Facilities, Sites and Services

8.5 The Role of Social Workers

References

Chapter 8. Social Factors Which Influence the Advancement of Housing Technology

8.1 Introduction

Socio-Economic Studies. Innovative technologies capable of responding to the need for low-cost earthquake and storm-resistant housing can be successful only if compatible with local social and economic conditions. In order that existing and future constraints or barriers to the successful implementation of this project be determined, socio-economic studies were undertaken by consulting organizations in Peru, the Philippines, and Turkey.

A study format was developed by the National Bureau of Standards in order to facilitate the collation and interpretation of data. The format includes a list of 17 work items, with appropriate adjustments for the specific country, as follows:

1. Review in meaningful and appropriate detail the history of the response of different types of houses to earthquake (or typhoon) disturbances.
2. Identify climatic conditions by region and their effect on the physical requirements for housing and the social and economic patterns of the rural environment.
3. Identify the gross national product, its distribution, growth patterns and future potential.

4. Prepare a demographic analysis which shows:

   a) Where the people are moving;

   b) Village and urban population ratios;

   c) Method of settlement;

   d) Forecast of population trends through 1980.

5. Determine the average family size in different regions, nature of the family as it grows and how various parts of the house are used.

6. Investigate the trends of living space expansion in housing. Determine alternate criteria for expansion in the horizontal or vertical direction and give reasons.

7. Define the need for community and municipal facilities as they relate to existing population centers and to newly planned villages or towns.

8. Determine the range of prices that people can afford for housing measured by their income and geographical location.

9. Prepare a detailed review of the availability of mortgage funds, private and government loans, other capital sources, and their terms and interest rates.

10. Determine, by category, the availability of raw and fabricated construction materials, building elements or components and their delivered costs in different regions of the country.

11. Determine the availability of oils and asphalt material for adobe (Kerpic) stabilization. Also, determine the availability of urea, formaldehyde and other chemicals used to produce plastics.

12. Determine the scope and capacity of the housing industry, including prefabricated housing, as it exists and as it might be for the period 1972-1980.

13. Compare labor rate trends in different regions and analyze productivity in the building industry, including prefabricated housing.

14. Perform a survey to determine public reaction to the use of new designs and new materials such as plastics as construction materials in housing and suggest a marketing strategy if such innovations were used.

15. Investigate the methods and procedures of housing construction in various regions of the country. Prepare, in an order of preference, by region, recommendations defining the most favorable types of construction which would be both economically feasible and socially acceptable.

16. Identify the effective level of local building codes, code enforcement and building technology. Identify the existence and extent of illegal practices such as bribery and graft at local and national levels and the effect these practices might have on the successful implementation of this program. Determine the flexibility of existing policies and codes to accept new or innovative building technology.

17. Prepare a detailed summary of conclusions and recommendations based on the information and data collected for this study.

The objective of this chapter is to discuss the socio-economic factors which affect decision making on housing projects. The following items will be discussed: user requirements, acceptance of innovative designs and of new materials, and population growth.

The sections on User Requirements (8.2) and Population Growth (8.4) were contributed to this report by Mrs. Tarja Cronberg during her tenure as Guest Worker at the National Bureau of Standards.

8.2 USER REQUIREMENTS ON BASIC HOUSING By: Tarja Cronberg

8.2.1 General Outline of Requirements

8.2.1.1 Introduction, Housing Goals

Access to decent housing and community services is defined in the U.N. Declaration of Human Rights as a basic right for all.

A recent expert group meeting on housing at the U.N. recommended that steps should be taken to assure the universal recognition that housing is a fundamental human right and that no individual should be denied housing benefits and rights related thereto on the basis of ethnic origin, beliefs, age, sex, social and economic conditions.

The above framework has led individual countries to define their respective goals such as: "decent homes in suitable environment," "adequate and safe housing," "healthy, spacious, well planned and adequately equipped homes of good quality at a reasonable cost." These goals, although defined in very broad terms, not only take into account man's basic needs for shelter but also the creative role played by housing in the process of personal development. As a setting for man's activities, the house is an important instrument in fulfilling his physiological, psychological and social needs.

However, in spite of the recognition of the role played by housing in man's development, the world housing situation

is claimed to have become worse during the second U.N. Development decade. Words like crisis and critical state are used to describe it.

User needs and their relations to elements in the physical environment are complex and not well understood even in the most developed countries. The methodological problems encountered when identifying individual user needs and relating these to user requirements on the physical environment are often considered to account for this situation. However, a systematic analysis of the user and his requirements during the design stage with information and methods available today will--even if it may not provide a house conforming to all user needs--increase our knowledge of the user's preferences and contribute to the elimination of some of the main causes for the deterioration of human settlements.

Factors related to user requirements for safety in earthquake and storm-exposed housing areas will be dealt with in other sections of this report. The objective of this section is to focus on the remaining factors affecting the user's safisfaction or dissatisfaction with his physical environment. These factors, together with the technical factors concerned with earthquake and storm resistance, should form the basis for the design solutions and housing systems to be proposed.

8.2.1.2 Methods for obtaining information on user requirements

In spite of the lack of a valid definition for user needs, and the claims that people either don't know what they want or

tend to prefer what they have, a great deal of useful information can be gained by studying the user and his behavior in the built environment.

The methods today available for obtaining this information belong to two main categories: surveys or observations.

- Survey or interview techniques are today most widely used. This implies cooperation either with actual user groups or with reference groups if the actual users are either not known or not accessible.

Objections to the use of these techniques usually deal with the difficulty of interpretation and generalization of the results (to other user groups, to other empirical situations) and the interview situation's freedom of consequences. However, even if the people do not know what they want or cannot express themselves, questions concerning activities, features in the existing dwelling, the occupant's likes and dislikes will provide useful information as feedback of a particular design. Also, faced with meaningful alternatives (provided by actual designs, photos, plans), the occupants are able to state their priorities. By comparing the survey results, regular patterns to provide the basis for a new design, may be discovered.

- Through observation both the behavior of the occupant(s) and the built environment as such may be studied. Direct observation of occupant activities in his actual environment is theoretically the best situation. The use is often limited by

people tending to act in a different way in the presence of an observer. Also the activities will be limited by the constraints posed by the existing environment which may not necessarily correspond to an optimum situation.

Some of these difficulties can be avoided: the presence of an observer by a camera, the existing environment by simulating alternative environments by photos, floor plans and drawings. The output of the use of this technique should be data on activities, their duration, location and flow, and information on which family members are participating.

Even if the above techniques have their disadvantages and require considerable experience of the person interpreting the results, important data is provided to the designer concerning the user's way of life, his activity patterns, the type of spaces used and family members involved.

What is said above about methods to analyze user requirements applies for studies conducted in the developed countries, usually within the middle income groups in conventional housing. To study the user requirements in developing countries, in geographic areas where the need for earthquake and storm resistant housing is most urgent, several problems arise:

- When housing built by traditional methods and using conventional building materials does not exhibit the necessary characteristics on earthquake and storm resistant housing, new designs and non-traditional building materials will

most likely be recommended. No past experience data on the user acceptance and reaction to these designs and materials will thus be available.

- Earthquake and storm resistant housing is sometimes provided in an emergency situation. No time will be available for extensive studies on local user requirements.
- The techniques discussed above: surveys of users, and observations in the existing building environment will have to be modified due to the occupant's limited experience of various built environments, lack of understanding of the user's way of life on the part of the interviewer/observer, illiteracy, and unfamiliarity with strangers.

Because of these anomalies three main sources of information are recommended when gathering data on user requirements in these areas:

1. Statistical sources of information. Information is usually provided in each country concerning: birth rate, age of marriage, size of families, average income, type of employment, average family income, expenditure on housing, etc.
2. Interviews with local builders, architects or construction workers. These persons are probably the best source of information concerning the user's way of life, activities and preferences in relation to the built environment.
3. Observations of existing built environment. The information available to observations is often difficult to

interpret. Experts should have previous knowledge of local conditions.

8.2.1.3 Identifying User Requirements

The methods and sources of information for the study of user requirements were discussed above. Independent of the sources used, certain types of data should be provided in order to enable conclusions on user requirements and their consequences for design and choice of technical solutions. The information needed is discussed below, divided into two categories:

- user characteristics
- user activities

User Characteristics

Physiological characteristics of the user, of interest for design and related mainly to the requirements of confort, are:

- Physical development: size and proportions
- Motor development: the ability to move and manipulate features in the environment.
- Sensory development: sight, hearing, smell, taste and tactile sensitivity.

Data of this type, dealing with differences and variations in these respects among groups of people (age, sex, ethnic groups, urban/rural, social situation, etc.) can be found in anthropometrical studies, nutritional and medical data and in more general terms in census data.

Psychological characteristics such as the occupant's attitude and values, his intellectual and emotional development determine his identification with the community and the dwelling, his desire to maintain or modify his physical environment and his acceptance of available technical solutions and materials.

Sources of information are the occupant's past experience of housing, present housing conditions, his religious and cultural background, level of education and his social situation which are available mainly through local surveys and observations.

Socio-economic characteristics of the user include family size and structure, mobility, group identification (ethnic, religious, geographic), as well as educational background and past and present employment and income level.

Most conventional studies on user requirements seem to over emphasize the physical qualities of an environment at the expense of social and economic requirements. Instead of a minimum standard approach - providing a physical shelter - housing should be seen as a process reflecting the changing social situation of the occupant. (These aspects of housing have been stressed by both Turner [9] and Hole [2]). The economic requirements are closely related to the occupant's social situation. As pointed out by Turner, cost/benefit analysis are not sensitive for social processes and he suggests the following factors to indicate social and economic values:

- sale price of dwelling/household income
- household income/operating costs

Data on the socio-economic characteristics of the users is available through census data and sociological studies. However, these characteristics should be established for each housing project separately, through local surveys, since these characteristics may vary to a great extent even within certain income groups or geographic regions.

User Activities

User activities, as an expression of user needs, forms a link between the user and the physical environment:

- the building is built in order to establish an optimum environment for certain activities.
- the activities of the user express his reaction/adaptation to a building.

The design of a house may stimulate certain activities or make them easier whereas others will be excluded. Knowledge of activities is not only important when studying the spatial attributes of the physical environment but also for the requirements of safety and comfort as well as the need for privacy and social interaction.

In low-cost or basic housing the core of activities usually comprises traditional household activities such as food preparation, eating, sleeping, personal sanitation, storage, etc. It should be stressed that the user requirements related to

these activities may vary to a great extent, depending on indigenous characteristics, especially religious and cultural considerations, and the occupant's family and social situation.

In addition to these household activities, the activities related to the user's locomotive or manipulatory skills such as standing (the shape of the Bayer Polyurethane Shelter, for example, permits erect standing only in the middle of the shelter) entering/going out, opening/closing, should be studied as for their requirements in the house. Other activities of interest relating to the psychological acceptance of the technical solutions, are identification (pride, security), participation, learning and orientation.

Activities should be studied in relation to by whom, when and where they are performed in order to establish the activity patterns of the family members in the house.

Data can be obtained by observing the users in their environment, by studying the built environment as such, or by interviewing occupants or persons (builders/architects) involved in the building field in the country in question.

8.2.1.4 User Requirements In Basic Housing: Some Examples.

In order to demonstrate how the user requirements identified on the basis of user characteristics and activities can be used as an operational tool in planning and design, the relations between user activities, user requirements and design factors affected are discussed in view of some examples.

As stated before, the objective is not to study the user requirement of safety in relation to earthquake and storms as these aspects are treated in detail in other parts of the report, but rather to study how considerations of other user requirements may increase the acceptance of the physical investment by making it more adapted to the user and his way of life. Even as a detailed discussion of the former type requirements is omitted, it is recognized that there is often a close relationship between the user requirements on one hand and factors affecting earthquake and storm resistance on the other hand. Thus, changes in the design (added on space, etc.) made later by the user to meet his individual requirements may, in a critical way, change the characteristics of the house and consequently the building's structural resistance to dynamic stresses.

The type of dwelling to be considered in this generalized case study is defined by some of the social, economical and technical constraints identified in other sections of the report as follows:

- Family size 4-6
- Number of rooms 4-6
- Surface area. . . . . 55-65 M^2
- Services. . . . . may or may not be available
- Land. . . . . not included in cost
- Cost. $3,500-5,500

Since user characteristics are established within each housing project separately a basic activity list is considered as an example of a source of information for identifying user requirements.

In the following exhibit [1] the basic activities are listed together with the environmental attributes in a matrix form. The activities chosen represent the main household activities which the dwelling should support (either inside the house or in the close vicinity) together with activities related to the "softer" functions of the house: man's pride and feeling of security in his home (identification), ability to use and structure the information provided in his physical environment (orientation) his integration with the family and community (participation) and his process of learning when it relates to the environment and stimuli provided by it.

Exhibit 1

ACTIVITIES/ENVIRONMENTAL ATTRIBUTES

	Health and Safety	Shelter and Comfort	Functional Characteristics	Acceptance
Sleeping				
Food Preparation				
Eating				
Personal Sanitation				
Storage				
Work				
Recreation/Play				
Receiving of Visitors/ Social interaction				
Moving (inside, in/out)				
Identification				
Participation				
Orientation				
Learning and personal development				

The environmental attributes chosen for the physical environment are:

Health and Safety - referring to the protection of the occupant when performing the various activities from any disease, injury, intrusion or violence as well as loss of property.

Shelter and Comfort - related to the creation of optimum climatic conditions for the various activities.

Functional Characteristics - related to the aspects of usability (livability) and accessibility of attributes such as space and spatial relations, furnishability, flexibility and maintainability, for each of the activities.

Acceptance - referring to the design solutions acceptability to the user from the point of view of appearance, privacy/social interaction, and ability to order the information in the environment.

When considering requirements at the intersections of these two dimensions and the design factors affected, not only the house but also its near vicinity should be considered, as many of the listed activities may take place outside the house as semiprivate outside space may be more economical or functional (food preparation, personal sanitation, recreation, etc.).

In Exhibit [2] the procedure is visualized by discussing two of the activities: sleeping and food preparation, their corresponding user requirements and design factors affected as a function of the chosen environmental attributes.

When choosing the user requirements to be satisfied by the design, close attention should be paid to their compatibility and possible trade-offs. (Examples are known where the occupants preferred to sleep outside in the wind which kept the insects away; similarly, the smoke generated by food preparation inside the house is often desirable due to its insect protection.)

ACTIVITY: SLEEPING

Exhibit 2

Attribute	User requirement Concerned With:	Design Factors Affected:
Health/Safety	- intrusion by insects vermin rodents people - fire - toxic gases - water	- location - design of openings - feature for protection (nets, locks, etc.) - choice of materials
Shelter/Comfort	- optimum/desired air temperature humidity air velocity - insects - rain	(sleeping inside) - location (house) - orientation - provision of shades, etc. - choice of materials (heat absorption, radiation) - openings (ventilation) (sleeping outside in hot dry climates) - orientation (wind) - protection (insects, rain)
Functional Characteristics	- adequate space for sleeping (size of individuals, number of family members) - easy access to sleeping space - storage (daytime)	- dimensions of the house - location size of sleeping space(s) (indoors/outdoors) - storage
Acceptance	- personal space - privacy between various groups in the family (family structure, religion)	(inside) - number of rooms - provision of partitions - location of openings (visual privacy) - choice of materials (acoustical insulation) (outside) - provision for visual privacy

ACTIVITY: FOOD PREPARATION

Attribute	User requirement Concerned with:	Design Factors Affected:
Health/Safety	- fire hazard	- location/type of stove
	- removal of wastes	- openings (escape)
	- access to potable water (contamination)	- sewage and garbage disposal
	- adequate storage for food	- storage space (protection)
Shelter/Comfort	- odors	- openings (light, ventilation)
	- smoke	- location/type of stove
	- adequate light	- lighting (other than openings)
Functional Characteristics	- adequate space for food preparation	- dimension of the house
	- easy access to eating space	- spatial relations
	- access to storage space	- location/size of space
	- ability to supervise children (while preparing food)	- openings (visual contact)
Acceptance	- religious considerations	- depend on individual user characteristics
	- tradition	

The examples given demonstrate how user activities and the corresponding user requirements affect design and choice of design and technical solution. The activities chosen: sleeping and food preparation enable this to be done, because of their more or less universal character, without detailed knowledge of the user characteristics. However, in order to make similar discussion of other activities possible--and the choice of such activities adequate--more detailed information on user characteristics should be available.

8.2.2 CASE STUDY: User Requirements for Basic Housing in Peru.

As the user requirements have been outlined in general terms in the above section the main objective of this section will be to relate these to the specific information available on Peru, one of the earthquake prone areas to be dealt with in this report. Since the information available is not related to any specific housing project and/or any specific occupants, no detailed list of user requirements can be provided. The considerations presented will thus only provide a broader framework for the formulation of the individual user requirements within a specific design process.

The analysis is based on the Peruvian socio-economic study provided in chapters 8 and 9 of this report, references [8]-[11] and observations made on a trip to Peru. As suggested in section 8.2.1.3 the data will be discussed in two categories: user characteristics and user activities.

8.2.2.1 User Characteristics in Peru

The following general user characteristics for the whole population are abstracted:

- ethnic origin:	46% indians, 43% mestizos, 11% caucasians
- language:	Spanish, for the mountain indians Quenchua or Aymara
- religion:	Roman Catholic
- age distribution:	45% under 15 years, 32% over 64 years, life expectancy 59 years
- education:	55% of adult population illiterate
- rural/urban communities:	53% of population lives in communities of less than 1000 (68% of the above in communities of less than 50), migration from rural to urban areas, from mountains to costal area (expecially to metropolitan Lima)
- size of family:	average about 5 persons (mostly 4-7)
- economic situation:	yearly GNP growth 4.7%. 53% of all families are estimated to have a minimum monthly income of S/4000 of which 16-22% is spent on housing.
- occupation/ employment:	mainly agriculture, cattle breeding in the sierra (only 73% of total agricultural labor force is estimated to be employed)

This data, although it gives a general picture of the user characteristics, is too general to be useful for design discussions. This is especially true if the above data is compared with corresponding data for low-income families, to which very different characteristics may apply.

According to an estimate [11] about 300,000 persons or about 20% of the population in Peru where in 1969 living in the "pueblos jovenes" or young towns - urban communities, where the great majority have build their dwellings without having title to the land or access to community services. In 1968 the Junta Nacional de la Vivienda, published a survey on the occupations of the family heads in there communities [11] with the following results: 49% workers and artesans, 15% merchants, 12% office and service employees, 18% other occupations. Unemployment in there communities is estimated to 30% of the potential labor force. No statistics are provided on the income level, which is likely to be considerably lower than the national average.

It is this fraction of the population for which the housing needs are most urgent. This was also established in the objectives of the Peruvian National Plan 1970 which states:

> ". . . promote the improvement of housing conditions through construction of social housing and to create and improve urban and community services in those urban areas which have a need for them."

When considering the three groups of user characteristics suggested in section 8.2.1.3: physiological, psychological and socio-economic the following conclusions may be drawn (with special regard to the low income groups) of the information above:

- physiological characteristics: Little information is provided According to [11] only 4.2% on the dwellings in the young towns have potable water connections in the dwelling and only 6.7% have sewage. These facts imply inadequate health standards, why more physiological data should be provided. (medical expenditure also affects the user's economic requirements).

- psychological characteristics: One of the main factors in low income housing projects is the user's acceptance of the project and the technical solutions provided. A positive reaction will lead to pride and identification with the community and to participation in local activities aimed at the improvement of the physical environment. (Several of the young towns have through participation achieved roads, and schools, the original straw houses have been replaced by brick constructions. The reverse-deterioration of the physical environment - is true of communities with lack of identification [9]).

Several factors contribute to identification:

- Satisfaction with location: availability and proximity of employment being one of the main determinants [9]. This question must be dealt with individually in each housing project.

- Ownership and control: Title to land and the dwelling.*

Turner [9] has pointed the advantages of autonomous housing projects built and later improved by the occupant/owner as compared to identical projects where the occupant has no influence on the location, design, financing and construction and

*(Information on land ownership not provided)

where the control of the settlement is maintained by investment interests even after occupancy.

- Acceptance of technical solutions and materials. According to Conger [11] the residents of the young towns have a strong interest in building a house of "noble material" - in Lima of brick and cement ("adobe is shunned as a weak material, perhaps because it is less prestigeous than brick"). This factor will be dealt with in more detail in another section of this chapter.

A psychological factor of importance when considering the earthquake and storm resistance of housing is the attitude which the people exhibit towards these catastrophies. When they are met with fear, the occupants will be more motivated to spend more on housing of this type and to take precautions, than when the attitude is that of indifference.

- Socio-economic characteristics: As stated above in section 8.2.1.3 the social situation of the occupant should not be viewed only at a certain point of time but also with respect to trends in order to anticipate future requirements and to predict the physical performance on the dwelling as reflected by changes in the occupants social status and mobility.

The overall growth of GNP gives only a very inadequate measure of these changes in the low income group. Even within the latter group the pace of social change will vary greatly and should therefore be individually studied within each housing project. Turner discusses [9] the young towns in Lima in three different categories: communities of despair, slums of

hope and progressively developing communities. In each of the groups, changes in the occupants social situation will be reflected in changes in the physical conditions. Factors determining, to which of these groups a housing project will belong are: employment opportunities for the family, participation in local activities, social interaction and the psychological factors mentioned above. The questions of employment opportunities and participation in local activities have already been discussed. Social interaction is supposed to be very limited for newly arrived immigrant families without relatives in the city. Neighborhood kinship is developed only after several years. In the young towns the relationships are also impeded by cultural differences between the criollo - usually a coastal mestizo speaking Spanish and the serrano - an indian from the sierra speaking Quenchua or Aymaro. Class lines between these groups are maintained in the settlement until the serrano becomes a "criollo", for which he usually needs 3-4 years. Differences between these groups have been discussed by Patch [10].

In order to study the economic requirements of the users, more detailed information on the income distribution and trends should be provided in order to establish the values of the factors suggested by Turner (section 8.2.1.3) for each individual housing project.

8.2.2.2 User Activities in Peru

Information of user characteristics should be supplemented with information on user activities on order to get a comprehensive picture of the user requirements to be satisfied by housing.

In the information sources used very little data is provided on user activities. Some conclusions may, however, be drawn on the basics of the information provided on existing housing conditions in Peru. The available data is summarized below:

- 68% of the units have one or two rooms, 85% of the households living in these units have more than four members
- 16% of the households in the country are estimated to have both portable water and sewage service in the units, 70% are estimated to lack portable water and 50% are estimated to lack sewage facilities.
- 38% of the households have electricity, 45% use kerosene for lighting (remaining 17% use various other means for lighting.)
- 75% of the houses have floors of stamped earth, 54% have adobe walls and 53% have flammable roofs.

Corresponding figures for the residents of the young towns are [11]:

- 42% have portable water service in the home, for water is provided by public storage tanks and for the remaining 44.3% by trucks selling water.

- only 6.7% of these households have sewage facilities, 11.8% use irrigation ditches and 81.5% have no service at all.
- 7.6% have electrical lighting, 23% partial electrical service and 68.7% lack all forms of electrical service.

No data is available on the size of the houses or the number of family members but the percentage of households living in overcrowded conditions in these communities is no doubt higher than the overall percentage for the whole country. Because of this most of the basic activities of the household must be either staggered in time or performed partly outside the house. Because of this the question of semiprivate open space - where, depending on the climate; laundry, drying, receiving visitors, recreational activities and in some cases even cooking can take place - should be considered together with the space inside the house (possibility of trade-offs).

When listing activities to be performed in the dwelling, and which the design should support, attention should be paid to the family size and structure, the activities of a one-person household being essentially different of those of a family of five. In Peru special attention should be given to the fact that over 47% of the population is under 15 years of age, indicating that activities such as recreation and play, learning and education, child care and supervision should be provided for accordingly.

Below the basic activities listed in exhibit 1 are discussed in relation to the environmental attributes suggested by considering the design parameters or technical solutions involved. The solutions to these problems in the existing housing are presented when corresponding information is available. The list is by no means exhaustive, its objective being to clarify the proposed way of identifying the user requirements. The discussion is confined to the low income group of users, whose characteristics have been considered above.

Activity Environmental Attribute	Design Parameters	Present Solutions
<u>Sleeping</u>		
Health and Safety:	- intrusion (people/ animals)	- urban: iron gratings in windows
Comfort:	- ventilation	- rural/coast: provided through holes in the structure
		- rural/sierra: minimum ventilation to avoid heat losses, windows and other openings often blocked by adobe blocks
		- urban: windows
	- heating	- coast: not needed
		- sierra: small space (1 room), insulation by use of adobe, blocking of openings, additional heat provided by all family members sleeping in the same room, and cooking inside in the evening

- Functional Characteristics	- space and spatial arrangements	- average space provided 5-7m^2/person majority of homes 1-2 rooms
		- coast: usually two rooms, one of which is used for sleeping
		- sierra: usually only one room, providing space for all inside activities including sleeping
Acceptability:	- privacy	- family members sleep in one room, no privacy provided
Food Preparation		
Health and Safety	- fire	- open fire or kerosene stove used. Since roofs are of flammable materials, fire protection is probably provided through caution and experience (lerning)
	- storage of food	- see storage
	- disposal of wastes	- see personal sanitation
Comfort:	- ventilation	- when cooking inside see above
	- lighting	- coast: windows, holes
		- sierra: only limited daylight, windows blocked to avoid heat losses, kerosene lamps
Functional characteristics:	- space	- coast: cooking often done on a patio or semi-private courtyard
		- sierra: indoors, in the only room provided, adds to heat content

	- equipment	- kerosene stove or open fire
<u>Storage</u>		
Health and Safety:	- fire safety: storage of fuel (kerosene, wood)	
	- security: storage of personal belongings	
	- contamination: storage of garbage	- when no garbage collection is provided (rural/ some urban areas) this is either burned or dumped outside (road nearby field)
Functional Characteristics	- storage space and location food (human/ animal)	- depends on size of family, the access to stores/markets and whether the family produces its own food (agriculture or cattle). In the latter case storage space is necessary for the whole season.
	- water	- when no connection in the home, water is provided by public storage tanks or trucks, and stored in 50 gallon tanks outside the house (Need 4-5 week)
	- fuel	- health and safety
	- personal belongings	
	- sleeping equipment (during daytime to allow for space for other activities)	

	- utilities for work (artisans, farmers, etc.)	
<u>Personal Sanitation</u>		
Health and Safety	- access to water	- washing of body/clothes usually takes place: rural: on a river or irrigation ditch, drying of clothes on the ground urban: semiprivate courtyard
	- access to sewage/disposal of body waste	- since majority of the low income housing lacks any kind of sewage facilities, open air latrines in backyards, nearby vacant lots (urban) or fields (rural) are used to excrete.
Acceptability:	- need for privacy	- Most activities performed without provision for privacy
<u>Work</u>		
Functional Characteristics	- need for space when work done at home or in close vicinity/ artisans, shopkeepers, etc.	
	- storage of utilities (farmers, etc.)	
Acceptability:	- location of house in relation to employment opportunities for the family members	- urban: according to [11] only 21% of the employed work in the vicinity of their residences
	- possibility for childcare and supervision while away at work	- small children are known to be locked inside the home when parents are working

Recreation/Play		
Functional Characteristics:	- access to space	- most activities performed in the streets, football fields provided in few areas
Acceptability:	- possibility to creative and joint activities for parents and children (family cohesion)	- urban: robberies, thefts because of lack of organized activities and amount of time spent away from home by the parents - rural: participation together with parents in work (guarding cattle)
Receiving of Guests, Social Interaction		
Functional Characteristics:	- access to space	- because of the lack of private space, streets, shops and markets function as places of social contact
	- access to TV, radio, etc.	- the homes of families with TV are meeting points of the neighborhood
Acceptability:	- access of social interaction related to ethnic groups, religion, etc.	- criollo/serrano
Identification/ Participation		
	- design parameters affected should be established	

Learning

Accessability:	- location in relation to schools	- urban: most "young towns" have elementary schools, no childcare centers provided by community - urban: exposure to physical and social environment limited exposure to different physical and social environments, children exposed to delinquency in several of the "young towns"

Orientation

Functional Characteristics	- location/ orientation of home - roads, alleys - special characteristics: monuments, squares etc. - inside of home: view of the outside world

8.2.3 SUMMARY AND RECOMMENDATIONS

SUMMARY:

It is generally recognized that the provision of a physical shelter is not a sufficient goal for housing. Its acceptability from the point of view of the user; to allow for his personal development and fulfillment of social needs, is considered to be at least equally important. To achieve this latter goal two main constraints are set on the designer:

- inadequate knowledge of user requirements
- costs

The objective of this section is to deal with the first of these constraints recognizing the special importance of the user requirements in cases when new designs and the use of non-traditional materials will be considered, as is the case for earthquake and storm resistant housing discussed in this report.

Analysis of user requirements is discussed from two aspects:

- how to find the necessary information
- which type of information one should look for

It is evident that no single solution exists to fulfill the social needs of various low income groups in different geographic areas. Therefore housing should be looked upon as a process at all times corresponding to the user's social and economic situation. The process will be defined both by the level of social development as well as by the trends of development, thus enabling us to better understand why similar

physical environments in certain conditions decay and others upgrade. By studying the user's characteristics - physiological, psychological and socio-economic - and his activities, which housing is to support, the parameters of this process can be established. The combined information on user characteristics and user activities will implicitly state the user requirements to be considered in each design process.

The methods used to generate this information based on surveys and observations have been developed in the industrialized countries and may not be feasible in the geographic areas to be studied. Therefore, other sources of information are suggested, including statistical data in the country in question, interviews and discussions with local people involved in the building trade, and observations of existing built environments.

To demonstrate the approach proposed for the identification of user requirements examples are discussed both for basic housing in general and for basic housing in Peru.

RECOMMENDATIONS:

1. In order to avoid future deterioration or abandonment of the physical environment to be provided identification of user requirements for individual housing projects is essential.

2. This should be done in cooperation with local experts, familiar with the existing conditions and the user's way of life, combined with actual observations of existing built environments.

3. The information provided should include data both on the user's physiological, psychological and socio-economic characteristics and on the user's activities (all family members) for which the home is to provide a framework.

4. In order to establish priorities for the satisfaction of user requirements more information is generally needed in

- health standards in existing physical environments (urgency for community services)
- need for personal space and privacy (in the generally overcrowded housing conditions)
- contact patterns for social interaction within the neighborhood and community
- activities of specific user groups such as children and the effect of the provided physical environment on them.

5. Because of its vital importance for the development trends for the physical environment more basic knowledge should be provided on the factors affecting the user's identification with his community and dwelling and his interest in participating in local activities, as the improvement of the environment.

8.3 Acceptance of Innovative Designs and of New Materials

The Philippines

The economic advantages of standardized designs have resulted in their relatively widespread acceptance by most low and middle income homeowners, especially when, as is often the case, small individual modifications in the housing units are possible during occupancy.

Most practicing architects and engineers readily accept new construction materials which exhibit desirable technical properties and are economically advantageous.

Peru

The introduction of new construction materials in Peru has always resulted in an initial period of strong rejection, and there are very few products which have survived this reaction and maintained a place in the market.

In 1957 an attempt was made to introduce the product "Durisol," manufactured under a Swiss patent, which consists of mineralized vegetable fibers encased in cement and used for the manufacture of hollow blocks for walls, thick panels for partitions, and thin panels for facings. A feasibility study prepared by E. Keller has proved the existence of a market for this line of products, which had been widely accepted in Switzerland and Germany. A "Durisol" operation was set up in 1959 with a capital of 20 million soles (about 1.25 million dollars) but had to close down at the end of 1960 after losing its capital.

In 1965 a factory was built for the production of products of expanded (or cellular) gypsum, under the "Belroc" patent. The principal product consisted of 2.40 x 1.20 x 0.10 meter panels for building partitions. The product had good structural characteristics and was easy to handle and install; however, it was never able to expand its initial market, and the demand lessened gradually until production was stopped recently.

Other construction materials produced in Peru besides Triply are reconstituted wood, asbestos-cement products, glass fiber plastics and fiber-cement sheets.

"Mapresa" or reconstituted wood, is made of shavings or fragments of soft wood mixed with synthetic resins and then pressed. It is offered on the market as sheets of various thicknesses (.6 cm to 5 cm) and in sections of 1.2m x 2.4m and 1.2m x 3m. This product enjoys broad use in furniture manufacture, generally in veneered or duco-painted pieces, but its application to the construction of houses has been limited to temporary camps. As a construction material it possesses the disadvantage of absorbing moisture.

"Maderita" is a product similar to the above, based on sawdust. Its use in construction of housing is even more limited than that of Mapresa, as it is very fragile and brittle.

Corrugated sheets of plastic (PVC) and glass fiber for roofs, which had considerable initial acceptance, are losing their market because of high price and poor mechanical properties.

Sanitary fixtures of glass fiber, such as bathtubs and basins, have not had any better acceptance and their production recently ceased. The prices at which these products were offered did not represent any saving over porcelain or enameled iron and were higher than those of artificial granits. However, the manufacture of plastic tubing for water supply and sewerage (rigid PVC) has had success and its market continues to grow.

Fiber-cement is a product extensively used in industrial construction. It consists of wood (shavings) or cane fiber held together by cement. It is made in sheets 1.2 cm to 5 cm in thickness, 0.50 m wide and 1.00 to 2.00 m long. Its mechanical and physical properties are poor.

The introduction of "sandwich" panels based on wood has not had much success in Peru, even in building construction, where masonry walls and partitions are preferred, even though their dead weight is considerably larger. The small success of the above mentioned products in the field of housing construction is mainly due to their lack of economic advantages over brick and concrete and to the lower price of construction using the traditional adobe and quincha.

The only construction materials which have had broad acceptance are "calamina" (corrugated sheets of galvanized iron) and corrugated sheeting of asbestos-cement. Although, calamina is widely used both on the coast and in the sierra, its physical properties, especially those of thermal and acoustic insulation, are very poor. Nevertheless, due to its light weight and resistance to fracture, it can be easily and inexpensively

transported, even on the backs of beasts of burden, and this makes it much prized in the Sierra region.

Corrugated sheets of asbestos-cement have better thermal properties than calamina. They are mainly used on the coast as, because of their fragility, there is a high percentage of breakage during transport on second-class or inferior roads. The high number of sheets lost by breakage during transport and delivery in the sierra (which can reach 30% of the cargo) makes it an expensive product. Asbestos-cement is also used in the manufacture of flat sheets, tubing for water and sewerage, posts for electric wires, and other preformed products, such as water tanks.

After the May 31, 1971, earthquake, emergency shelters consisting of sprayed polyurethane domes, or igloos, developed by Farbenfabriken Bayer, Leverkusen, West Germany, have been provided in Caraz. The igloos were soon abandoned by their occupants, for the following reasons:

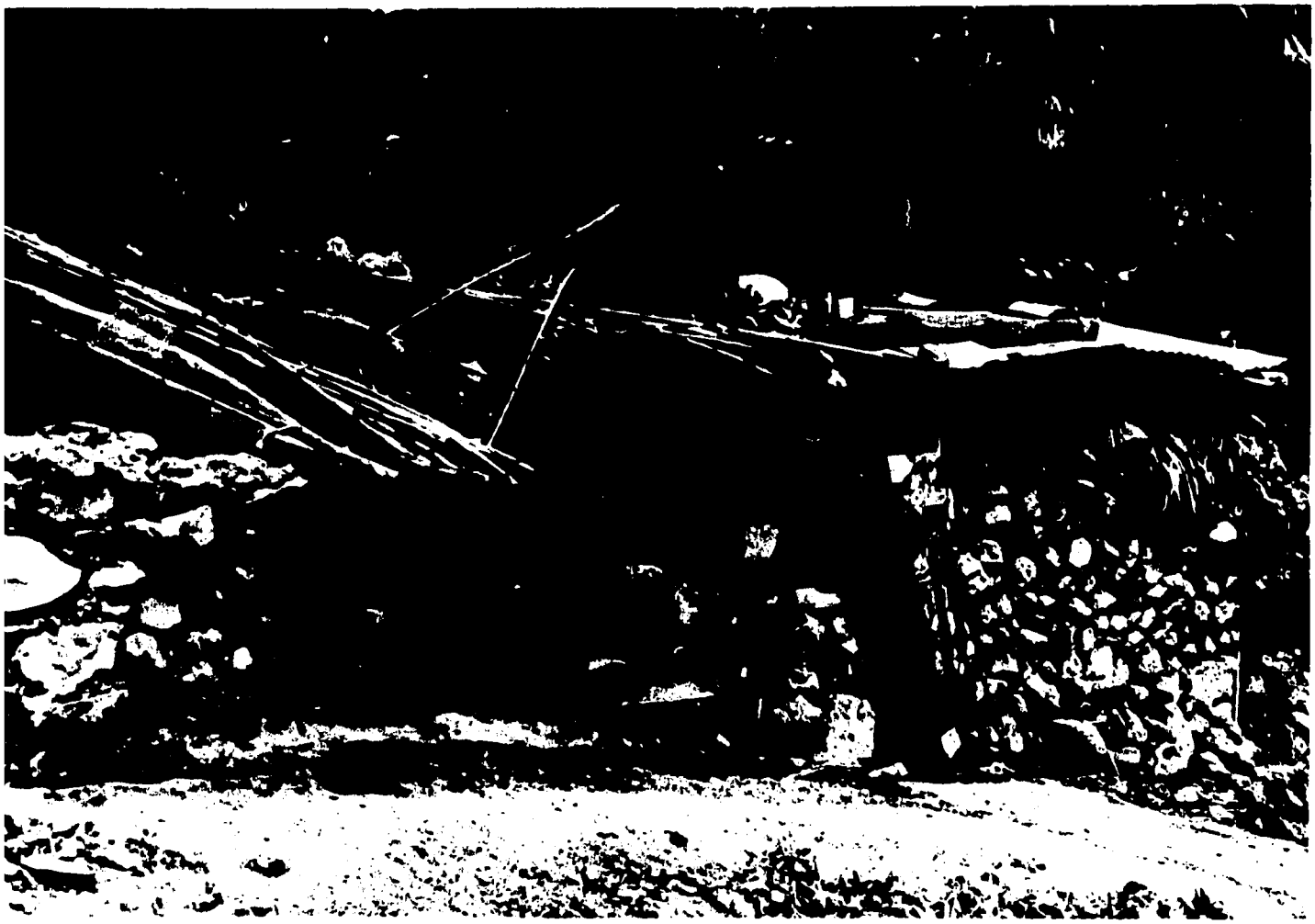
1. The lack of corner areas became a source of family strife as, in the opinion of the inhabitants, one could never put anything "out of the way."
2. The interior acoustics were such that the sound of two or more people speaking simultaneously proved unnerving.
3. The lack of property lines made it impossible to fence in animals raised for consumption.

General view of polyurethane "igloo" homes
at Caraz built by the German firm, Bayer, Inc.

"Igloo" homes at Caras. Exterior view.

Improvised kitchen facility adjacent to "igloo" home. Note failure of polyurethane shell.

Owner-built entry to "igloo" home.



Recycled portion of polyurethane shell forming portion of roof of traditional structure.

It is noted that, according to a report by Dr. Heinz Schultheis of Bayer A.G. at a recent UNIDO Plastics Meeting in Vienna, Austria, igloos provided by the German Red Cross near Gediz, Turkey, after the March 28, 1970, earthquake were also abandoned.

In a survey done in 1962 by students of the Architecture Department of the National University of Engineering with the purpose of finding out the attitude of the public toward prefabricated housing, the following conclusions were reached:

1. The lack of consumer interest in this type of housing is due to the following reasons:
   a. Prefabricated houses represent only a small margin of economy compared to brick and concrete houses.
   b. Prefabricated houses are more expensive than adobe and quincha dwellings.
   c. Prefabricated houses built enmasse have the disadvantage of being of uniform architecture.
   d. The public did not truly appreciate the savings caused by the shorter construction time required for this type of housing.

2. The lack of interest of builders in this type of housing is due to the following reasons:

   a. The market was very restricted, and this resulted in high sales costs.

   b. Because of limited acceptance of prefabricated housing, there was no system of financing prefabricated housing projects in Lima.

   c. Prefabricated housing projects in the provinces outside the area of Lima turned out to have very high construction costs because of the difficulty and high cost of freight transportation.

Housing constructed by so-called conventional procedures has greater acceptance than any new procedures that have been proposed, and at present most approved projects involve conventional construction types.

8.4 Population Growth and Consequences for Housing

8.4.1 Population Growth

In addition to meeting the user requirements the produced housing must do this in a manner deemed acceptable to the occupant and adapted to his social situation.

It has become increasingly difficult to raise housing standards and to maintain even the present quality of life in the face of the world's population growth, especially in the developing countries where two-thirds of the world's population live and where five-sixths of the 1972-80 increase in world population will occur. Such increases impose large economic burdens. In a sample of 22 developing countries in the mid-1960's, about two-thirds of the total annual investment was devoted to maintaining per capita income at a constant level, leaving only about one-third to raise living standards. The corresponding figures for a representative sample of 19 developed countries were one-quarter and three-quarters. This shows that present rates of population growth in developing countries are penalizing the hundreds of millions who are living on the margin of subsistence; if developing countries are to achieve sustained social and economic development, population growth must be controlled.

Prior to World War II, the developing countries too were characterized by high birth and death rates, and low rates of natural increase. The demographic transition began with a rapid postwar decline in death rates unaccompanied by a

corresponding decline in the birth rate. Growth rates began to increase. Today, the average is 2.8% with the level in some countries as high as 3 to 4%. Developing countries today are at various stages of demographic transition. In some, fertility and mortality both remain high. In others (most Asian and African populations) fertility is high and the death rate is falling. In still others (two-fifths of Latin America) fertility is high, but death rates are already low. In a few (temperate South America and parts of Oceania, Taiwan, Singapore, and Korea), death rates are low and fertility is declining.

In the Philippines for example, the already acute housing problem in the urban centers has been further aggravated by the heavy in-migration stream of the rural populace escaping from the underdeveloped economic opportunities available in the rural environs. The additional pressure on the urban housing stock is reflected not only on the required number of housing units which must be constructed annually but also on the already high living space densities within the already existing dwelling units. Additionally, because most of the in-migrants belong to the low-income groups, their housing requirements can only be financed with the assistance of the public sector.

To hasten the development of economic opportunities outside of the major economic centers and to likewise disperse the socially unfavorable concentrations of unskilled and low income migrant families in the major urban centers, the

government of the Philippines through the various regional development authorities and through the priority programs of the Board of Investments has favored, with fiscal incentives, those economic activities which will locate in the smaller urban centers. In addition, provinces and municipalities are starting to encourage and attract investors to set their facilities within their jurisdictions.

The increasing demand for adequate housing facilities is expected to be slowly supplied during the present decade but expectations are that there may still be a backlog by 1980. The efficient distribution of mass-produced prefabricated houses will definitely accelerate the achievement of the objectives of the housing programs. To implement these programs, the government together with whatever external assistance may be forthcoming will have participated actively not only in terms of project promotion but also in terms of financial support.

8.4.2 Family Planning

The high rates of population growth being experienced by most developing countries result from their traditional high birth rates and declining mortality rates. Improved health services and medical technology will cause further mortality declines, which will require fertility rates to be reduced from present levels simply to avoid further increases in population growth rates.

The response of governments in developing countries to the population problem has been both encouraging and inadequate;

encouraging because there has been a dramatic increase in interest and concern in the sixties; inadequate because of the size of the problem. In 1960, only three countries had an official policy designed to slow the rate of population growth; by 1971, 26 countries, with over two-thirds of the population of developing countries, had an announced policy and/or an official program, and another 24 or so, with 12% of the developing country population, supported private family planning programs although there was no official policy. By 1970, 30 heads of governments, including those of 19 developing countries, had signed the UN Declaration on Population, which characterized unplanned population growth as one of the world's great problems and called on national governments to recognize family planning as one of their vital interests.

Despite the present efforts of the Philippine government to promote family planning, household size has increased from 5.7 in 1969 to 6.0 in 1970 and is expected to further increase to around 6.2 by 1980.

Variations in sizes by locality is pronounced in the urban-rural dichotomy rather than among different regions. Rural households are larger than their urban counterparts due to the strong extended family kinship system practiced in the rural areas where relatives live with a nuclear family in the same dwelling unit.

Because the majority of households belong to the low-income group, one-bedroom dwelling units, predominantly shanties and

"accessorias," are common. Living space densities are of necessity high and most of the available spaces in these housing units are used as living accommodations. Ideally, the design of typical low-cost dwelling units should provide for at least two bedrooms.

8.4.3 Urban Growth

8.4.3.1 General

From 1920 to 1960 the urban population of the developing world grew by 255 million from 73 to 328 million.

Assuming a 2.5% general rate of population increase as being fairly typical, if 85% of the population is rural, a migration of one-fifth of the natural rural population growth will reduce the rural growth to 2% and produce an urban rate increase of 5.3%. If the existing rural/urban population ratio is 60/40, the rate of increase of the urban population will be only 3.2%.

8.4.3.2 Housing

Of all the problems of urbanization, that of providing shelter for the expanding city populations and of improving housing conditions of a majority of existing habitants appears in many respects the most difficult. Housing problems are, of course, common in the cities of developed countries; but there is a quantum difference in their problems from those of the developing countries. In the developed countries, the basic issues concern primarily social and institutional rigidities rather than a basic lack of national resources. In the developing countries, national resources including skills are generally grossly inadequate for investment of the

magnitudes required while maintaining economically productive investment.

Progress in solving the housing problem in the cities of the developing world has been, with few exceptions, conspicuously slow. It is probably true that in very few cities are housing units being constructed at more than one-third of the annual rate considered the minimum required. The housing situation is deteriorating progressively each year. Yet on all evidence the rapid growth in large cities of the last two or three decades, due to the population explosion and to rapid economic development will not slow down significantly in the next two or three decades.

In most developing countries, traditional, contemporary housing of types presently provided cannot be offered at rents or mortgage costs that the poorer population can possibly afford. At least in the case of the poorer countries of the developing world, public provision of new housing for the urban poor is not economically feasible.

One may conclude that attention should be directed much more than in the past to improving squatter settlements and slums rather than to their demolition. This in turn entails planning the growth of shanty towns, supplying a modicum of basic services and harnessing the dynamism so evident in shanty town construction and it's social organization by providing the

essential elements which the shanty town inhabitants cannot themselves provide. Nor is it sufficient to deal with the amelioration of existing shanty towns. Unless provision is made for such settlements on a more organized basis, the pressure of population growth may submerge the improvements achieved.

8.4.3.3 Slums and Squatter Settlements

For many of the poorer developing countries, the idea of improving squatter settlements will be difficult to accept. Understandable emphasis has frequently been placed on a refusal to provide less than so-called "adequate housing." In many countries low-cost housing projects have been constructed which are a source of pride. Unfortunately, for many of these countries such schemes are only marginally relevant to the size of the task.

Squatter settlements and slums are typically the fastest growing areas of cities and already frequently cover one-quarter, sometimes over a half of the city area. They exist because they can be constructed quickly and in a variety of forms to meet rapid population growth, providing accommodation at rents, if any, that can be afforded. The squatters are themselves providing a housing solution and community development, rudimentary but effective. In their expansion, they are shaping the fundamental structure and character of the urban areas.

By dawn what had been a barren parcel of real estate becomes one of Lima's new Pueblos Jovenes, or young communities, as the barriadas or slums are sometimes called.

This was how El Salvador, Lima's newest slum, was born last fall. Today it has some 130,000 inhabitants.

All told, more than a third of this capital's three million people live in such shanty towns, despite a housing boom that is shattering construction records each month.

El Salvador was conceived perhaps three years ago, according to social workers interviewed in older slums. Probably the idea took hold after the birth of a slum at that time.

After the migration from the downtown mansions and other buildings and older shanty towns took place, the squalid dwellings began filling up with new arrivals from countless Andean villages and towns.

Those who drift down from the highlands into older shanty towns quickly become a problem to their hosts. The traditional organizational ability of the descendents of the Incas, however, produced a ready solution.

The elected leaders of the older communities organize the newcomers and begin seeking a new site. A committee is formed to survey the site, usually an idle parcel of land.

Careful note is taken of existing buildings, if any, and the nearest police post. Then the site is mapped and divided into plots. Major and minor streets, community houses, space for shops, etc., are defined.

Self-help and community action are typical of squatter settlements. More permanent structures and facilities are constructed as the settlement becomes more established. High morale of the inhabitants is evident in most squatter settlements. This provides hope for dealing more effectively with the housing problem than has been possible so far.

The following is a description of the history of a typical squatter settlement in Peru.

"On a given day the migrants gather at dusk in the courtyards of dozens of former palatial mansions and elegant business houses that today barely hide Lima's decaying downtown slums.

As they await the signal from their elected leaders, the slum dwellers roll their esteras, or woven fiber mats, about sturdy poles and put their household goods in sacks.

The signal is given as night falls, probably in Quechua or Aymara, the languages of Peru's highland Indians. Then, quietly, hundreds of people move out of the courtyards and alleys to board decrepit trucks for the ride to the city's outskirts.

There they are joined by hundreds of others from nearby shantytowns for a night of frantic work. The poles are driven into the sandy soil and the mats become walls and roofs.

Meanwhile, the prospective tenants have begun to gather the basic materials needed for their new homes - poles and fiber mats; and at the given signal the operation begins.

Invariably the startled landowner calls the police. The police order the huts removed. Angry words are exchanged, shots fired, and a few people killed and injured and the police report that they have left the area to avoid further bloodshed.

The matter is then placed in the courts and soon forgotten. Hundreds of new migrants begin swarming into the slum. Leaders are elected and committees formed to procure basic services from the city, such as water and electricity.

Shops are opened, public and private bus companies extend their routes and within a year or so the new community acquires an established look.

Gradually the mats are removed and walls of adobe rise. Billboards from nearby highways become roofs.

The committees, using volunteer labor, frequently collect rubbish and pave streets and perform other services normally expected of municipal governments.

Lately, with government assistance, the existing slums have been given water, power, telephone service and medical clinics as well as transport facilities. Temporary schools are sometimes included, although the language and culture barriers often make them ineffective."

One of the consequences of the emergence of squatter settlements is that landlords have given up whatever efforts they

previously made to maintain their properties.

The following figures present a summary of slum and squatter conditions in selected developing countries at various dates. While the population in developing countries typically grows at 2 to 3% per year, and urban populations grow at 5 to 6% squatter settlements commonly grow at rates of 12%, and sometimes 20%. At 12% growth per year, the population doubles in less than 7 years.

8.4.4 Infrastructure, Municipal Facilities, Sites and Services

8.4.4.1 General Problems

Major cities in developing countries vary so greatly in their urban characteristics so as to make generalization particularly hazardous. Nevertheless, certain common problems, varying in intensity from one city to another, exist. As a rule, large growing segments of the poorer elements of the population are located in pockets on the outskirts of the town where land is often acquired by squatters as was described in the preceding section. Other segments are concentrated in central districts in dilapidated older buildings. In general, central locations are severely limited, and progressively the poorer elements of the population are forced to live far from their work. Even on the periphery, however, the price of land and construction place the provision of housing of minimal standards at rents sufficient to cover costs beyond the capacity of the poorer elements of the population.

Water and sewage combined probably amount to 10% to 15% of urban capital investment in the larger cities. Sewage facilities present a particular problem when the city has expanded into a metropolis, often by incorporating unsuitable ground. The cost of providing sewage facilities may then increase out of proportion with the value of the houses to be served.

Costs of education and health amount to approximately 15 to 20% of urban infrastructure costs. These costs appear not to depend strongly on the degree of expansion of a city.

The electrical power distribution costs appear typically to present a relatively small proportion of total infrastructure costs.

8.4.4.2 Sites and Services

Given the impracticality of eradicating slums and squatter settlements, emphasis should be placed on development of innovative low-cost housing designs and of low-cost methods of improving existing settlements.

What can reasonably be accomplished can only be decided in the local setting.

It is suggested that new development areas with minimum services be provided for self-help housing. For example, in the World Bank's pilot scheme in Dakar, Africa, attention is centered on provision of the barest housing infrastructure and the stimulation of self-help measures in actual construction work. The cost of providing land, basic infrastructure and utilities was estimated at $800 per unit against $4,700 for the average cost per housing unit in 16 public housing programs.

8.4.4.3 New Committees

An alternative to unplanned reconstruction of damaged communities is to construct a new community at a new and, if feasible, safer site. In Iran after the recent earthquake of April 10, 1972, post-disaster plans are being considered whereby the survivors of the earthquake can be resettled in three or four agricultural villages which are the basic elements of large farm corporations along the lines of 32 such units that already exist. Such a plan might be expanded in the future to identify and designate appropriate new community sites in advance of the actual need.

8.5 The Role of the Social Workers

The role of social workers is central in preventing any program from being too mechanical and losing sight of the human dimension.

The social worker should enter into the community long before any program or project is undertaken. Many future projects can be successful if there is someone who really feels the pulse of the community.

The social worker should be trained and prepared in the best professional manner, with an in-depth knowledge of the project envisioned for the community.

The social worker must, at the same time, have access to those doing technical planning, conveying to them the real sentiments and aspirations of the community. Subsequent collaboration depends greatly upon this communication.

In the Philippines, the Department of Social Welfare has decentralized and expanded in social services by setting up eight regional offices. These offices are authorized to make all necessary decisions to suit national programs to local needs. evicted squatters are given special attention with financial and material aid, counselling services, training in vocational skills, self-help projects and relocation to designated sites for rehabilitation.

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Chapter 9 Economic Factors Which Influence the Advancement of Housing Technology

9.1 Introduction

9.2 National Economic Policies

9.3 Housing Programs in Developing Countries

9.4 Economic Factors Directly Affecting Housing Construction

9.4.1 Land Use

9.4.2 Labor Rates and Productivity

9.4.3 Availability and Cost of Construction Materials

9.4.4 Credit Mechanisms for Housing

9.1 Introduction

This chapter will examine the relation between economic conditions and policies in developing countries on one hand, and housing problems and their solutions on the other hand. In addition, economic aspects of large-scale housing programs will be discussed, as well as economic factors, such as "labor rates and productivity, availability and cost of construction materials, land prices and credit mechanisms, which directly affect the housing construction sector.

9.2 National Economic Policies

In order that the basis for mass markets for manufactured goods of lower import content be created and that a stimulus be provided to growth and employment, a more even income distribution within the developing countries must be achieved.

It is widely recognized that a large gap exists between incomes in the towns and those in the countryside. The average gross domestic product in the major urban centers of the developing countries may be three to five times that of rural areas, with a somewhat lower differential for the smaller towns. Even allowing for higher prices in the towns, the gap is wide and, on somewhat scant evidence, appears to be widening. A similar situation exists with a small and increasingly wealthy group separated socially and often physically from the poorer mass of the population.

This situation reflects the impact of the technological revolution, an impact much sharper than it was in today's

developed countries. The differences between productivity in the contemporary and the traditional sector are much greater than they used to be--for production of non-agricultural goods, for agriculture, and for services. Not until modern technologies are accepted much more widely in both urban and rural areas will the underlying causes abate. While the choice of technological alternatives will play a large part in the speed of diffusion of impact, the time required should still be measured in decades for most developing countries.

Present trends and the pressures of population and labor force thus indicate a further worsening of income distribution over the near future at least.

Reasons similar to those discussed above dictate that economic policies be pursued which tend to reduce the gap between various regions within a developing country.

One of the effects of helping the development of rural areas is the decrease of the migration from these areas into urban centers. Savings are thus achieved in housing, infrastructure and welfare costs, which are lower in rural areas than in cities.

The areas of contrast between the population of the slum community and that of the urban center should also be pointed out. The urban population has a greater degree of urbanization, economic power, health and education. Its labor force is relatively organized both for job protection and for salary increase. Generally speaking, the level of skill and the productivity of its labor force are high Its greater degree of urbanization is

reflected by a lower birth rate, together with lower infant mortality rates. The result is that the urban-center labor force grows more slowly.

By definition, the population of the slum community is less urbanized, with considerably less income and educational formation. The labor force that it produces is inferior to that of the urban center in terms of the level of its skills and the degree of its organization. The typical slum worker is unskilled or semi-skilled, and probably is more apt to be undernourished and sickly, although this difference has yet to be proved. The slum labor force tends to grow proportionately to the urban labor force, with the result that the urban market has an increasing supply of unskilled labor in the face of a relatively inelastic demand.

The relative lack of labor organization within the slum puts the slum worker in a weak position in terms of job and salary protection. As an unskilled worker, he is more likely to lose his job in periods of recession. As an unskilled worker unsupported by a labor union, he is more likely to find his real salary decreasing in times of inflation. In this connection, it is important to remember that a substantial proportion of slum workers are self-employed as street vendors and odd-job workers.

The labor force differential between the slum and its urban center becomes even more important in terms of production. Like any developing economy, the slum community tends to produce

primary goods and to export them in order to gain the exchange necessary to import goods and services. In the case of the slum community, its main production for export is unskilled labor. Unskilled labor time is purchased by private enterprise in the city, by the various Government agencies, and by private citizens in need of part-time labor services. There is also a small market for unskilled labor within the slum community, but this may be largely non-monetary.

The important market is that of the urban center. This market has several characteristics. First, the urban center tends to establish the price for unskilled labor based on supply and demand factors within the urban center itself. The individual slum worker is in no position to bargain, nor is he protected by a vigorous labor organization. The fact that the supply of slum labor tends to increase rapidly also exercises a depressing effect on wages.

The slum worker has less defense against the salary squeeze resulting from inflation, because he is less organized, both economically and politically, than his urban counterparts. He is therefore an easier target for inadequate, Government-controlled, salary raises. This inequity is even harsher for those who work on their own, receiving the wage they are given, or who receive some form of pension which has little anti-inflation protection.

Inflation tends to accelerate certain economic activities within the urban center, especially construction activities.

In the short run, these activities may generate jobs for unskilled workers; but the inevitable changes in the rate of inflation immediately affect such activities and therefore the demand for unskilled labor. Jobs and income of the slum worker are highly sensitive to changes in economic activity; Government efforts to stabilize the economy by reducing economic activity can increase the economic insecurity of the slum labor force.

Inflation works to the special disadvantage of the slum community in its needs for housing. Slum families have the least adequate share in the housing market and in the output of new housing services. A commonly observed phenomenon is that costs in the housing sector rise faster than other costs. This means that the group of families most in need of new construction and least able to defend itself against inflation is particularly prejudiced when it comes to the purchase of new or improved housing services. The same argument holds true in relation to rising land prices.

The burden of the argument that flows from the foregoing analysis is that the incidence of inflation falls more heavily on the normal slum family than the normal urban-center family. It may be an over-simplification to conclude that inflation makes the poor poorer and the rich richer; but it is certainly true that a slum community integration policy which does not take into account the differential impact of inflation on the economic capacity of the slum family can scarcely hope to be successful.

9.3 Housing Programs in Developing Countries

The Inter-American Development Bank (IDB) ("Financing housing in Latin America's urban settlements", working paper No. 11 prepared for the United Nations Interregional Seminar on Improvement of Slums and Uncontrolled Settlements, Medillin, Columbia, 15 February-1 March 1970.) distinguishes two basic approaches to the housing problem in Latin American countries.

The first approach envisages the problem as one of insufficient quantities of standard modern housing units, coupled with inadequate financial resources to remedy the situation. In the second approach, housing is not judged by an arbitrary standard which may be unrelated to the social, cultural and economic levels of the residents. Rather, housing is evaluated on the basis of how well it facilitates access to areas where family activities occur daily, how adequately it provides protection from a hostile environment and to what degree it assures security of tenure. In other words, "traditionalists" are more aware of the appearance of the housing; while "environmentalists" are concerned with the way in which the housing accommodates the residents in relation to their life situations.

The traditional approach which is frequently used for planning housing programs has been criticized for the following reasons. First, housing deficits are calculated arbitrarily without taking into consideration the values or preferences of the persons to be housed. Secondly, some calculations of housing deficits show the traditional solution to be well

beyond current capital investment rates. In the case of Latin America, for example, the traditionally conceived housing deficit in 1967 was estimated to be about 22 million units, projected to be at least 100 million by the year 2000. It was estimated that it would be necessary to build more than 3 million units per annum in order to eliminate the deficit over the period to that time. If each unit of land cost only $US 1,800, the annual investment in housing would be $US 5.4 billion, or 6.6 percent of the regional gross domestic product at 1967 levels.

Even in developing countries in which the expected rates of growth are relatively high, the competing demands of development programs in agriculture and industry leave funds available for housing construction in amounts far inferior to actual needs. It is therefore necessary that self-help be encouraged for the partial fulfillment of these needs. For example, in Peru the Organismo Nacional de Desarrollo de los Pueblos Jovenes has the responsibility of studying, planning, proposing and co-ordinating programs to intensify efforts at incorporating slum-dwellers into the development process. More than 20 percent of the urban population (over 1.3 million) live in squatter settlements; some 78 percent are entirely without services, 10 percent have only electricity, and just 12 percent enjoy water and sewage facilities. Under such conditions, "site-and-services" type schemes warrant emphasis. Several laws were passed in 1968-69 for the purpose of facilitating

improvement of these conditions; the progress achieved has been so far relatively slow. In Turkey, where the urban and rural housing requirements for the period 1968-1972 have been estimated at 900,000 and 300,000 respectively, the second five-year plan aims specifically at encouraging self-help for squatter house dwellers, by providing roads, basic services, etc., and allocating plots and making long-term loans in order that houses be built by their future dwellers themselves.

For the period 1960-1980, it is estimated that 5,790,000 additional new houses will be needed in the Philippines, plus another 3,640,000 owing to replacement, obsolescence, disuse, disrepair, and natural disasters. This would call for twelve new dwellings per 1,000 population, requiring about 5.7 percent of the gross national product. Whereas in 1965 only 1.5 percent of the gross national product was invested in housing, 2.8 percent was invested in 1967. In either case, the small investment did not create conditions benefiting the low-income groups. As a result, slum and squatter conditions accelerated; and 10 percent of the total population of Manila and 30 percent of the population of Jolo City, Luzan, Visayas and Mindanao currently live in slums.

In the Philippines self-help (of which some aspects were described in Ch. 6) is used extensively for the construction of dwellings and buildings.

The magnitude of the task involved has led to government involvement in the housing construction sector in a large number

of developing nations, among which are Peru, Turkey, the Philippines, and Iran.

9.4 Economic Factors Affecting Housing Construction

9.4.1 Land Use

Land use is regulated by building codes, legislation on zoning, on pollution, on public purchase of land, and by taxation of land and property. The problems connected with land use are zoning of industry and housing, consolidation and acquisition of land for specific purposes and reduction of land speculation.

Ineffective land use regulation and inadequate policies of public acquisition of land present a serious obstacle to rational urban development.

To the extent that provision of subsidized housing is not feasible, "site-and-services" type schemes, whereby land is provided for self-help housing may offer an interim solution.

9.4.2 Labor Rates and Productivity

Peru. Salaries paid in civil construction in Peru are fixed by the government. Generally, salary changes are a consequence of long-standing demands by labor unions and are retroactive, at times up to 6 months, producing difficulties for the construction industry. In the Peruvian socio-economic study, Table 1 gives basic salaries for 1969 and 1970. The 1970 figures, valid for the whole year, were decreed on February 23, 1970.

In the table it can be seen that a general increase on the order of 12% took place during this period, and no further

increase has occurred to date. Also it can be noted that there are no major variations between wages within a single region, save for such exceptions as the case of Metropolitan Lima.

Outside the Lima area foremen and specialized operators are not available so that it is necessary to bring in labor from the capital for many projects in the provinces. On projects in isolated areas, which have their own construction camps, personnel are given food and lodging at an estimated cost of S/50.00 daily per person. In cases involving minor projects, without their own camps, an additional amount of approximately S/180.00 is paid per person per day for food and lodging.

By official decree the Ministry of Labor has fixed minimum output standards for labor in civil construction for the area of Metropolitan Lima.

Table 2 summarizes these minimum output standards which are really a measure of the productivity of labor at the present time. In practice, to obtain a higher output it is necessary to offer some program of economic incentives, which even if they do not decrease construction costs, do often reduce the time needed for the completion of the project.

Decrees of minimum output standards have not been issued for work areas outside Metropolitan Lima, but in general it is accepted that productivity is about 10 percent less.

The construction sector is known in Turkey as one of the most financially unstable sectors at present. This is due to the contractors who try to earn money in the shortest possible

time with a minimum of capital. Then generally, the work is hard, and the salaries are medium.

Wages of technicians and surveyors are generally between one half and two thirds of what architects and engineers earn.

Salaries of architects, engineers and technicians employed by the State have been increased by 200 percent in the period 1950-1955. Therefore, the salaries in the private sector were increased too, and the members of the construction sector were among the best payed people, for years. But the situation is now quite different and practically no difference exists among the labor wages of different sectors.

Turkey. The salaries of craftsmen vary considerably according to specialities (from 40 TL to nearly 100 TL daily). Plasterers have the lowest salaries. Masons earn slightly more, although less than carpenters. The mechanical trades get the highest salaries. No statistical data regarding the differences in salaries between rural areas and cities and between regions are available.

For unskilled workers who constitute 70 percent of the manpower employed in the construction sector, the labor law of 1969 had fixed the minimum gross salaries between 15.50 TL and 19.50 TL daily.

Recently, the Government has investigated possibilities of fixing higher minimum wages. While the conflict between trade unions and contractor firms on this subject has not yet been solved, it appears that a rise of approximately 30 percent in all regions will be applied.

The unskilled workers in the construction sector are paid at most 20 TL. per day on the basis of minimum rates in Eastern Anatolia (East of the Samsun-Gaziantep line), while the Western region salaries are slightly higher and can reach 30 TL. in July and August.

Unskilled Labor in Developing Countries. Relatively small amounts of capital combined with properly utilized large supplies of unskilled labor may result in significant increases of both output and employment. Given the considerable weight of the construction sector in the national economy, particularly in the case of developing countries, such increases produce in turn important beneficial effects on the development of the economy as a whole.

9.4.3 Availability and Cost of Construction Materials

The Philippines. In the Philippines construction materials together with the skilled labor needed in conventional methods of construction are readily available. Delivered prices of materials are reasonable because production is dispersed throughout the country. The potential for cost reduction exists notably in the area of bulk handling and of delivery. Prefabricated construction components are relatively expensive because the current size of Philippine markets is not large enough to achieve economies of scale and because transportation and distribution costs are high.

The chemical process industry for plastic products is small, protected by high tariffs and generally produces simple types of household construction materials.

Under the recent Investment Incentives Programs, the seventies will witness the development of larger and more complex chemical process plants and of an integrated petro-chemical complex base. Judging from the experience of countries which do possess such a base now, it is doubtful that the capability to produce plastic materials will have a strong impact on the construction industry in this or in the next decade.

It may be stated that, in general, material costs do not constitute an important economic factor as far as housing construction in the Philippines is concerned.

9.4.4 Credit Mechanisms for Housing

Turkey. Credits for low-cost housing are mainly provided in Turkey by the Social Insurance Institution, by the Real Estate and Credit Band and by the Pension Fund. A description of the conditions and procedures for granting dwelling credits is given below for two of these institutions.

The Social Insurance Institution: The Social Insurance Institution is a large organization that provides medical and social care for workers. Dwelling credits are also provided to the insured. The conditions and the procedures of dwelling credits are shortly given in the following:

(a) The insured individuals who want dwelling credits must form a cooperative.

(b) To be entitled to a dwelling credit, the insured, his wife or husband or children should possess no dwelling and have received no credit from the Institution.

(c) The insured or his relatives should not be members of any cooperatives formed for similar purposes.

(d) The insured should have paid a certain amount of premium to the Institution.

(e) The dwellings to be built should befit the social dwelling standards.

(f) No credit is provided for dwellings outside the municipal areas of cities or towns or in settlements with a population less than 10,000. However, the Institution may approve exceptions after conducting a survey.

(g) No credit is given for dwellings with a gross area larger than 100 square meters.

(h) The maximum amount of dwelling credit is TL. 60,000, regardless of the income of the insured.

(i) The term of credit is 20 years and the rate of interest is 4 %. The term starts from the date that housing permission is given.

(j) The payment is done according to a payment plan, based on equal monthly payments.

(k) The dwellings may not be sold to another person for a 10-year period.

The credits provided by the Institution in the years 1969 and 1970 were as follows:

Year	No. of Dwelling Units	Value (TL.)
1969	1,449	45,527,129.00
1970	1,649	55,000,495.00

The Real Estate and Credit Bank: The Real Estate and Credit Bank is the main bank that provides credit for dwellings. It is connected to the Ministry of Reconstruction and Resettlement. The requirements and procedures are shortly given below:

(a) The bank opens a "Dwelling Saving Blocked Account" upon the request of the individual.

(b) This money is not subject to interest or to any kind of lottery for encouraging savings.

(c) The quality of the dwelling should conform to the related regulations.

(d) The person, his wife or husband or children should not possess a dwelling and should have received no credit from the bank.

(e) The nominal value of the saving account can be between 10,000 TL., and 50,000 TL.; this is called the contract amount. This includes the amount deposited in the bank by the individual as 25% of the total amount.

(f) The contract amount can be increased or decreased, provided that it remains between the upper and lower limits, and the approval of the bank is obtained.

(g) No money can be drawn from this account. Only under obligatory conditions the bank may approve a partial payment. In this case, the priority points of the person are reduced accordingly.

(h) The individual may cancel the contract at any time with a written application.

(i) The individuals who can preserve the account in the bank for at least two years, who deposit 25% of the contract amount in cash, are deemed as qualified to receive dwelling credit.

(j) These rights can be transferred to children, father, mother, wife or husband, provided that the bank approves. A second transfer is not accepted.

(k) The term is 15 years and the annual interest is 6%. The interest rate may be, however, subject to change if new rates are stipulated by the State.

(l) The money can only be used within the boundaries of the municipalities and the urban reconstruction areas.

Chapter 10 Synthesis of Feasible Technical Improvements

10.1 Introduction

10.2 Stabilized Soil Building Blocks

10.2.1 Oil-Stabilized Adobe Blocks

10.2.2 Polymer-Stabilized Adobe Blocks

10.2.3 Lateritic Stabilization

10.3 Composite Systems

10.3.1 Structural Sandwich Panels

10.3.2 Bamboo Reinforced Concrete

10.4 Prefabricated Housing

References

Chapter 10 Synthesis of Feasible Technical Improvements

10.1 Introduction

The preceding chapters have defined, in broad terms, the various factors to be considered in determining the feasibility of improving the dwelling environment. Social acceptance, national and individual economics, construction methods and materials, codes and regulations, and design modifications comprise the baseline from which a synthesis of feasible technical improvements can begin.

Innovation is sometimes a process of simplification or a unique application of existing systems or techniques. The following sections explore innovation in context with this thought. Section 10.2 on stabilized soil building blocks identifies the existing potential of oil stabilization for the manufacture of the basic building block component. Polymer and other chemical stabilization procedures appear worthy of further investigation, particularly in those countries where there is an abundance of lateritic soil.

Innovation in building systems where the structural sandwich panel is utilized appears to merit serious consideration for application in developing countries where labor intensive production and local materials are used to create new methods of building technology appropriate to the region.

The over-all goal of these innovations can be consumated in the development of building systems utilizing modular

components in various schemes, with future provision for the ultimate luxury of complete "mechanical cores" capable of utilizing electrical or solar energy.

10.2 Stabilized Soil Building Blocks

Among the numerous and varied methods of soil stabilization currently in use, the following methods appear to offer the highest potential for innovation and improved performance in low cost housing.

10.2.1 Oil-Stabilized Adobe Blocks.

The principle of stabilization of adobe is based on the instability of clayey soils in the presence of moisture. By mixing a rapid curing oil or emulsified asphalt with water and a clayey soil, the oil globules cover the surface of the clay particles and remain after the water and curing agent evaporate. The oil film repels moisture thus eliminating the expansive characteristic of the clayey soil.

Rapid curing road oil or emulsified asphalt stabilized adobe block or bricks exhibit desirable characteristics of good insulation, impermeability, erosion resistance, vermin and termite resistance and durability. The block or brick is relatively maintenance free and need not be plastered or painted which significantly reduces construction time and labor costs.

Generally speaking, sun dried adobe block or bricks are less expensive than common fired-clay bricks or concrete blocks.

The cost to manufacture the adobe block or brick varies with the method of manufacture, the characteristics of the soil, and the cost of delivery if the block or bricks are not made in the immediate vicinity of the construction site. The price of adobe block manufactured by hand in Cuzco, Peru was about .05¢ per block in 1971, and was approximately doubled by delivery costs.

10.2.2 Polymer - Stabilized Adobe Blocks

The potentials of oil, lime, sulfur and portland cement stabilization of soil have been identified although not always fully exploited as in the case of oil stabilization. An example is the controlled production of adobe block or the use of the "CINVA-RAM" process of mixing cement, aggregates and soil and compressing the mixture into a steel mold using a simple hand-operated device. Chemical stabilization techniques of soil for intricate or unstable excavations or lining of deep cavities are also well known and frequently utilized. Polymer stabilization techniques were suggested as a result of preliminary experiments and research into the potential uses of plastic resins in low-cost housing schemes. An applied research project should determine the feasibility of using polymer chemicals and soil mixed with various organic fillers such as bagasse, rice hulls, and jute, or mineral fillers such as vermiculite and expanded shale for the production of inexpensive building materials.

10.2.3 Lateritic Stabilization

An example of a recent breakthrough in technology is the production of blocks or bricks from lateritic soils.

Laterite is the common reddish soil that can be found in large land areas of the earth's surface, particularly in tropical and subtropical areas of South America, Africa, South-East Asia and India. Laterite is the residual product of rock decay with a high content of iron oxides. Lateritic soil is usually considered unsuitable for production of building blocks such as burnt brick or tile because it generally lacks sufficient silicates and also has an excess of aluminates. However, the use of a chemical additive can alter the characteristic reaction of a mixture of lateritic soil and water to produce a sun-cured brick or block that should compare favorably with a baked product [1]. The lateritic soil block is handmade in the same manner as the classic adobe block, using a wooden mold and rudimentary mixing techniques. The manufacturing process can be adapted for labor intensive production.

10.3 Composite Systems

10.3.1 Structural Sandwich Panels

10.3.1.1 Characteristics and Uses of Structural Sandwich Panels

One of the most efficient structural systems is the structural sandwich. Basically a structural sandwich has a relatively thick, low strength core bonded to thin, relatively high strength facings. The structural sandwich system when

used as a flexural member in a roof system would consist of three components; 1. the upper, exterior facing, 2. a core material, and 3. the lower, interior facing.

The exterior facing material must have reliable compressive properties and must either be water resistant or be waterproofed by an applied coating.

The interior facing material must have reliable tensile properties and be fire resistant. An alternative to the fire resistance requirement for the facing would be application of an auxilary fire resistant layer to protect the interior facing.

The core material must have reliable shear properties and should be of relatively low unit weight, and should provide the required thermal insulation.

The bonding medium used in sandwiches must have sufficient strength and durability against moisture and under temperature extremes of the exterior environment.

The strength required in this bond depends on the sandwich design, on the materials used and on the loads expected in service. For example, the tensile strength of the bond between the core and the interior facing must be sufficient to support the dead weight of the facing. In addition, the shear strength of the bond must be sufficient to transfer all shear stresses to the facings without excessive creep. The magnitude of the shear stresses is a function of the thickness and span length of the panels as well as the intensity of applied loads.

Roof systems for structures utilizing low flexural strength wall constructions should be of relatively low mass in earthquake zones. To achieve low mass in the roof there are but two alternatives: 1) either use small amounts of high-strength materials, or 2) use lower-strength materials in a highly efficient manner. High strength materials are usually relatively expensive and their use is often not possible in many areas. As a result the only method available in many developing areas for construction of a suitable roof system is to use locally available materials as efficiently as possible. Structural sandwich panels, which are both light and structurally effective, are therefore suitable for use in roof systems.

Structural sandwich panels may also be successfully used for interior and exterior walls.

10.3.1.2 Performance of Structural Sandwich Panels

Tests recently conducted on an experimental unit constructed in 1947 by the U.S. Department of Agriculture - Forest Service, Forest Products Laboratory, Madison, Wisconsin, using structural sandwich panels, showed that their performance was quite satisfactory.

The sandwich panels in the experimental unit were constructed of paper honeycomb cores with plywood or other wood-base facings, and other materials. The paper honeycomb cores were produced by assembling sheets of Kraft paper

weighing about 22 kilograms (45 pounds) per ream, impregnated with phenolic resin. The plywood facings were treated with phenolic resin. The walls, floor and roof of the experimental unit was constructed of sandwich panels. The Forest Products Laboratory issued the following summary of observations in publishing the results of their tests:

> "Performance of sandwich panels in the experimental unit over 21 years indicates that panels of nominal thickness and construction can be satisfactorily used for housing construction. Minimum stiffness and strength requirements are easily achieved, and most constructions retain their stiffness and strength properties even after long-time service.
>
> Adhesive bonding techniques proved to be adequate with good bonds even after as much as 21 years of service. No moisture problems at the bond were observed. Synthetic resins in the honeycomb material also afford a degree of moisture resistance that insures adequate strength and stability even if the material is immersed. Plywood-faced panels have demonstrated excellent performance during 21 years of service. They had a minimum of movement due to temperature and moisture changes, and retained stiffness and strength. Mechanical fasteners used in assembling a house might govern the thickness of facings. In some cases, thinner prefinished plywood with a non-marring plastic surface might be used for the interior facing.

Although plywood was relatively stable, the other wood-base facing were more affected by moisture and temperature changes. In normal construction, much of the bowing would be eliminated by fastenings; however, restricting the panel edges might result in cross bowing or cupping. Therefore, facings that are highly sensitive to temperature and moisture changes are undesirable. The feasibility of radiant heating coils in sandwich floor panels was demonstrated in the original experimental unit. The coils did not cause any deterioration in the core material or the bond between core and facing. Minimum insulation requirements for many areas of the United States are satisfied by the corrugated core; however, this core may not provide adequate insulation for the colder climates. Expanded honeycomb core provides even less insulation. The panels with styrofoam core or urethane foamed into expanded core both have insulating properties comparable to conventional wood-frame house construction with two inches (5 cm) of blanket insulation. The long-term durability test with panels exposed for periods as long as 21 years has shown the feasibility of using this type of construction in housing. The requirements for satisfactory sandwich panels are selection of proper combinations of facings, core, and adhesives; careful fabrication techniques; and good quality control."

10.3.1.3 Materials Used in Structural Sandwich Panels

One commonly used core material is paper honeycomb which is made from a phenolic resin impregnated kraft paper. The phenlolic resin impregnation stiffens the paper, increases the wet strength, and provides fungus resistance. Paper honeycomb is manufactured in both a hexagonal configuration and a corrugated configuration similar to that in cardboard used in making paper cartons.

Sheet metals are often used as facing material, but other materials that are available in large flat shapes such as plywood, hardboard, gypsum board, plastic laminates, cement-asbestos board are also used.

In evaluating the possible materials for use in the roof system, paper honeycomb as the core material is considered feasible in most countries. Alternative core materials would be a low density pressed fiber board or even bundled reeds, although the density would not be as low as paper honeycomb. Most countries have corrugated paper cardboard plants in which corrugated honeycomb could be made. These products would have to be impregnated with either phenolic resin, a readily available inexpensive polymer product, or some other material which would provide the required properties.

A possible facing material is gypsum plaster which would have to be reinforced for the interior facing because of its poor tensile strength. Gypsum has good fire resistance, but

deteriorates in the presence of water although additives, such as emulsified asphalt, can make the gypsum more water resistant. Thus, reinforced gypsum might be satisfactory for use as the interior facing but would have to be well protected from rain if used as the exposed exterior facing.

The use of cast gypsum faced sandwiches appears to be structurally feasible for a roof system especially if the interior facing is reinforced with woven steel wire or glass fibers. This concept should be explored further to see if the expected benefits of strength, stiffness and other properties from the better reinforcement are realized, and if the gypsum can be made suitably waterproof.

The use of emulsified asphalt and other additives in the exterior facing should be studied to determine the effect of weathering on the mechanical properties of the modified facing material.

The use of locally available core material such as bundled reeds and split bamboo should be investigated.

Polyurethane foam sandwich panels using bamboo cane reinforcement have been experimentally tested at Washington University in St. Louis, Missouri. Also being evaluated is an application of polyurethane foam on a woven thatch wall panel. The results of the experiments indicate that one may anticipate difficulties in the production and control of the polymer and thus the finished panel. The high comparative cost of the basic resin appears prohibitive at this time.

10.3.2 Bamboo Reinforced Concrete

Results of recent studies of the feasibility of using bamboo as reinforcement for temporary reinforced concrete structures indicate that bamboo reinforcement can develop from two to four times the ultimate flexural load-carrying capacity of unreinforced members of equal dimensions. The study is based on results obtained from small cane and is believed to be conservative when other species of bamboo are used. The principal problems associated with bamboo reinforcement are swelling and shrinking due to moisture changes and low bond strength. Pre-soaking split bamboo for 72 hours and applications of surface coatings are effective in mitigating these problems.[2]

10.4 Prefabricated Housing

Technical improvements which may contribute substantially to the capability of producing inexpensive dwellings better resistant to natural disasters include the use of prefabricated systems compatible with local conditions and lending themselves to large scale industrial production.

Among innovations that may be introduced is the pre-assembled utility core package housing appropriate mechanical, electrical and sanitary systems. These units may contain the kitchen, the toilet or bathroom area and the utility complex. All wiring, plumbing, heating and cooling lines and ducts are pre-assembled, and may include a heating unit, plumbing fixtures, lights, storage units, and sinks. They eliminate from the building site the most difficult and costly portion of the entire con-

struction process. Typically, one may erect the utility core on the building site, usually over a foundation or sub-core with the remaining units or components of the house then built around it. The core may be stacked like a sectional box, with all connections between sections of the core made in the field. Solar energy may be used in mechanical cores for the heating of water and possibly for other purposes (water treatment, heating and cooling). [3]

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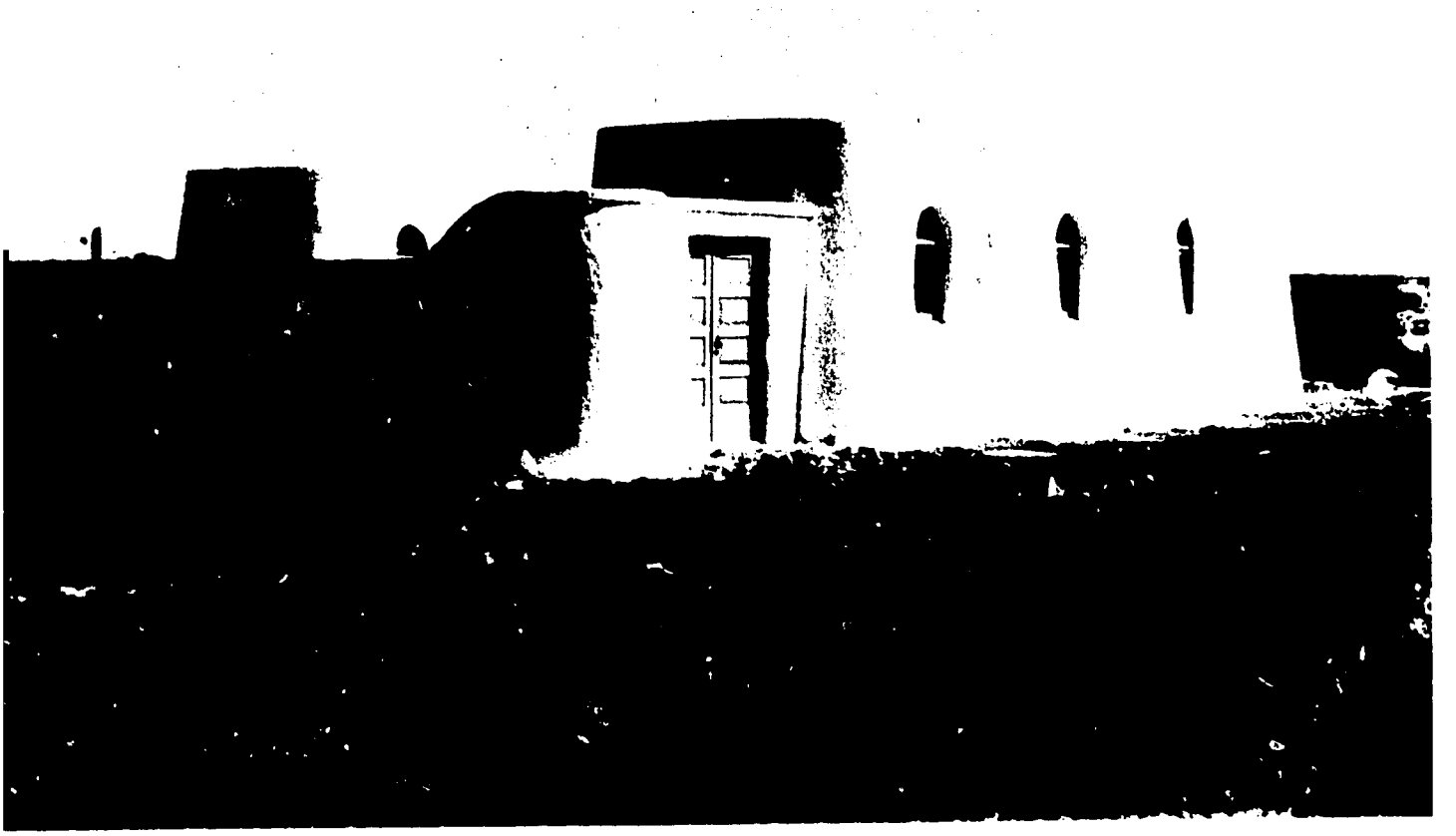
Adobe wall constructed at National University of Engineering, (U.N.I.), Lima, Peru, 1972.

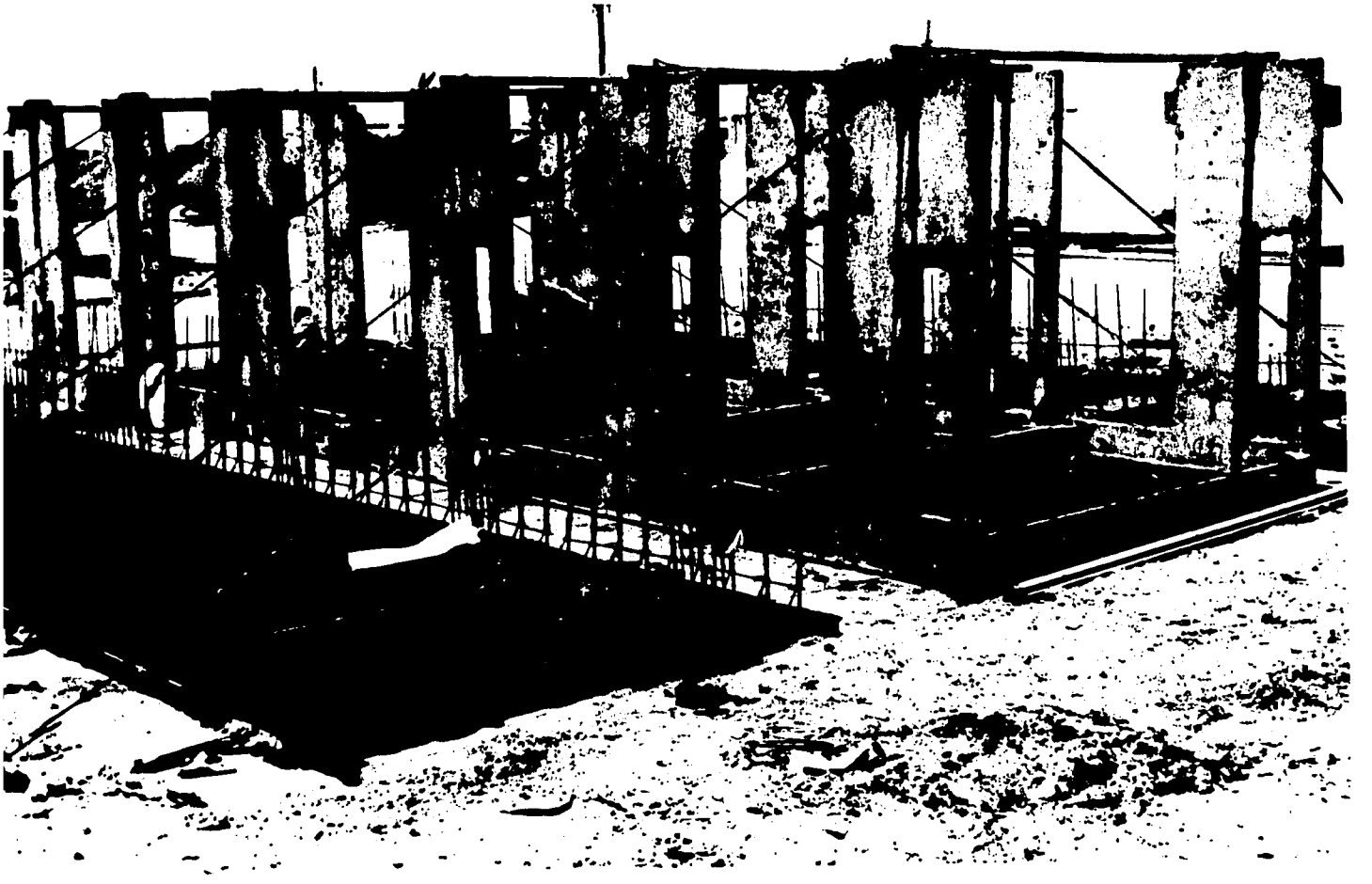
Structural test of split cane reinforcement
for adobe walls. U.N.I., Lima, Peru 1972



Experimental adobe dwellings constructed by the Ministry of Development and Housing of Iran, 1971.

Production of Cinva-ram cement stabilized soil block in Bangladesh (courtesy of Care, Inc.)

Self-aligning concrete block, panel and column system developed under the UNDP "Previ" research project. Wall panels create voids which are filled with grout or insulative material.



Unicrete precast concrete plant at Chimbote. Wall panels have been cast, tilted 90° to a vertical position and are ready to receive roof panel. At the same time reinforcing has been placed for new wall panels which will be cast.

Experimental mould for fibre-reinforced plastic dwelling in Bangladesh. (1971)

Chapter 11 Communication and Transfer of Technology

11.1 Introduction

11.2 The Interamerican Development Bank

11.3 The World Bank

11.4 United Nations Agencies

- 11.4.1 The U.N. Center for Housing, Building and Planning
- 11.4.2 The U.N. Industrial Development Organization
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11.5 Care, Incorporated

11.6 National Institutions

- 11.6.1 Peru
- 11.6.2 Turkey
- 11.6.3 The Philippines

Chapter 11. Communication and Transfer of Technology

Specific cooperative programs in the area of earthquake and wind storm resistant housing for low income groups provide the opportunity for an effective interaction process between experts of both the assisting agencies and the developing countries. It is within such a process that communication and transfer of technology are best achieved.

In order to illustrate various ways in which such a process can occur, the activities of several agencies involved in housing development programs are briefly described in the following.

11.2 The Inter-American Development Bank

The Inter-American Development Bank (IDB) has played a significant role in the last ten years with regard to urban development activities by financing two types of projects: 1) basic infrastructure and 2) construction of housing (not including land). Recent bank policy changes, based on mixed results of these programs have resulted in the discontinuance of housing programs per se. The bank is now interested in integrated or total community development wherein all appropriate infrastructure is provided, including surface access and potential transportation networks.

As of December 30, 1970, the IDB had twelve on-going projects in Latin America. These projects range from infrastructure to integrated community development.

The IDB offers technical services along with financing of projects. Transfer of technology is achieved mainly in the process of providing these services.

11.3 The World Bank (I.B.R.D.)

The World Bank does not contemplate direct lending for house construction at this time. It considers, however, lending for seed capital to develop housing finance institutions. The emphasis here is on the leverage effect in prompting savings and developing capital markets in a form which will lead to amelioration of the overall housing and employment situation. Particular attention will be paid to the income groups for which housing is proposed, the mobilization of small savings and the possibilities for supporting improvements to substandard housing.

In line with these considerations, the urban project program in this field is concentrated on "site and services" and similar projects to provide urbanized land on which the occupants can build their own dwellings using self-help methods. One project is already being appraised in Senegal and several others are envisaged. The first project is illustrative. The land provided by the Government will be equipped with roads, water, sewage and power facilities. Most water and sewage facilities will be provided on a community basis. Education and health facilities are included in the project as well as sites for industrial, commercial, recreational and other developments. Exclusive of the social facilities and power grid, charges to occupants are expected to cover costs which

will be only a small fraction of those of minimal housing schemes in the city. A new institutional organization will be built up with technical assistance to form the basis of a national program on similar lines. The emphasis on use of local labor and employment will result in a somewhat higher proportion of local costs than has been customary in bank lending.

11.4 United Nation Agencies

11.4.1 The U.N. Center for Housing, Building and Planning

The United Nations Center for Housing, Building and Planning (UNCHBP) is performing most valuable work in, for instance, devising housing programs compatible with technical and financial resources and on the social organization of sites and services schemes. The World Bank is assisting the UNCHBP in instituting regular inter-agency exchanges of information on activities with a view to sharing information and completing necessary studies by the most appropriate agency, avoiding duplication of effort, and reducing the burden on developing country administrations resulting from numerous uncoordinated missions. An area of Latin America has been selected for trial exchange of information. In the field of water supply and sewerage, a joint program has been established with the World Health Organization, and in education with UNESCO.

11.4.2 UN Industrial Development Organization (UNIDO)

A UNIDO sponsored Expert Working Group Meeting on the "Use of Plastics in the Building Industry" was held at UNIDO

headquarters, Vienna, Austria, September 20-24, 1971. The meeting covered the following areas of interest: building systems using plastics, plastics deterioration in building in tropical areas, prefabrication trends with plastics in buildings, user requirements and performance specifications, and research and development needs. The basic thrust of the meeting was focused on developing mass produced low-cost housing schemes for the developing countries in Africa and the Middle East.

The information and practical experiences exchanges during the conference indicated a significant potential for plastics in low-cost housing schemes. As a result of this meeting, experts are currently participating in a practical development program of a plastic dwelling for emergency use in Bangladesh. Also under way is an applied research effort to investigate the potential of urea-formaldehyde foam for insulation in a lightweight roof sandwich panel composed of a cardboard honeycomb core, U-F foam, and an outer skin of gypsum reinforced with a jute fabric. Ultraviolet ray protection is provided by a surface coating of a special water soluble plastic paint.

The UNIDO meeting served as a forum for developing working relationships that have produced useful and practical results in a short period of time.

As a result of the discussions, the technical experts group formulated certain recommendations for action that might be

initiated by developing countries and by UNIDO in cooperation with developed countries with a view to encourage development, introduction and promotion of the use of plastics in the building industry. Significant recommendations are summarized below:

1. The use of plastics as building materials should be encouraged wherever found suitable and economical. Also this would help supplement the shortages of traditional building materials in the region.
2. Keeping in view the varied climatic and socio-economic conditions in the developing countries, the development and introduction of plastics building products should be gradual and systematically organized.
3. It would be essential to educate architects, engineers and building contractors in the proper selection and use of plastics building components. This would necessitate organizing appropriate education/training programs.
4. Relevant performance specifications in respect of plastics building components should be formulated to facilitate their ready acceptance by the local building industry.

The following recommendations pertain to action by developed countries:

1. Devote attention to assisting the developing countries to encourage mass-production techniques for housing.

2. Take part in specific projects to encourage dissemination of information about plastics for building applications, particularly bearing in mind that this offers opportunities for faster rates of house production. This could include the provision of non-commercially oriented literature and specialist advisers and the provision of models and full-size samples of buildings put up with systems suitable for use in developing countries, to be displayed at seminars and building exhibitions.
3. Participate, as far as possible, in setting up industrialized housing systems to use present and potential local resources.

The following recommendations pertain to action by United Nations and other international organizations and agencies:

1. Provide inter-disciplinary teams of experts to developing countries to examine user requirements and relate this information to the possibility of local industrial production of housing using plastics with emphasis on present and potential local resources.
2. Initiate fellowship programs for experts from developing countries and organize, as early as possible, inter-regional seminars in developing countries on the use of plastics as building materials.
3. In order to expedite the organization of necessary meetings, consider the joint participation with outside professional organizations in provision of facilities and funds for such meetings.

4. Establish criteria for evaluating housing systems, which incorporate the use of plastics, make available this information at the request of developing countries and assist them in evaluating the cost, performance and adaptability of any proposed system to local climatic and socio-economic conditions.

11.4.3 United Nations Development Program

The U.N. Development Program (UNDP) is the world's largest program of multilateral technical assistance. In 1970 UNDP carried out a record volume of development assistance, working on 3,500 projects in about 130 countries [9]. In June 1968, the UNDP Governing Council requested the UNDP Administrator to handle a greatly enlarged program. A report entitled "A Study of the Capacity of the United Nations Development System" was completed in 1969. As a result of the recommendations of this report five reforms were approved in December 1970, which may enhance future UNDP efforts of assistance with recipient countries' development plans. The principal reform provides for the adoption of a United National Development Cooperation Cycle, a process which emphasizes country programming in order to coordinate UNDP assistance with the recipient countries' development plans. The cycle also provides new procedures for the formulation, appraisal, approval, implementation, evaluation and follow-up of specific projects.

Experimental Housing Project in Peru:

Typical of the type of project that the UNDP has initiated

in the past is the Experimental Housing Project in Peru which was to assist the Government of Peru in establishing a long-term housing policy through the planning, construction and initial management of an experimental housing project with particular emphasis on the needs of low-income sectors of the population. It consists of four pilot projects the first three of which are located in Lima. The fourth was added after the earthquake of May 31, 1970 to assist the Government in reconstruction and is located in the affected region in northern Peru. The Experimental Housing Project espoused methods and techniques which might be applied on a larger scale as part of Peru's housing policy.

The following is an outline of the project:

Pilot Project I (New Community)

The first pilot project is for the design and construction of a new community of approximately 1,500 low-cost houses complete with all community buildings. The design of the community is based upon the concept of high-density, low-rise houses with internal patios which can expand and adjust to accomodate the changing requirements of low-income families. Special emphasis is placed upon improved design, rationalized building methods and materials, dimensional standardization, and use of suitable building plant and equipment. The first building state of approximately 500 houses would consist of prototypes of 13 Peruvian and 13 foreign designs including a community sub-center, kindergarten and school.

The first stage has been carefully planned to compare and evaluate the various building methods, house types and groupings. The favorably evaluated house types will be repeated in larger numbers in the second stage which will complete the neighborhood with all facilities and appropriate infrastructure.

Pilot Project II (Housing Rehabilitation)

The second pilot project is to develop procedures and techniques to extend the functional life of existing substandard housing stock by rehabilitating older dwellings and urban areas to meet contemporary environmental standards. By applying these techniques on a larger scale in urban areas a substantial contribution to the reduction of housing deficits could be made at considerably less cost than through the alternative of new houses. In the selected location a comprehensive social and economic survey on all families and condition-of-structure survey on all houses has been carried out and this data forms the basis for the rehabilitation planning. The rehabilitation program provides for structural improvements and additions to sub-standard dwellings, new sanitary and electrical installations and general upgrading of groups of houses and their urban environment. Some new houses will be built on vacant lots and lots with houses to be demolished. A new sub-center will provide a community and spatial focus for the area. Vehicle and pedestrian streets are being replanned and a planting program for landscape improvements will be

carried out. In the rehabilitation of the individual dwelling, self-help methods will be widely employed for occupant families. A community action program will aim at maintaining social homogeneity and obtaining maximum participation from the 300 families in the area of the project.

Pilot Project III (Sites and Services)

The third pilot project is for families whose low incomes are not sufficient to amortize a loan to purchase a contractor-built dwelling unit. Self-help building methods, which can reduce the cost of a house by 40%, will be fully employed. Families will be organized and trained for building their own houses with new construction methods using small building elements and improved traditional methods. Technical supervision will be provided to the families. A social plan runs parallel with the training, construction and management aspects of the project. The main work phases of the project are: a) defining socio-economic characteristics of the families, b) development of community plan, house designs and building methods, 3) community development and housing management.

Pilot Project IV (Earthquake Resistant Housing)

The fourth pilot project is for low-cost, earthquake resistant and fast-to-erect permanent housing and includes the development of basic building materials industries. Two groups of dwellings are planned. One group of approximately 60 houses is to be located at Casma on the coast and one group of approximately 60 units at Catac in the Sierra.

Small workshops are located on each building site for the production of building components and the training of families in self-help building methods by technical experts. Manuals of practical building methods have been prepared as instruction aids and for widespread circulation in the region for use by self-help builders. Social workers are collaborating in the training of families and the organization of the groups of families for participation in the project. The project also includes technical assistance to small local industries to improve and expand the productivity of building materials and components.

A workshop has been constructed on the site of Pilot Project I, fully equipped with tools, machinery and plant provided by the United Nations, for the development and testing of building materials and methods to be employed in all four pilot projects.

The Project is directed by a project manager in cooperation with a national director appointed by the Government. A Coordinating Commission of representatives of national housing and planning agencies coordinates the Project with related development agencies of the Government. The planning and implementation of each pilot project is carried out by a separate development group consisting of Peruvian and United Nations personnel. An inter-development group and specialized personnel assist each pilot project as required in technical areas including engineering, productivity, costing and finance, training and housing management.

11.5 Care, Incorporated

The cooperative for American Relief Everywhere, Inc. is currently employed in a major relief operation in Bangladesh where, in addition to the many and diverse needs, housing has become critically essential. The Care, Inc. Organization contacted the National Bureau of Standards as a result of preliminary conversations with members of the Building Research Advisory Board and the National Academy of Science in Washington, D.C. Care, Inc. requested an informal evaluation of a new composite building material made of pulp from the core of the jute plant, jute cloth and a plastic resin for binder and facing material.

From this combination, other variations of plastic resin and jute materials have been formulated for laboratory testing, prototype construction and wind testing of a full scale unit.

11.6 National Institution

The initial phase or information gathering stage on this project included the establishment of appropriate communication and exhange of information with a number of National Institutions. The opportunity to develop potential areas of collaboration in the transfer and utilization of innovative technology was evident in each country visited during this phase of the project.

11.6.1 Peru

In Peru, for example, local recognition of this Pilot Project has resulted in a significant field mission to develop and teach improved methods and materials for adobe construction.

The program will help fulfill one of the principal objectives of a current technical assistance project initiated by the local U.S.A.I.D. mission in Lima, Peru, in collaboration with the following National Institutions: Ministerio de la Vivienda (Ministry of Housing); Banco de la Vivienda (Housing Bank); Universided Nactional De Ingenieria (National University of Engineering); and the International Institute of Housing Technology of Fresno State College, California, and the National Bureau of Standards, Center for Building Technology.

The specific objectives of the program are:

1. Production of a low-cost, high quality stabilized adobe block;
2. Development of adequate structural designs and building techniques for anti-seismic adobe construction.
3. Construction of a number of prototype houses and training and technical assistance to families on the new construction methods and promotion of these new methods.
4. After the technical and economic feasibility of constructing houses with stabilized adobe have been determined, large-scale projects would be developed and implemented throughout Peru, with different sources of finance.

11.6.2 Turkey

As a result of visits by NBS personnel to Istanbul and Ankara in 1971, it was possible to establish a sound working relationship with three leading Universities in Turkey: 1. Istanbul Technical University; 2. Bosphorus University (Roberts College); and 3. Middle East Technical University. Also, a working relationship has been established in the Ministry of Reconstruction and Resettlement, especially with the Earthquake Research Institute and the General Directorate of Natural Disaster Affairs.

As a result of meetings and discussions with these institutions a joint venture and team effort approach to the socio-economic study in this country was proposed. The study provided an opportune mechanism to join together, for the first time, many of the leading engineers, architects, and scientists in Turkey for a common goal. The National Committee of Earthquake Engineering in Turkey was thus formed, headed by the Dean of Turkish Engineers, Professor Dr. Rifat Yarar. Also, a Board of Research Associates and Consultants were formed as contributory experts for the socio-economic study, under the guidance of the National Committee.

The Minister of Reconstruction and Resettlement, the Director of the Earthquake Research Institute and the General Director of Natural Disaster Affairs support and contribute to the socio-economic study.

The National Committee of Earthquake Engineering in Turkey is planning future projects related to seismology,

geology and innovative technology transfer. An Earthquake Engineering and Training Center is envisaged in conjunction with symposiums, seminars and other academic gatherings for purposes of teaching and information exchange.

The Ministry of Reconstruction, Department of Building Materials, Research and Testing Laboratories in Ankara has expressed interest in construction and testing of prototype dwelling units in their facilities. Interest was noted in applied research of low-cost housing constructed of honeycomb cardboard cores, gypsum and stabilized adobe (KERPIC).

The General Directorate of Natural Disaster Affairs expressed interest in a field mission to develop and teach improved methods and materials for adobe construction and other innovative techniques that might be appropriate.

11.6.3 The Philippines

The serious consequences of natural disasters on the economic and social development of the Philippines and other developing countries in similar circumstances prompted Institutions such as the World Meteorological Organization (WMO) to intensify appropriate action for mobilizing ways and means to mitigate the harmful effects of typhoons and minimize their destructive potential.

In the ECAFE 27th Session in April 1971, the Philippines committed itself to support typhoon modification experiments. The Philippine Weather Bureau has proposed a five-year integrated research project entitled "Typhoon Research" to the

National Science Development Board. The objectives of the project are to: 1. Assess the prospects of artifical modification of typhoons notwithstanding the economic benefits of precipitation from these storms; 2. Achieve a better understanding of structure of typhoons, their development and motion, and improve their prediction; 3. Obtain adequate climatological and hydrological data for the Philippines to support economic development planning [11].

The Typhoon Research Project may be administered by a number of National Institutions including but not limited to: The Department of Foreign Affairs, Office of the Executive Secretary, Department of Agriculture and Natural Resources, National Science Development Board, Weather Bureau and the Philippine Air Force.

In the course of this project there were meetings with members of the National Science Development Board, the Weather Bureau and the Bureau of Public Works. These meetings engendered considerable interest in an applied research program to develop a wind-resistant, low-cost house, to construct one or more prototype units at selected weather observation stations, and to instrument and measure the prototype units under actual typhoon conditions. The National Science Development Board expressed interest in providing some funds for such a project if other proponent funding was made available. The Weather Bureau has stated their willingness to provide the sites for the prototypes.

The University of the Philippines, Department of Engineering, has also expressed an interest in technical collaboration to develop and test a prototype in the University's Building Research Institute-Civil Engineering Laboratory.

A project joining together various attributes of the above institutions holds significant promise for successful implementation of an applied research program.

11.6.4 Iran

Adobe brick was developed in Iran almost 5,000 years B.C. [12], and as today, it was formed by hand using a primitive mold and a clay soil mixture. It is estimated that almost 80% of all houses in Iran are constructed with adobe brick, wood, straw and stone [13].

Under Iran's Third Development Plan (1963-1968) approximately 17,000 government assisted housing units were built. About 200,000 units were built by the private sector, and private sector investment in urban construction projects is increasing at a rate of about 12% per year [14]. The Fourth Development Plan (1968-1973) calls for a total of 275,000 new housing units, 25,000 of these governmentally assisted, not including industrially oriented housing development or rural housing.

Most of the government assisted units will be replacements for slum housing, and efforts are being made to provide more living space per unit. Most of the new housing is built of brick walls approximately 40 centimeters thick. The average size of the brick is about 5 x 11 x 22 centimeters.

Earthquake damage is prevalent and virtually continual in several areas of Iran. Many dwellings are lost to earthquakes when they occur, with deaths resulting from collapsing roofs and walls.

A visit to the Ministry of Housing and Development in Tehran was informative and established an excellent working relationship. It was learned that the Ministry had completed a program to construct a number of prototype houses in an experimental village located in Narmak, a suburb of Tehran. The houses were each of a different design, with the majority constructed of traditional adobe brick and adobe plaster. One design utilizing a double-curved adobe wall was well conceived and innovative in shape and form. This prototype and several others are scheduled for static testing to determine their structural qualities.

The Ministry of Housing and Development expressed a strong interest in several areas of technical assistance, including an exchange of technical information, a training program for qualified engineers and an extensive field mission to develop and teach improved methods and materials for adobe construction.

Chapter 12 Summary of Conclusions and Recommendations of Consultants' Reports

12.1 The Philippines

12.2 Turkey

12.3 Peru

References

Chapter 12 Summary of Conclusions and Recommendations of Consultants' Reports

12.1 The Philippines

12.1.1 For the national economy, a better-than past average growth of 7% in GNP is targeted over the next four years which is the basis for strong government programs in the various development sectors. However, this growth rate and competing priorities would still not allow resources to be directed towards the total requirements for adequate housing. The competing demands for agriculture and industrial development, where there are both economic-social and commercial returns, will exert the strongest pressure on the available private and public investible funds in the economy, leaving only a limited amount available for housing construction. This situation may likely continue throughout the rest of the seventies.

Fund assistance from external sources would be necessary to enable extensive achievement of housing programs. Bilateral aid specifically designed for housing would significantly bolster the actual accomplishment of construction programs for the requirements of the low-income majority of the Philippine population.

12.1.2 The already acute housing problem in the urban centers has been further aggravated by the heavy in-migration stream of the rural populace escaping from the underdeveloped economic opportunities available in the rural environs. The additional

pressure on the urban housing stock is reflected not only on the required number of housing units which must be constructed annually but also on the already high living space densities within the already existing dwelling units. Additionally, because most of the in-migrants belong to the low-income groups, their housing requirements can only be financed with the assistance of the public sector.

To hasten the development of economic opportunities outside of the major economic centers and the likewise disperse the socially unfavorable concentrations of unskilled and low income migrant families in the major urban centers, the government, through the various regional development authorities and through the priority programs of the Board of Investments has favored, with fiscal incentives, those economic activities which will locate in the smaller urban centers. In addition, provinces and municipalities are starting to encourage and attract investors to set their facilities within their jurisdictions.

The increasing demand for adequate housing facilities is expected to be slowly met during the present decade but expectations are that there may still be a backlog by 1980. The efficient distribution of mass-produced prefabricated houses will definitely accelerate the achievement of the objectives of the housing programs. To implement these programs, the government together with whatever external assistance may be forthcoming will have participated actively not only in terms of project promotion but also in terms of financial support.

12.1.3 Despite the present efforts of the government to promote family planning, household size has increased from 5.7 in 1969 to 5.0 in 1970 and is expected to further increase to around 6.2 by 1980.

Variations in sizes by locality is pronounced in the urban-rural dichotomy rather than among different regions. Rural households are larger than their urban counterparts due to the strong extended family kinship system practised in the rural areas where relatives live with a nuclear family in the same dwelling unit.

Because the majority of households belong to the low-income group, one-bedroom dwelling units predominantly shanties and "accessorias" are common. Living space densities are of necessity high and most of the available spaces in these housing units are used as living accommodations. However, the ideal design of typical low-cost dwelling units should provide for at least two bedrooms.

12.1.4 Low-cost housing units designed specifically for the major urban centers will out of necessity have to be high-rise (about four to six story tenement buildings). The factors affecting such design are the relative scarcity and the high value of residential land in urban areas, the large magnitude of the housing problem, and the low average household income levels.

It is expected that this approach to the housing problem

which has already been implemented though still on an unprogrammed basis, will grow rapidly in the future. Commercial multistory condominium apartments, catering more to the higher income brackets, have increased in popularity in the housing market of the Greater Manila area and in other urban centers.

For rural housing, the foreseeable trend will still lie with the single detached dwelling unit because of the dispersed nature of rural settlements and the availability of land.

12.1.5 In most urban areas, community facilities such as power, communications and commercial and recreation services provided by private enterprise are generally considered adequate. Other services such as water systems and infrastructure, normally taken care of by the public sector, are insufficient due to lack of capacity and inefficient management. In the high growth and high density urban centers, the demand for most community facilities has far out-paced the development of capacity due to high investment costs and oftentimes the absence of efficient operation.

Most privately promoted housing projects have incorporated as an integral element in their plans the provision of the basic community facilities needed by the residents. This is apparently a critical factor in the commercial success of these projects.

The rural areas have lagged behind in the development of the necessary community facilities because the concentration

of purchasing power, essential to the viable commercial development of these facilities by private enterprise, has not been available.

12.1.6 Among the low-income households, there is a limited portion of budget available to construct makeshift dwelling units or to rent living spaces and there is no financial capacity to buy and/or amortize a well-built structure mainly because the lack of land or available collateral. To counter this vicious cycle of poverty, the government has already extended the repayment periods for housing loans from 15 to 25 years to allow more households, especially the lower-income ones, to avail themselves of these programs.

A possible complementary solution to this problem is for the government to promote low-cost housing projects to those individuals who would have not only the land on which to construct the low-cost housing units but also the capacity to go into long-term debt financing, using their land as collateral. From the rental payments of these low-cost units constructed on his land, the landowner will be able to fund his amortization payments.

12.1.7 While the government financial institutions have already restructured their portfolios in favor of housing loans, the need for housing loans is still so much greater than their combined capabilities.

The government agencies are already offering the lowest terms currently available (6 to 9% annually) over a twenty-five year amortization period. There is still an untapped source of funds for low-cost housing in the banking sector, but the rates are quite high (12%), with short-term repayment.

There will be great need for external sources of funds and if these can be reloaned at the minimum government level of 6%, it will contribute substantially to the realization of the housing needs.

12.1.8 The construction materials together with the skilled labor needed in the conventional method of construction are readily available. Delivered prices of materials are reasonable because of the regional dispersal of productive capacities. The current size of Philippine markets for fabricated construction components is not large enough to achieve economies of scale. Furthermore, the transportation and distribution system in the eleven major islands are not developed and will generally result in higher delivered costs for these products.

Further fabrication of construction material components must be of sufficient economic scale and must incorporate cost improvements to more than offset the higher distribution and transport costs as compared to the price structure of conventional construction components.

For the distribution of construction materials used in the conventional system, there would be room for cost improve-

ments in the areas of bulk handling, larger volume or lot sizes in delivery shipments and scheduling.

12.1.9 The basic chemical process industry for plastic products is small, protected by high tariff and generally produce simple types of household construction materials.

Under the recent Investment Incentives Programs, the seventies will witness the development of larger and more complex chemical process plants and the industry will probably develop an integrated petro-chemical complex base during the decade. Over the long-term the availability of these chemical process products can be applied to manufacturing materials for use in mass housing construction.

12.1.10 As indicated, the demand for housing is great and the financial and technological resources available to supply this are limited. As projected, the total requirements for new and replacement housing units will more than double from 590,000 units in 1972 to over 1,360,000 by 1980.

Prefabricated housing is seen as a major approach to the low-cost supply capabilities.

12.1.11 Wages in the construction industry are good and productivity is generally considered high. There are, however, indications of apathy towards high standards; short cuts in working procedures are, in general, tolerated.

In prefabricated housing construction, the recent experience of some contractors indicate a ready adaptability by labor to handling prefabricated systems at a high rate of productivity. No significant obstacles are foreseen in the manpower development for modular construction.

12.1.12 Low-cost housing designs for government-sponsored projects are guided by the paying capability of a prospective homeowner and have the same basic cost-saving features in space allocation and materials. Private projects in various regions offer a broader range of alternative designs. Among the low and middle income homeowners, there is still general preference for individualistic requirements but standardized mass housing designs are accepted for cost advantages since the houses are generally subject to individual modifications during occupancy.

Usage of specific construction materials appear to be determined primarily by availability and secondly by the relative price value of substitute products.

Most practising architects appear to be receptive to the use of new construction materials and their recommendation is a strong determinant in introducing new materials and products.

The most effective introductory and sustained marketing effort for new products is through the distribution channels and networks developed by private enterprise engaged in the selling of construction materials.

12.1.13 The conventional method remains the most accepted and commonly used method of housing construction in all the regions. This is due to the relative ease of securing the materials and labor needed for housing construction which allows housing developers and individual homeowners much leeway in implementing their design preferences. At the same time, there appears to be a receptivity towards new products and designs.

Thus, the development of prefabricated systems for low-cost housing must offer significant economic advantages in addition to structural design efficiencies in order to replace the traditional preference for the conventional construction method.

It would appear that a marketing strategy for prefabricated housing units, emphasizing "typhoon-resistant" features might be an effective promotional idea to highlight their structural advantages over dwelling units constructed by the conventional systems.

12.1.14 Most municipal codes used in the various regions are straightforward, providing the basic minimum specifications - mechanical, electrical and plumbing - for the construction of a housing unit. At the same time, they are so basic in their stipulations that there is little room for highly innovative designs.

Enforcement of these minimum requirements is generally strict in the review of designs and plans. However, there appears to be laxity in enforcement during the actual construc-

tion stage, wherein periodic inspections by the enforcing agency are supposed to be made to determine adherence to the codes.

It is generally felt that with advances in construction methods and/or more usage of prefabricated systems, the level of code enforcement would further improve, particularly in the smaller municipalities throughout the country. This may be a strong point in the introduction and marketing of prefabricated housing components.

12.2 Turkey

Since housing construction in Turkey is basically financed either by owners and individuals or mostly by small businessmen, there is not much prospect for a rapid progress in the methods of construction and in the use of material for low-cost rural dwellings. With the prevailing conditions of financing and building regulations, the rural dwellings will be constructed using the same old conventional methods utilizing cheaply available local material.

Unless an efficient and reasonably priced pre-fabricated system is established across the country, nothing will prevent 80% of the future houses to be built out of stone, brick or adobe masonry, which in most cases possesses little or no lateral load carrying capacity. In a very few regions where timber is locally available, the prosperous builder may construct timber frame structures.

12.2.1 Points of Interest and Recommendations

Based on the experience of low-cost housing construction in Turkey as well as the field observations of damaged structures in recent earthquakes, several points of interest and areas of possible development regarding the earthquake resistant design and construction may be summarized as follows:

12.2.1.1 A realistic approach to the problem of improving the present methods of rural dwelling construction in Turkey, would be to study the earthquake response of stone, brick and adobe masonry structures. New rigid requirements of strength and ductility should be imposed in order to make these structures capable of resisting strong earthquakes without total collapse. It is very difficult to determine analytically the earthquake response to a masonry or timber frame rural dwelling. Therefore, experimental research on real or model structures is highly desirable. In these experiments, alternative methods of constructing the foundations, walls, lintels, bond beams, corners, ceilings, etc., should be investigated in great detail.

12.2.1.2 Geological and sub-soil conditions should be taken into account in selecting a site and also in designing a house. The predominant period of vibration, especially of soft soils should be determined. Depending on the availability of funds, analytical studies combined with laboratory tests and field measurements of shear wave velocity may be used for this

purpose.

12.2.1.3 Coincidence of soil-structure periods should best be avoided by following the principle of building rigid structures on soft soils and flexible structures on hard soil.

12.2.1.4 Care should be given not to use unnecessarily heavy partition or in-fill walls, especially of the kind which do not contribute to the strength of the structure.

12.2.1.5 One and two-story houses should be designed and constructed to withstand a minimum static lateral load of 0.10 g in the first degree earthquake zone.

12.2.1.6 Symmetry in all possible planes as well as uniformity throughout the structure should be maintained. Uniformity in the arrangement of rigidity, weight, geometry, materials, etc., is most essential for a safe earthquake-proof design.

12.2.1.7 Strength of adobe masonry structures should be increased by adding stabilizing materials into the mixture, without raising the cost of construction significantly.

12.2.1.8 Infrastructural facilities like roads, sewage systems, water supply, electricity, telephone, etc., should be included in the overall design and planning of rural dwellings.

12.2.1.9 Architectural planning or rural dwellings should take into account the socio-economic needs of the people living in different regions.

The Consultant's report emphasizes the immense need for the development of new techniques of construction and material for low-cost housing. It concludes by expressing the opinion that any analytical and experimental research conducted in any part of the world and concerned with the promotion of better and safer living conditions in rural areas should be regarded as service to mankind.

12.3 Peru

The accumulated deficit in housing in Peru is at present on the order of 1.7 million units, and it is estimated that by 1978 it will reach 2.3 million. It is evident that this represents a serious social problem which will continue to grow as long as there is no development of a new system for constructing basic low-cost housing, antiseismic in character, which will at least satisfy the annual demand for housing, which is on the order of 100,000 units.

Policies of mass housing construction applied so far in this country have not had frankly positive results.

The solution is difficult mainly because of the low level of income of the majority of the population and of the low financial capacity of the nation.

At present the National Housing Plan faces the necessity of massive construction of "basic housing units" at a cost not

exceeding S/. 32,500 per unit. Meanwhile, organizations which finance economic housing programs in the social interest are investing on the order of S/. 200,000 to 300,000 per unit. It is obvious that these last programs can serve only a small percentage of the population.

The problem becomes still more serious when one recognizes the operative deficiencies of the construction industry, principally the scarcity of skilled labor and the absence of research leading to the development of new construction materials and new procedures of construction and prefabrication.

On the other hand, the housing deficit exists both in the urban and the rural sectors, and the solutions to these two types of problem will have to be different.

It is obvious that in the principal cities of the country one should not seek the solution in the construction of large neighborhoods of single-story houses, as this greatly increases the cost of expanding and maintaining cities.

Taking Lima, the largest city in the country, as an example, it is believed that the investment necessary to maintain basic services of electricity and drinking water will require on the order of 2,000 to 3,000 million soles a year for the next 10 years. The water supply which at present (1970) is 18 liters a second must be increased to 30 in 1980 and to 40 in 1990, necessitating the diversion to the Rio Rimac of a large volume of water which at present flows into the Atlantic Basin.

The solution to the problem of lowering the costs of services in this city may lie in the erection of high-rise buildings constructed by the method of sliding forms and perhaps with unfinished concrete, or any other system which represents of lowering of costs per square meter of construction. The concentration of the population in less area would lower the cost of public safety, water and electric supply, sewerage, markets, hospital and schools, when transport, trash removal, etc.

In general the large cities of Peru have low population density indices, which necessitates an excessive extension of their service networks. There are no recent studies of this important aspect of outlying neighborhoods varied between a minimum of 400 inhabitants per hectare and a maximum to 900 per hectare (San Cosme), while the density in the residential zone of San Isidro was estimated to be 20 to 50 inhabitants per hectare, and in the new Neighborhood Units with buildings of 4 stories the mean density was 300 per hectare. Relative to this, it must be noted that the new National Construction Regulations establishes that residential areas of low density should vary between 30 and 140 inhabitants per hectare, those of medium density between 200 and 330, and those of high density between 530 and 1,350 inhabitants per hectare. It is estimated that neighborhoods of high-rise buildings, proposed as the solution to the housing problem in the large cities of Peru, should have between 800 and 1,200 inhabitants per hectare,

thus permitting an economic reservation of parks and recreational areas.

In any case the attempt to solve the urban housing problem should not be made with rural-type solutions, as appears to have been the intent in recent years in Lima (villa El Salvador).

The rural housing-deficit problem has different characteristics from the urban. Public services, except for electricity, do not require maintenance of large networks, and thus population density is not a major problem. Villages and towns can be built of single-story houses.

Rural housing should keep adobe as the basic element of the solution. Adobe is a material of high thermal and acoustic insulation indices, resistant to the most common grades of seismic shock in the country, easy to manufacture, and of low cost. Its use should be subject to technical standards which would assure good construction, both in the design phase and in the execution. It would be necessary to establish the depth and width of foundations, waterproofing norms for walls or the adobe itself, maximum heights of walls, maximum span for roofs, dimensions and forms of making openings for doors and windows, and last, to develop an appropriate and low-cost roofing system.

Roofing of reinforced concrete should be discarded because its characters of rigidity and resistance are very different from those of adobe. Roofs of wood with a mud covering or tiles are very high and expensive. Roofs of asbestos-cement or

calamina will satisfy many conditions but give little insulation and require the addition of a false ceiling, which makes them expensive. Roofs of cane or matting are unhealthy and are a constant fire risk.

In order for adobe housing to fulfill the requirements of modern and economical construction it is necessary, above all, to solve the problem of the materials or elements of the roof construction. The conditions that these must satisfy are good thermal and acoustic insulation properties, lightness and ease of construction, freedom from insects, non-flammability, and above all low-cost. In order for these roofs to be applicable to construction in the Sierra, they must also be waterproof, and the materials must permit construction of gabled roofs. Maximum span of the units should be 3.50 to 4.00 meters and their design, if possible, should not require the use of rafters, as these raise the construction cost.

On the other hand, adobe is a material easily adapted to the climatic characteristics of the environment - Coast and Sierra and is socially acceptable to the great majority of the population. Technically improving its manufacture and use in construction, which would not require more skilled labor, could lower construction costs and could be applied to programs of do-it-yourself construction or self-help. In fact, this system is the most common one in rural areas.

The introduction of new construction materials in Peru has always resulted in an initial period of strong rejection,

principally because of lack of confidence in the behavior of such materials in the future.

New construction elements, new materials, or construction using prefabrication or other innovative techniques or concepts, may be effectively introduced by using the social laws recently passed by the government.

Houses built with new materials and/or using new methods of construction, which have adequate antiseismic properties and the cost of which is relatively low, have a guaranteed initial market in the industrial, mining, and agricultural corporations which are required by law to build housing appropriate for the needs of their employees. Once their economic advantages and comfort are proven, the market for such houses would later extend into broader sectors of the population. A conservative estimate of the potential market during the introductory period indicates that there is a need for the construction of approximately 20,000 to 40,000 housing units in mining camps and 100,000 to 200,000 units in the fields of agriculture and fishing. Nevertheless, acceptance in these fields would be on the condition that savings in construction cost would be on the order of 10-20% over the present minimum for traditional construction, which in Lima is on the order of S/. 1,500 per square meter.

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