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(In ORA research project 05687)

9. ABSTRACT
(HOUSING R & D)

In 1962 the University of Michigan received a USAID grant to explore the potential of foam plastics for solving housing problems in developing nations. A feasibility study completed in 1962 (see PN-AAD-174) established the desirability of investigating the use of foam plastics as structural material. The project was conducted in two phases. The first phase involved experimentation to obtain information on a variety of foam plastics. Several structural systems were established as scale models before two structural concepts were selected for full-scale construction and testing. One concept involved application of spray polyurethane foam on a folding wood lattice armature. The other concept involved production of large structural components made of paper-laminated polyurethane foam board. During the second phase of the project, four prototype structures representing different techniques were built. One consisted of seven umbrella-shaped components made of sprayed polyurethane foam. A second was a two-story structure made of triangulated bents of folded paper-laminated polyurethane foam board. A third consisted of four square umbrella-shaped components made of flexible foam coated with reinforced polyester. The fourth was a room-sized unit in which polyurethane foam board served as the mandrel for filament-wound polyester. The research program also investigated requirements for production and marketing of chemicals and foam plastic products for structures and building components in underdeveloped countries. The major recommendation stemming from the project was

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that AID collaborate with the U.S. plastics industry in sponsoring construction and evaluation of suitable prototype dwelling units in developing countries. Interim reports of the project activities during 1964 and 1965 are available as PN-ADD-177 through PN-AAD-182.

ARCHITECTURAL RESEARCH LABORATORY -- THE UNIVERSITY OF MICHIGAN

Quarterly report: To the Agency for International Development
on ORA Project 05687
for the period April through June 1965

RESEARCH ON STRUCTURAL SYSTEMS UTILIZING THE FOAM PLASTICS AS A STRUCTURAL MATERIAL FOR HOUSING IN UNDERDEVELOPED AREAS

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REVIEW OF WORK PERFORMED

1. Development work on the four prototype structures is in its final phase. At the same time information is being collected from the testing of components representative of these structural systems.

   a. The folded plate system. The two-story prototype structure has so far been weathering very well. Survey targets have been attached to the structure to measure deflections over a period of time. An expandable folding structure produced by the Plydom Corporation, utilizing the same paper-polyurethane foam board, has also been erected and coated with polyester resin (see Appendix A, Plate 1). The ease with which this structure can be transported and erected makes it especially applicable in cases where emergency shelter is required.

   b. The spray polyurethane system (previously referred to as the folding armature system). The two 16' x 16' shells, produced by spraying polyurethane foam on both sides of a folding lattice wood armature, were tested and loaded to destruction. Analysis of the results from this experimentation led to the conclusion that it would not be advisable at the present time to proceed further with this method of spray application. Although refinements in the shape of the armature would contribute to the performance of the resulting shell, inconsistencies in the foam material resulting from the hand spray operation do not permit any predictable structural performance. Thus, the structure would have to rely on the stiffness of the armature rather than on the foam plastics for its performance. It was felt that the possibility of mechanizing the spray operation should be explored in the interest of eliminating the inconsistencies experienced thus far. For this purpose, a 12' diameter hexagonal umbrella was constructed by stretching flexible foam to the desired shape and then placing it on a rotating mechanism. The component was sprayed with polyurethane foam by setting the spray gun at fixed positions and rotating the form-giving device at a constant speed (see Appendix A, Plate 2). The results are very encouraging from the standpoint of both appearance and performance. A component produced with this method failed at a loading of 48 pounds per square foot in contrast to failures of 15 and 20 pounds experienced in the earlier test shells. The main advantage of this new system lies in its potential for the erection

of structures beyond the stage of fairly crude shelters. It was therefore decided to produce the final demonstration structure through this method rather than by hand-spraying another armature. Arrangements have been made with Wyandotte Chemicals Corporation for the production of 7 hexagonal components, 14' in diameter, which are to be assembled into a demonstration structure. The components are scheduled to be produced in July.

c. The rigidized flexible system. The four 12' x 12' square umbrella-shaped components have been assembled into a 24' square structure (see Appendix A, Plate 3). Since one of the components has been produced with a polyester-glass fiber skin on one surface only, the umbrellas have been assembled with their apex up rather than down as was done in the case of the structure erected at Rice University.

d. The filament winding system. A filament wound room-size component (12' x 16' x 8') designed by the project staff was produced at the Rocky Hill plant of the Hercules Powder Company. The operation proved quite successful for a first run. The mandrel, which becomes part of the structure, consists of 2" square tubular steel ribs, spaced at 32" intervals, with 2 inches of foam board between them and an inner lining of 1/8" hardboard (Masonite). The mandrel was then wound with glass fibers impregnated with pigmented polyester resin. The structure was transported to Ann Arbor where it has been erected on concrete footings (see Appendix A, Plate 4).

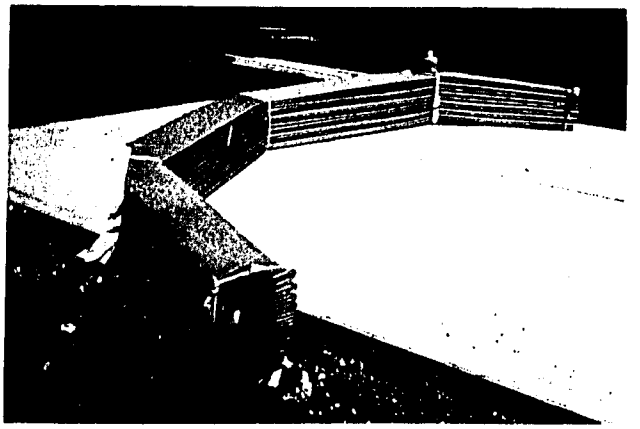
2. An outline has been prepared for the section of the final report concerned with the market potentials of foam plastics in emerging nations (see Appendix B). Material for this purpose is being collected and developed in the form of charts. tables and text.

The two papers prepared for the London conference on "Plastics in Building Structures" were presented there by Professor Oberdick and Mr. Crandall. These papers are to be published in Britain. The material covered is also to be presented at the "Conference on Cellular Plastics in Construction", which is to be held in Ann Arbor on September 22-24.

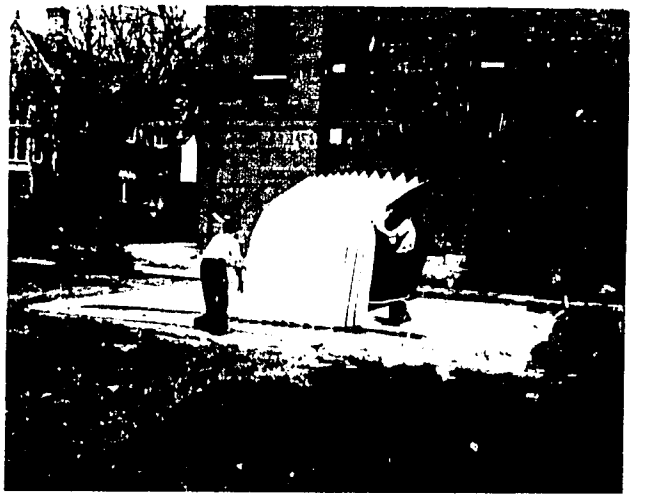
Appendix A

STRUCTURAL RESEARCH AND DEVELOPMENT

1. THE FOLDED PLATE SYSTEM



a



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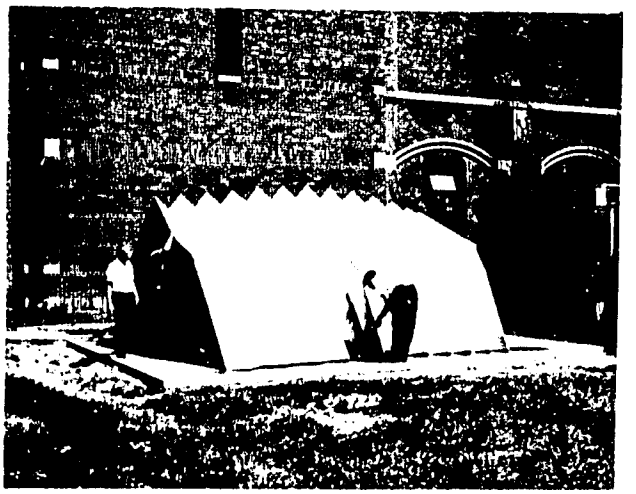

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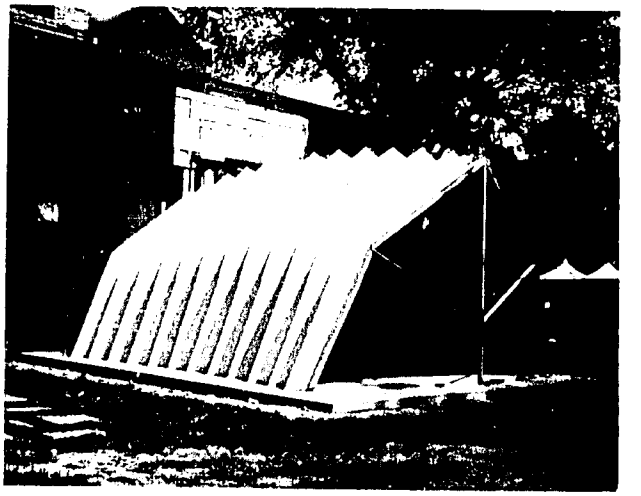
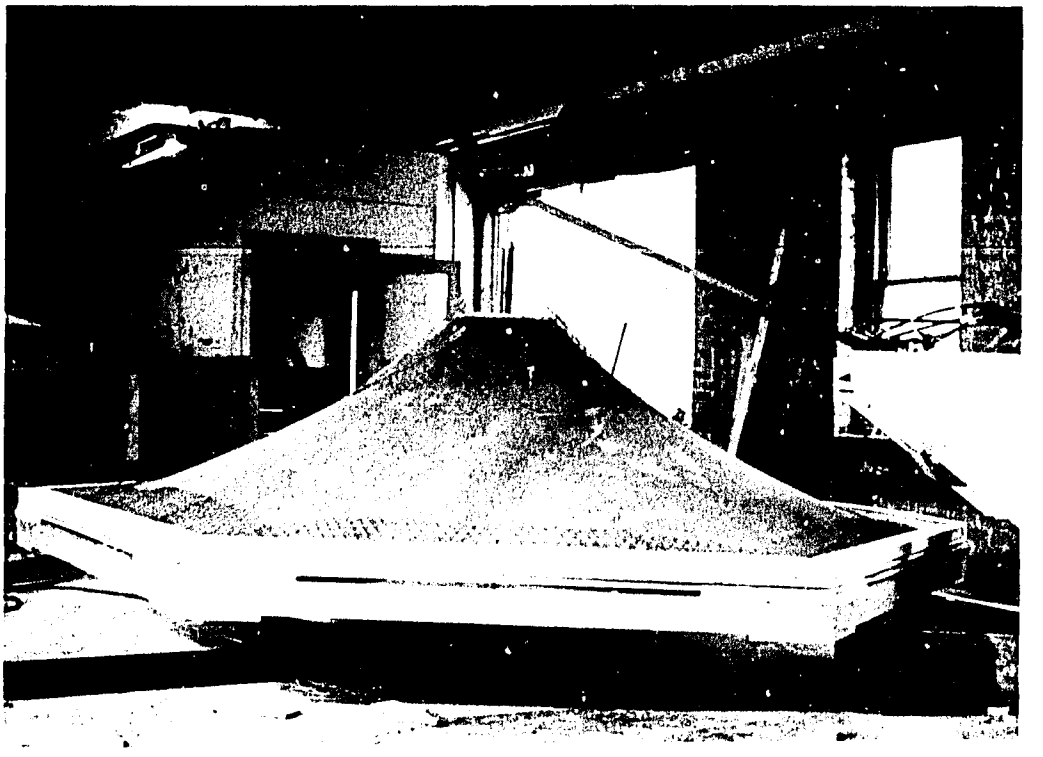


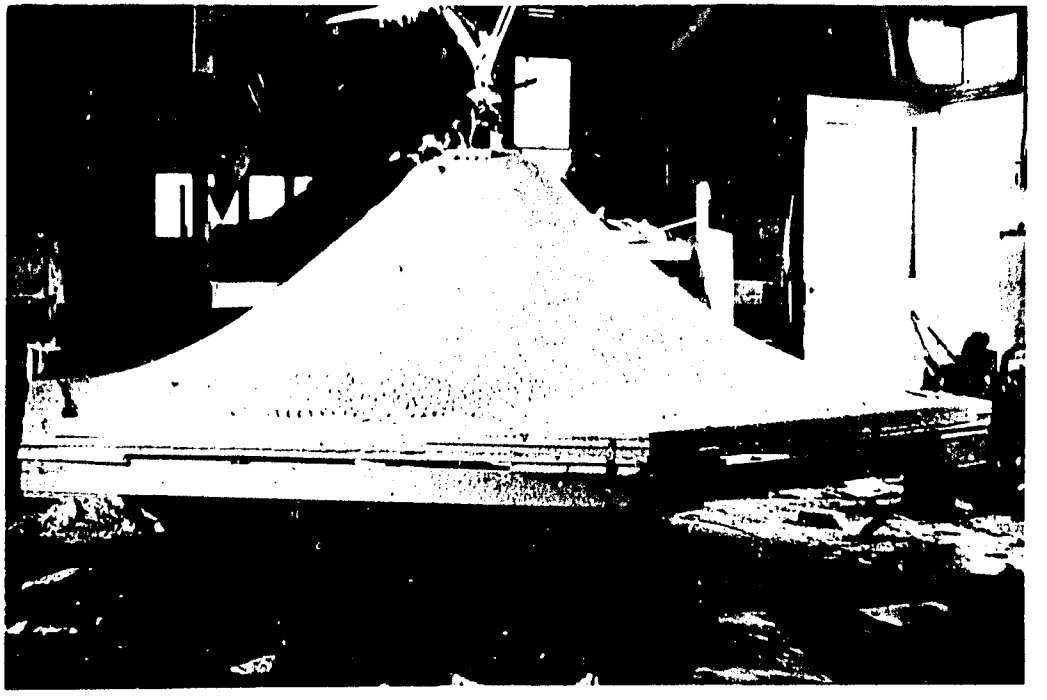
d

Erection sequence of expandable folded plate structure produced by Plydom Corporation

2. THE SPRAY POLYURETHANE SYSTEM

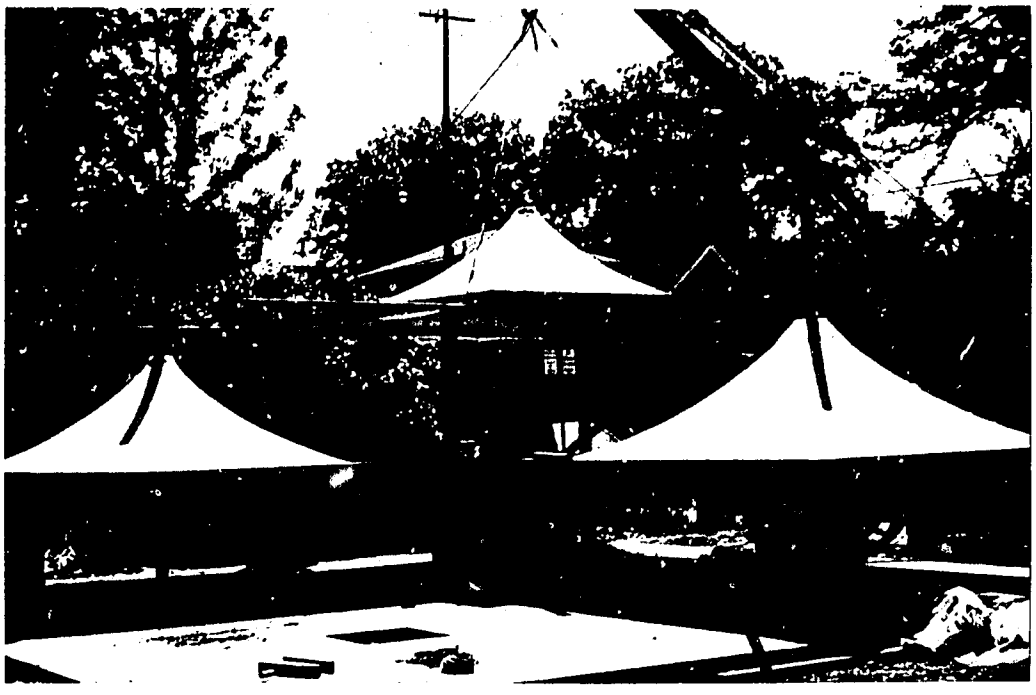


a. Stretched membrane on rotating mechanism

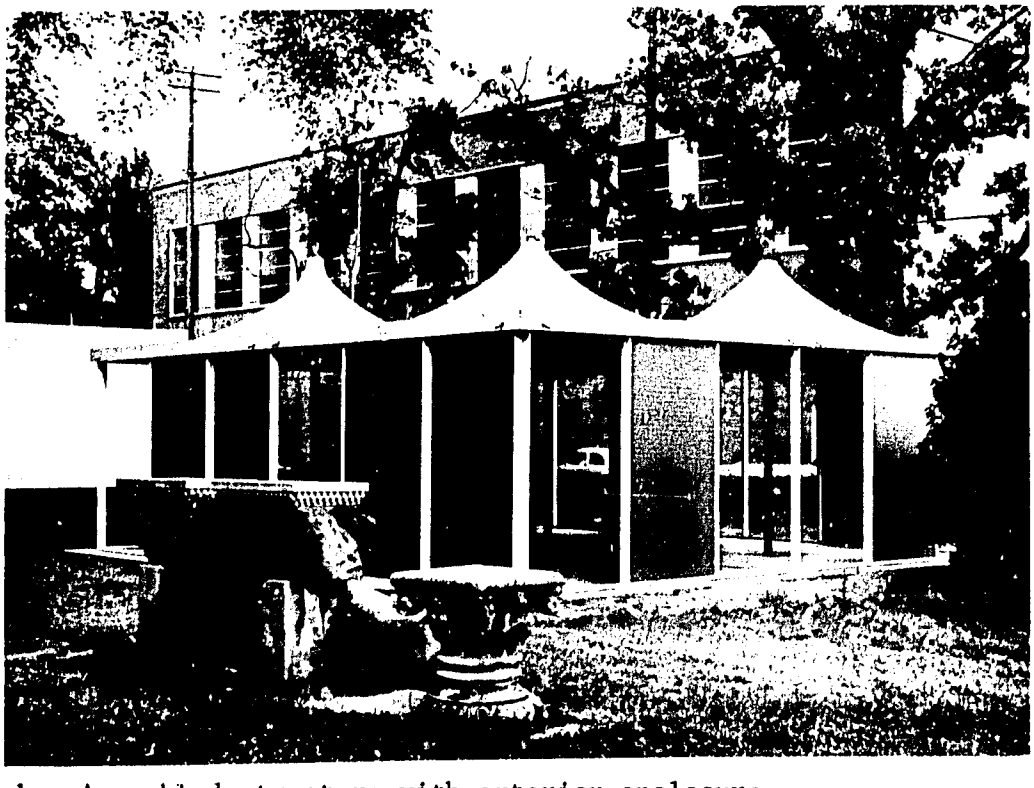


b. Surface of structural component produced by spraying polyurethane foam from a fixed position on rotating membrane

3. THE RIGIDIZED FLEXIBLE SYSTEM

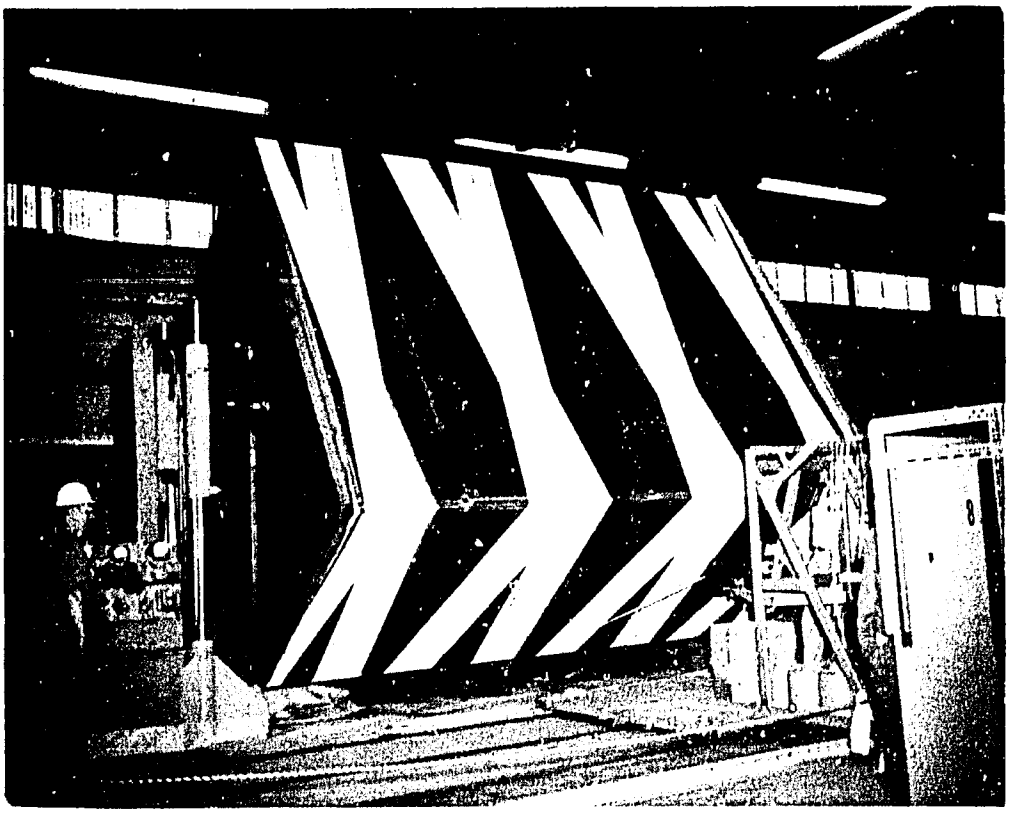


a. Assembling four 12' x 12' umbrella-shaped components into a roof structure

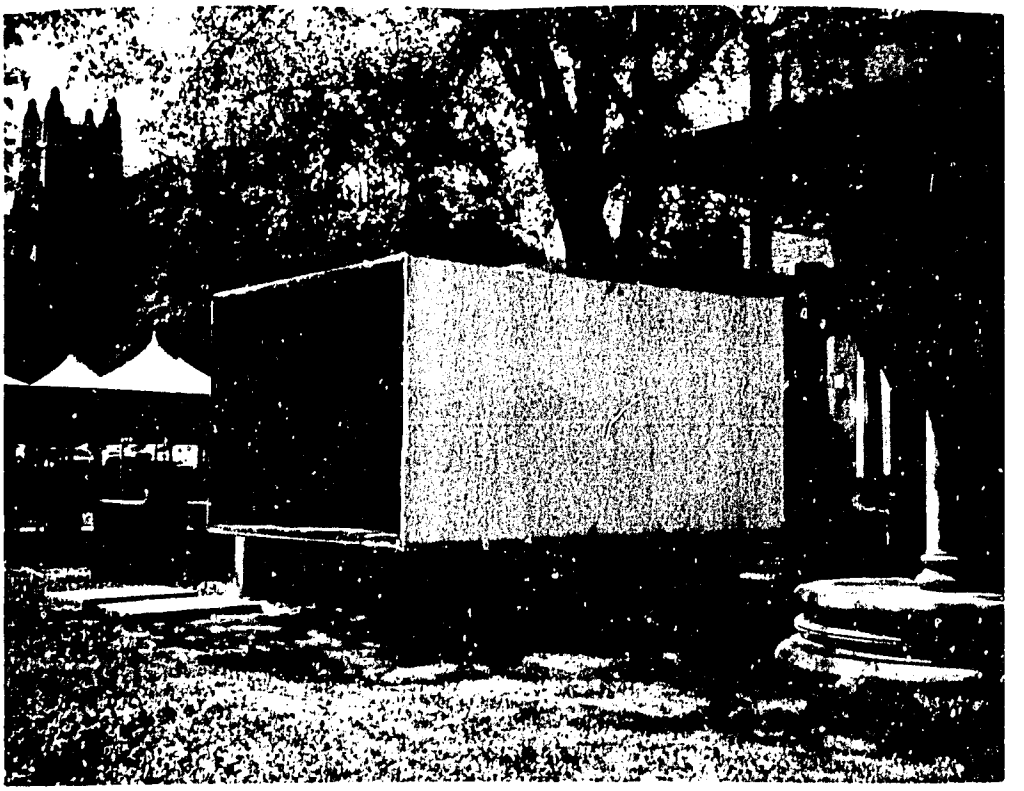


b. Assembled structure with exterior enclosure

4. THE FILAMENT WINDING SYSTEM



a. Filament winding mandrel for room-size unit (12' x 16' x 8')



b. The filament wound unit erected on concrete footings

Appendix B

OUTLINE OF SECTION OF FINAL REPORT CONCERNED WITH MARKET POTENTIALS OF CELLULAR PLASTICS IN EMERGING NATIONS

OUTLINE FOR PART B OF REPORT TO AID ON ORA PROJECT 05687

REQUIREMENTS FOR THE INDUSTRIAL PRODUCTION, DISTRIBUTION AND MARKETING OF CHEMICAL MATERIALS FOR PLASTIC STRUCTURES AND BUILDING COMPONENTS IN VARIOUS UNDERDEVELOPED AREAS OF THE WORLD

1.
Role to be played by the U. S. chemical industry

(a) The industry's present status:
figures and charts showing capital investment in plant facilities, cost-price trends for various plastic materials, range of structural and other applications developed so far, plus any other data that will illustrate the problem of an increasing surplus productive capacity which is perplexing the industry.

(b) International ramifications:
figures and charts showing the status of chemical companies in other countries and how they presently divide up the market on a worldwide scale preferably by regions (Europe, Asia, Africa and Latin America) and also, if possible, by individual countries.

(c) Development of plastic structures as a new marketing opportunity for the U. S. chemical industry and the importance of such structures to the developing nations as a means of encouraging industrial productivity and a rising level of national income:
figures and charts showing the relationship between industrial development and national standards of living in various areas of the world.

2.
The potential worldwide market for plastic structures

(a) The need for new housing:
figures and charts showing population growth rates in various countries and the disparity in the output of new living accommodations (dwellings and other household consumer products), as a basis for determining short-term and long-term housing requirements.

(b) The available buying power:
figures and charts showing per capita incomes in various countries and the development of mortgage loan agencies and other financing resources, including direct subsidies by local governments for low-cost housing.

(c) The specific product and its production requirements:
figures and charts showing quantities of chemical materials needed to produce typical plastic structures or components for housing, based on use of various structural systems developed by ORA Project 05687.

(d) Estimates of specific housing market demand:
figures and charts showing the number of plastic dwelling units or structural components and other household or consumer items, likely to be needed in light of the available buying power in various countries, to serve as a basis for calculating the potential market demand for various chemical materials.

3.
Housing production in relation to industrial expansion

(a) The extent of industrial development:
figures and charts showing the regional availability of natural resources (wood, coal, petroleum) used in producing the various chemical materials needed for the production of plastic dwellings and other household or consumer items, the regional development of processing and fabrication facilities, and the regional development of marketing systems.

(b) Minimum plant production and distribution requirements:
figures and charts showing output capacities needed to support local fabrication and processing facilities in an economical operation, below which it would be better to rely on importation of materials and products from areas that are more advanced industrially.

(c) The rate of industrial expansion:
figures and charts showing the various regional development factors -- availability of educational facilities (new skills), introduction of new transportation and communication facilities, new power sources, et cetera -- which might influence how rapidly new plastic dwelling production facilities are introduced into any newly developing area of the world.

(d) Recommended procedure or plan of action by U. S. chemical companies and foreign governments with AID support -- development of prototype dwelling unit designs, use of available AID aids, introduction of production training programs, field testing programs, regional exhibits, demonstrations, so on, in collaboration with AID.