NBSIR 74-567

FY 74 Progress Report on Design Criteria and Methodology for Construction of Low-Rise Buildings to Resist Typhoons and Hurricanes

N. J. Raufaste, Jr. and R. D. Marshall

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D. C. 20234

July 1, 1974

Interim (July 1, 1973 through June 30, 1974)

Prepared for
The Office of Science and Technology
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Under a
Participating Agency Service Agreement (PASA)
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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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SI CONVERSION FACTORS

This report describes measurements in metric units. It is recommended that the reader assume the responsibility for applying the appropriate conversion to English units. The United States of America, as a signatory to the General Conference of Weights and Measures (which gave official status to the metric SI system of units), recognizes the International Standard (SI) unit of measurement.

Length

1 centimeter (cm) = 0.394 inch (in)
1 meter (m) = 3.281 feet (ft)
1 kilometer (km) = 0.622 mile (mi)

Velocity

1 centimeter per second (cm/s) = 0.394 inch per second (in/s)
1 meter per second (m/s) = 3.281 feet per second (ft/s)

ABSTRACT

This report presents the major accomplishments of the second phase of a three year project to provide engineering and technical assistance to the Agency for International Development (AID), Department of State in developing improved design criteria for low-rise buildings to better resist extreme winds. During Fiscal Year 1974, project staff members of the Center for Building Technology, National Bureau of Standards, Washington, D. C. 20234 commenced several tasks. These tasks will serve as major inputs to the development of improved design criteria. The principal tasks included: 1) selecting a second and third field test site in the Philippines, 2) instrumenting four full-scale houses at the sites, 3) instrumenting the University of Philippines wind tunnel facility, 4) helping arrange and participating in an international workshop at Manila during November 1973, and 5) developing in conjunction with short-term consultants in Bangladesh and Jamaica a methodology for the transfer of the technology to those areas.

INTRODUCTION

The National Bureau of Standards (NBS) through this project is developing improved design criteria for low-rise buildings in developing countries to better resist the effects of extreme winds. The project is sponsored by the Agency for International Development (AID) under Participating Agency Service Agreement (PASA) No. TA(CE) 04-73 with funding under AID's central research program. The overall management is provided by William H. Littlewood, Associate Director, Office of Science and Technology, AID.

This research project originated from recognition of a need for additional research to supplement the limited amount of existing data regarding the wind effects on low-rise buildings, especially in developing countries. The existing criteria for wind loads in developed countries do not make provisions for steady and fluctuating wind pressures along the edges of roofs and walls where flow separation occur. Yet wind flows along these regions are one of the primary contributors to building damages. This research and the resultant development of suitable design criteria and methodologies will provide high benefits in reducing losses of structures and lives in the countries where the criteria are applied.

The Philippines experience the highest worldwide annual frequency and intensity of tropical storms. Within the Philippines, the frequency of tropical storms is greatest in Luzon. Statistics indicate that between 1948 and 1971 the Philippines were exposed to 482[1] tropical storms, or an average of 20 per year. As such, these occurrences make the Philippines a natural laboratory to measure wind loads on buildings.

The Philippines, consisting of over 7,100 islands, are located approximately 800 kilometers off the coast of southeast Asia. The archipelago extends north and south for approximately 1600 kilometers at its widest part.

The Philippines are generally divided into three regions: Luzon, the northern section: the Visayas, Palawan and Mindoro, the central section; and Mindanao and the Sulus, the southern section. Approximately 37 percent of the land area is included within Luzon, 29 percent in the Visayas area and 34 percent in Mindanao. There are about 90 different dialects spoken among the Philippine population of over 37 million people.

NBS's extreme wind study includes several components. It is based largely on field work (collection of wind loading data from seven field test buildings) and from wind tunnel testing of building scale models. The study also includes a review of climatological data from the weather bureaus of the Philippines and two other developing countries, Bangladesh and Jamaica. Socio-economic, architectural and structural data, and codes and standards information from the Philippines and other developing countries will be included in the implementation aspects of this study. In addition, knowledge about wind effects on buildings obtained in other countries such as the United States, Japan, Australia and the United Kingdom will be used as required.

1

"Climatology and Wind Related Problems in Philippines" by R. L. Kintanar, November 1973, Manila, Philippines (Paper presented at a workshop in Manila, Philippines).

The following Fiscal Year 1974 Project Status Report discusses the principal activities and accomplishments during the period July 1, 1973 through June 30, 1974. Also included is a summary of activities accomplished during the period from March 1973 to June 1973, the initial phase of the project.[1]

During FY 74 five principal tasks were completed. The tasks were:

a) selection of a second and third field test site at Daet and Laoag City (the first was selected at Quezon City in FY 73),

b) instrumentation of four of seven test houses and appropriate training of technical personnel by the NBS project team at the three field test sites (with three more to be instrumented by the Filipinos),

c) instrumentation of the University of Philippines wind tunnel facility, with appropriate training of the technical personnel,

d) participation in an international workshop in Manila during November 14-17, 1973 (proceedings of Workshop will be published during the Summer of 1974), and

e) selection and award of contract to short-term consultants to transfer research results to other wind-prone geographic areas (Bangladesh and Jamaica).

Each of these tasks was completed. It should be noted, the above items "b" and "c" include a teaching component. The wind tunnel training will be an on-going and continuous activity throughout the life of the project.

Other work accomplished during FY 74 included:

a) initial assesment of Philippine climatological data,

b) continuation of library research of related subject documents,

c) preliminary analysis of wind data collected on test house Number 1 (Quezon City) during two October 1973 storms,

d) preliminary analysis of socio-economic and housing considerations and

e) preliminary analysis of Philippine housing construction practices.

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[1] For additional information about the initial project phase references, see NBS report to AID entitled Fiscal Year 1974 Project Status Report-Design Criteria and Methodology for Construction of Low-Rise Buildings to Resist Typhoons and Hurricanes, July 3, 1973, available from the authors.

This report highlights the major results of each of the above tasks and presents general overall impressions. Where factual material is available, it is presented. Where the findings are based on interpretation of the available data, the underlying assumptions are given. The details of the task accomplishments are given in the next section of the report. This is followed by a discussion of the anticipated progress and plans for Fiscal Year 1975. Appendices found at the back of the report provide the reader with supplemental information about specific task accomplishments.

Five appendices are included:

Appendix A - Minutes of the 1st-6th Philippine Advisory Committee Meetings

Appendix B - Simulation of Atmospheric Flows in Short Wind Tunnel Test Sections.

Appendix C - Bibliography of Wind-Related Documents

Appendix D - Housing and Wind Problems in the Northern Caribbean and Indian Ocean Countries

Appendix E - Housing in Extreme Winds

A. SUMMARY OF PROGRESS FOR FISCAL YEAR 1974

Background Information

The first step in the initial research (FY 73) was to identify interested organizations, agencies, universities and other groups within the Philippines, selected Indian Ocean countries and several northern Caribbean islands, and to assess their degree of interest for possible in-country project participation. On April 27, 1973 the first major milestone occurred -- the formation of the Philippine Advisory Committee. Professionals from various building related fields were brought together. The response from the Philippine Government and the private sector numbered more than 30 scientists, engineers and researchers representing 9 government entities, four professional organizations and two private groups. Also included were the USAID Mission, to the Philippines and the U. S. National Bureau of Standards. The Philippine Advisory Committee serves as the focal point for coordinating project activities centering in the Philippines.

Since the initial formation of the advisory committee four additional groups have joined. Currently the committee is composed of the following:

- University of the Philippines (UP)
- Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)
- National Housing Corporation (NHC)
- Land and Housing Development Corporation (LHDC)
- Peoples Homesite and Housing Corporation (PHHC)
- Government Service Insurance System (GSIS)
- Social Security System (SSS)
- Philippine Standards Association (PSA)
- A. R. Flores and Associates
- National Building Code Committee
- Concio and Associates
- Association of Structural Engineers of the Philippines
- Philippine Institute of Civil Engineers
- Bureau of Public Works (BPW)

- Philippine Civil Aeronautics Administration (CAA)
- National Science Development Board (NSDB)
- USAID Mission to the Philippines
- Bangladesh University of Engineering and Technology
- CARE, Inc. - Bangladesh
- Douet, Brown, Adams and Associates, Jamaica
- U. S. National Bureau of Standards

In addition to NBS and AID support, principal members from the above groups personally donated their time and professional expertise; test buildings; land to construct test buildings; scientific facilities and funding for continuation of appropriate Philippine research activities. For example, The University of Philippines (made available their wind tunnel facility for scale model testing. They also provided over one man year of research associate services to operate the tunnel and one-third man year of construction laborers' time to modify the wind tunnel facility. The Philippine Atmospheric Geophysical and Astronomical Services Administration committed three parcels of land at Quezon City, Daet and Laoag City as sites for six test buildings. The PAGASA permitted their main building at the Daet weather station to be instrumented. They also provided about one-quarter man year of technicians' time to instrument the test buildings and operate and maintain the equipment. The Philippine Civil Aeronautic Administration donated a parcel of land at Laoag City for one test building and a meteorogical tower. The World Meteorological Organization United Nations Development Program donated one jeep for surface transportation trips to the field sites (Daet and Laoag City).

The National Housing Corporation donated the first test house, at the Quezon City site. The value of this donation is about 10,000 pesos ($1,500 US). The Land and Housing Development Corporation donated the second test house at Quezon City. The house is valued at about 12,000 pesos ($1,800 US). The Government Service Insurance System donated two test houses at Laoag City, houses are valued at about 15,000 pesos ($2,000 US). CARE, Inc. -Bangladesh donated a 200 square foot barrel vaulted house at Quezon City for instrumentation. They also absorbed the transportation costs to transport it from Bangladesh. It is expected that the Peoples Homesite and Housing Corporation will donate a house at Daet during the summer of 1974 (financial problems caused PHHC to postpone their Spring 1974 construction schedule). The University of Philippines constructed a new air conditioned equipment room adjacent to the wind tunnel. They are also absorbing the costs for computer runs.

Many of the above and other committee members provided services by hosting meetings, co-sponsoring an International Workshop and donating money for a general project fund.

The second milestone in the initial project activity was the identification of two individuals to represent the Indian Ocean countries and the northern Caribbean Islands. These individuals will transfer information about their respective geographic areas as inputs to the development of final design criteria, and will also transfer the project results to their respective geographic areas. Additional information about consultant activities is provided later in this report.

Lastly, it should be mentioned that the USAID Mission to the Philippines provided the NBS research team with a base of operations, for limited logistical and advisory services. The Mission's Capital Development Office USAID/Philippines, serves as a focal point for the NBS interactions while NBS personnel are in the Philippines. Mr. William C. Larson, Assistant Director for Capital Development, the NBS team's primary point of contact, has recently left the Philippines after serving three consecutive tours of duty. His replacement, Mr. Richard Dangler (from AID/Washington, D. C.) has already been briefed on the overall project. Mr. Larson's interest and help is greatly appreciated.

Appendix A "Minutes of the 1st-6th Philippine Advisory Committee Meetings" will provide a more complete overview of the project activities.

The strong Philippine and Mission support has provided a firm base which permitted the FY 74 activities described herein to occur smoothly and on schedule.

Wind Research Activities

a) Field Test Sites

Three field test sites are being operated under the full-scale phase of the test program. In order of selection and installation of equipment, they are as follows; (1) Science Garden at Quezon City, (2) Daet and (3) Laoag City. A number of factors had to be considered in selecting these test sites and the final choices required some compromise in the original selection criteria. The main factors in order of importance were as follows:

- High frequency of extreme winds,
- Statistical independence,
- Accessibility,
- Availability of commercial power,
- Type of wind exposure, and
- Security

The Science Garden site was an obvious choice since it is staffed with qualified PAGASA technicians. These technicians form the nucleus of a team trained by NBS in the installation, operation and maintenance of test equipment. It was thus possible for the NBS team members to transfer a significant portion of the installation work and associated responsibilities during the early stages of the program. Science Garden also serves, in conjunction with the University of the Philippines, as the center for reference standards, spare parts and service equipment.

Selection of the remaining sites was not so obvious. It had been concluded in the initial stage of the program that PAGASA weather stations would be used because of the security and personnel available to service the equipment. In addition, measurements of temperature and barometric pressure would be available, thus freeing data channels for additional pressure measurements. In discussions with the Philippine Advisory Committee, serious consideration was given to sites at Virac, Casiguran, Aparii, Baguio City, Daet and Laoag City. Virac and Baguio City were eliminated on the basis of unusual terrain features (mountain top locations) which are not typical of wind exposures for housing developments and would be extremely difficult to model in the wind tunnel. Casiguran was eliminated because of the difficulties of transporting equipment and personnel for periodic maintenance and calibration (boat service only). Aparii was eliminated because of plans to relocate the present PAGASA weather station site, and the lack of electrical power.

Daet and Laoag City were selected with some compromise on statistical independence (Daet) and frequency of extreme winds (Laoag). However, it is believed that other attributes of these sites more than offset these compromises (see fig. 1 for test site locations).

Arrangements were made with the Philippine Advisory Committee to build test houses at the sites and, where possible or necessary, to use existing PAGASA structures. Test equipment was assembled, tested, calibrated and packaged at the NBS for shipment to the test sites. One such shipment is shown (fig. 2) prior to transportation to the Philippines. The United States Air Force (USAF) provided authorization for two NBS project personnel to accompany the research equipment on USAF Military Airlift Command (MAC) aircraft from Dover AFB, Delaware to Clark AB, Philippines. Three such trips were arranged during FY 74.

Where possible, the signal cables, attaching hardware, etc. were specially made up at NBS for each site to reduce the amount of field work and installation time to a minimum. At the same time, spare cables and fixtures were shipped to and stored at the Science Garden so that unforeseen changes in test house geometry and location could be accommodated. A description of the respective sites and their status as of May 30, 1974 is given below.

1) <u>Science Garden, Quezon City</u>. The wind exposure at this site varies with wind direction, being relatively clear and flat from N to SE and slightly rough from SE to W due to construction of high-rise buildings some 1000 meters away. The site is moderately rough from W to N due to local topographical features and low-rise buildings on the test site. Two test houses are currently instrumented and a third house will be instrumented in July, 1974. Basic plan dimensions of the first two units are 9 x 10 meters (see fig. 3). The third unit was constructed by CARE, Inc. in Bangladesh and shipped to Quezon City for full-scale testing.

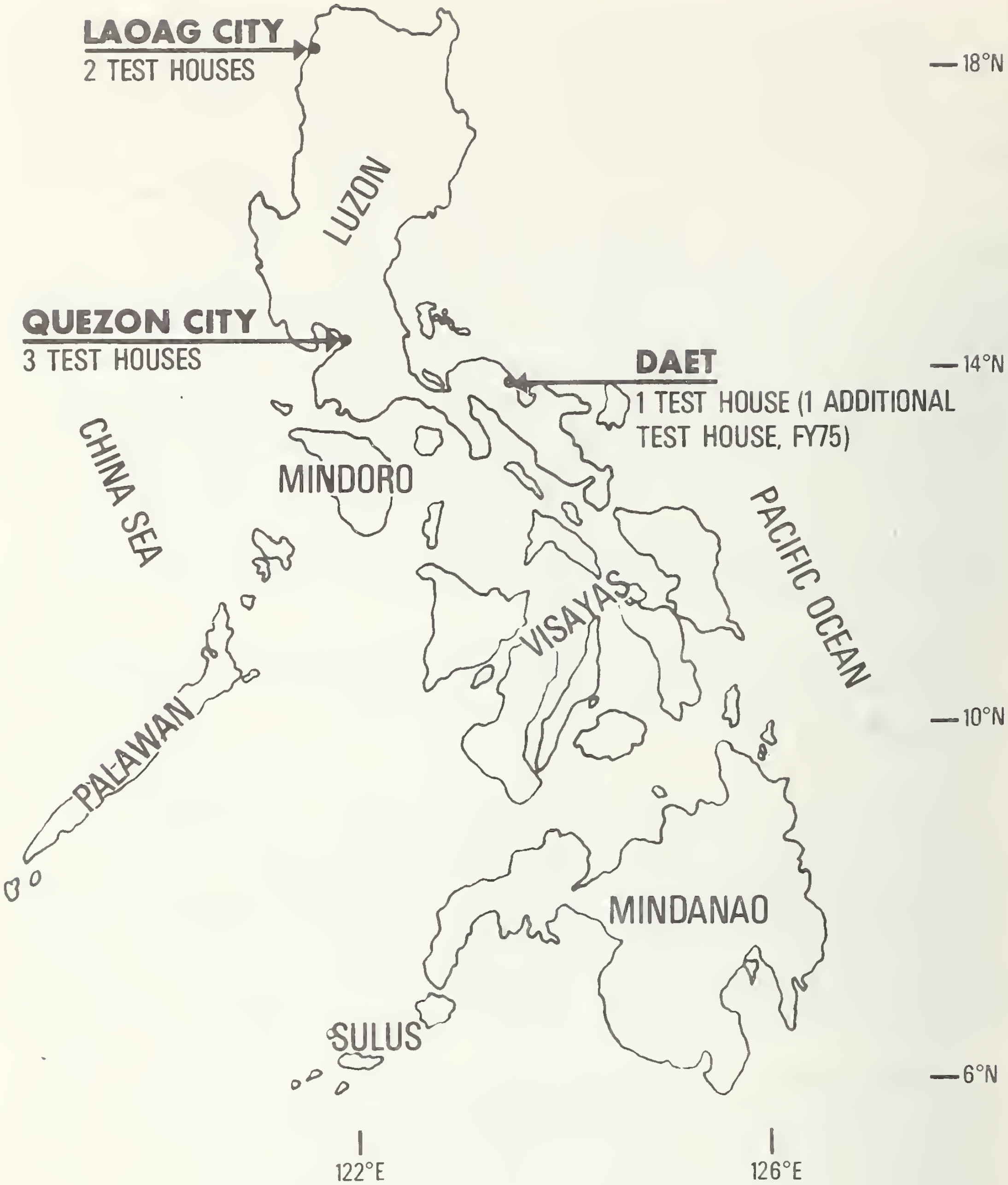


Figure 1 Building test sites

Figure 2 Wind research equipment undergoing final inspection by NBS team member prior to shipment to the Philippines by the USAF Military Airlift Command

Figure 3 The first (bottom) and second (top) test houses were instrumented for winds in September and November respectively. Note the pressure transducers (round disks) located on the corrugated iron roofs; others are fastened on the walls

This building is barrel vaulted in end elevation and has plan dimensions of 5.4 x 2.5 meters. A more detailed description of this structure can be found in previous NBS progress reports. The data acquisition system is located in the PAGASA Instrumentation Building (adjacent to the first test house) which is air conditioned and relatively free from dust. A total of 21 pressure channels are available (an increase of 7 channels through use of an auxiliary signal conditioning system).

2) Daet Weather Station. The Daet site is approximately 230 km SE of Manila. It is located next to the city airport which borders the Pacific Ocean. The site has a very flat and clear exposure with the exception of a coconut grove running from NE to SE adjacent to the ocean. Due to financing problems, the two test houses planned for Daet have not been constructed. It was therefore necessary to instrument the main PAGASA Station Building behind the radome (see fig. 4). This is the only building under test which has a hip roof. The data system is installed in the main building's radar equipment room which is air conditioned. An emergency generating system is available at this site in the event that commercial power service is disrupted.

3) Laoag City Weather Station. This site is approximately 450 km north of Manila. As with Daet, the site is adjacent to the municipal airport and has a clear and flat exposure for all directions. Two test houses with plan dimensions identical to the test units at Science Garden (but with different roof slopes and eaves overhang) have been constructed, one on the PAGASA station grounds and one on CAA property. The unit that is currently instrumented is located in close proximity to two existing buildings which will allow the influence of neighboring structures to be evaluated. Since no air conditioning is available at this site, it was decided to install the data acquisition system in the smallest room of the test house and add air conditioning at the time of the next trip (July 1974). The second test house will also be instrumented at that time.

b) Research Equipment

(1) Full-Scale Test Equipment. Based on technical needs, some of the data acquisition equipment was specially developed at NBS while the balance was specified. The data acquisition systems used in the full-scale test program consist of five basic subsystems; (1) the sensors or transducers, (2) a logic section, (3) a signal conditioner, (4) a recorder, and (5) a power supply. The equipment was assembled, tested and packaged for shipment to the Philippines by NBS project staff.

These systems are designed to continuously monitor input signals and to go into a calibration and record sequence when the signal being monitored exceeds a preset level. When the recording period has ended, the system enters a "hold" period during which no data are collected, regardless of the signal level on the channel being monitored. The "record" and "hold" periods are switch-selectable and are usually set at 20 and 30 minutes, respectively. The total recording time available on a reel of tape is approximately 6 hours. Thus, the total time period between changes in tape reels (assuming continuous high wind conditions) is approximately 12 hours which is considered to be sufficient for most typhoon passages.

Figure 4 Aerial view of instrumented test building at Daet Weather Station

Wind speed and direction are measured by a propeller-vane anemometer mounted on a 10-meter mast located far enough from the test buildings to register conditions in the undisturbed wind field. The anemometer is rated at 100 m/s and provides the signal which triggers the recording system. An ambient pressure probe is also mounted on the mast just below the anemometer and provides the differential pressure transducer with a standard reference pressure. The pressure transducers are mounted in low-profile housings which are designed to create a pressure intensity at their center equal to the pressure that would exist on the surface of the building without the housings installed. This obviates the problems involved with mounting the transducers flush with the wall or roof surfaces. The transducers are fitted with a solenoid valve which is activated by the logic system one minute before the generation of pressure records begin. This valve places the transducer in a "closed-loop" configuration, thus allowing the subsequent record to be corrected for zero offset due to thermal drift or loading of the transducer diaphragm with rainwater.

The logic portion of the data acquisition system normally operates in an automatic mode, but provisions exist for manual intervention for the purpose of calibration or periodic system checkout. The logic section also includes a time code generator which provides both digital and analog code of Greenwich Meridian Time (GMT) in days, hours, minutes and seconds. The time code generator is set by radio countdown from PAGASA Headquarters in Quezon City and normally requires correction only two or three times a year.

Analog signals from the pressure transducers are converted to DC voltages (demodulation) and filtered by the signal conditioner prior to recording. The signals are also attenuated to match the range of the tape recorder, thus providing a better signal to noise ratio than would be possible by straight recording of the transducer outputs.

The recording section consists of a 14-track analog tape unit with 26.7 cm reels containing 1097.3 meter of tape. Usual record speed is 4.8 cm/sec. The recorder is normally in a "powered down" mode and only operates on command from the logic section. As with the logic section, manual intervention is permitted for calibration, cleaning and rewinding tape. Recorded signals can be reproduced in the field to check recorder operation.

With the exception of the Laoag City test site, commercial power is used to operate the data acquisition systems. The Laoag City site is provided power by the CAA. To ensure availability of power under storm conditions, all three sites are equipped with a backup system of batteries. The batteries are continuously charged when external power is available and provide system power (115VAC) by means of an inverter. When commercial power is interrupted, the batteries automatically switch on and pick up the load to supply the data acquisition system for approximately 8 hours of continuous operation. The batteries are recharged automatically when service is restored.

Typical installations of test equipment are shown in figures 5 through 10. Since typhoon winds can be expected to come from any direction, it is extremely difficult to determine a "best" configuration of pressure transducers. Because roof structures are known to be the most susceptible to wind damage, they received the highest priority in transducer allocations. Extreme pressures acting along ridge lines, eaves and roof corners are of interest as well as the average uplift pressures acting on the overall roof area. As such the confirguration of pressure transducers are arranged differently on each test building, thus providing the ability to measure a greater range of wind loadings. The building in the upper right corner of figure 3 was instrumented to give information on the correlation of pressure fluctuations along the centerline on both sides of the roof structure, while the building in figure 10 was instrumented to give information on localized pressure fluctuations. In all of the test buildings, transducers were installed inside the building to measure internal pressures which significantly influence the net roof uplift loads.

(2) Wind Tunnel Test Equipment. Test equipment being used in the wind tunnel can be divided into three categories; (1) pressure transducers, (2) wind speed measuring equipment, and (3) signal conditioning and analysis equipment. The pressure transducers are quite similar to those being used in the full scale tests except for the cylindrical transducer housings. Normally, four transducers are installed in the building model although six units are available.

Wind speeds are measured by pitot tubes when mean values are required. For measurement of wind speed fluctuations, hot-wire anenometers are used. The anemometers have an extremely high frequency response and are well suited to making measurement over the frequency range of interest (0 to 500 Hz). Two anemometer systems are used, permitting simultaneous measurements at two points in the tunnel for the determination of integral scales (size of wind gusts). The second system also provides backup if a component should fail. A discussion of experimental techniques and data processing is included in another section of this report.

c) Wind Tunnel Modeling

The wind tunnel facility at the National Hydraulic Research Center (NHRC), University of the Philippines, is being used to carry out a series of tests on models of the full-scale test buildings. The cross section of this tunnel is 1.22 meters square and 3.70 meters long and produces a wind speed of approximately 30 meters per second. These model tests will aid in the interpretation of full-scale studies and will allow design pressure coefficients to be determined in a systematic manner.

Figure 5 Typical installation of ground anchors by PAGASA technicians prior to erection of meterological tower

Figure 6   PAGASA technicians assembling tower section

Figure 7 Erecting 10-meter meteorological tower which supports the anemometer and ambient pressure probe. Note guy wires running to ground anchors

Figure 8 Officer-in-charge at Daet Station receiving instructions on assembly of pressure transducer from member of PAGASA Headquarters staff

Figure 9 Typical installation of pressure transducers and signal cables on a test building roof

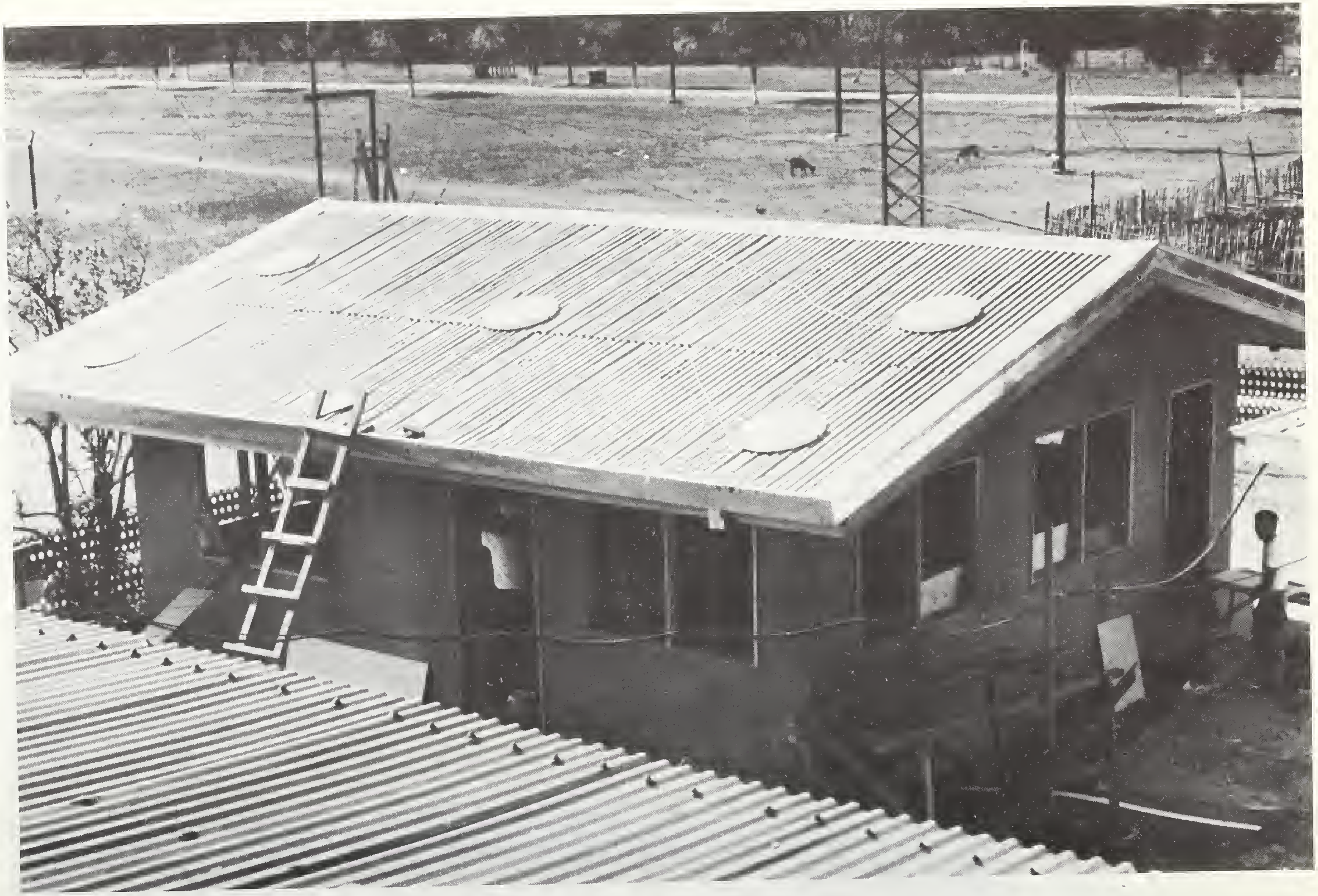


Figure 10 Installed pressure transducers on a test building at Laoag City

While it is not possible to exactly model atmospheric boundary layers in conventional wind tunnels, an acceptable degree of similitude can be achieved by proper use of surface roughness elements and vortex generators. The technique being used in the NHRC tunnel hass been used in previous wind tunnel model studies and was perfected for this application in a slightly larger but quite similar wind tunnel at Colorado State University (CSU). Tapered spires are placed at the entrance to the test section to produce a sheared flow of arbitrary turbulence intensity. The spires are followed by several rows of roughness elements located on the floor of the wind tunnel. The roughness elements generate a turbulent boundary layer which extends to almost the full height of the tunnel at the downstream end of the test section. Two combinations of spires and surface roughness elements were developed which produce turbulent boundary layers typical of smooth and moderately rough terrain, respectively. The model scale being used in these studies is 1:80. Ideally, this scale should be dictated by the integral scale of the turbulence, the effective surface roughness height and the length associated with the peak of the turbulent energy spectrum. Test results obtained in the CSU studies suggest a scale ratio of from 1:100 to 1:200. However, the physical size of the model precludes installation of pressure transducers at these small scales. Thus a compromise of 1:80 was used. Preliminary test results and results obtained in other wind tunnel model investigations suggest that scale matching is of secondary importance compared to intensity of turbulence and shape of the spectral density function. A report covering the CSU studies is included as Appendix B.

In addition to the wind tunnel modeling as described above, the NBS developed, specified, obtained and transported various items of test equipment for the UP wind tunnel facility. The equipment was installed in the wind tunnel and training sessions were conducted in the operation of equipment and the interpretation of test results (see fig. 11). Major items of equipment transferred to the University of the Philippines include a signal correlator and probability analyzer, hot-wire anemometers, pressure transducers, electronic filters, signal amplifiers, x-y and stripchart records, voltmeters and an oscilloscope. This test equipment is housed in an air conditioned room built by the University. A typical plexiglass building model installed in the wind tunnel is shown in figure 12. Computer programs developed at the NBS for the analysis of random data are being transferred to the UP Computer Center. In addition, an extensive collection of documents dealing with the wind tunnel modeling of buildings and other engineering structures was placed in the UP Library. The list of documents is included in Appendix C.

d) Collection, Reduction and Analysis of Field Data

All data collected at the field test sites are recorded on analog magnetic tapes which are shipped in special containers to the NBS for processing. Typically, these tapes contain one channel each of wind speed and direction data, 11 channels of pressure data and one channel of time code. Prior to the recording of data, a tape is assigned a site designation and tape identification number. This information, along with the time code, uniquely identifies the data.

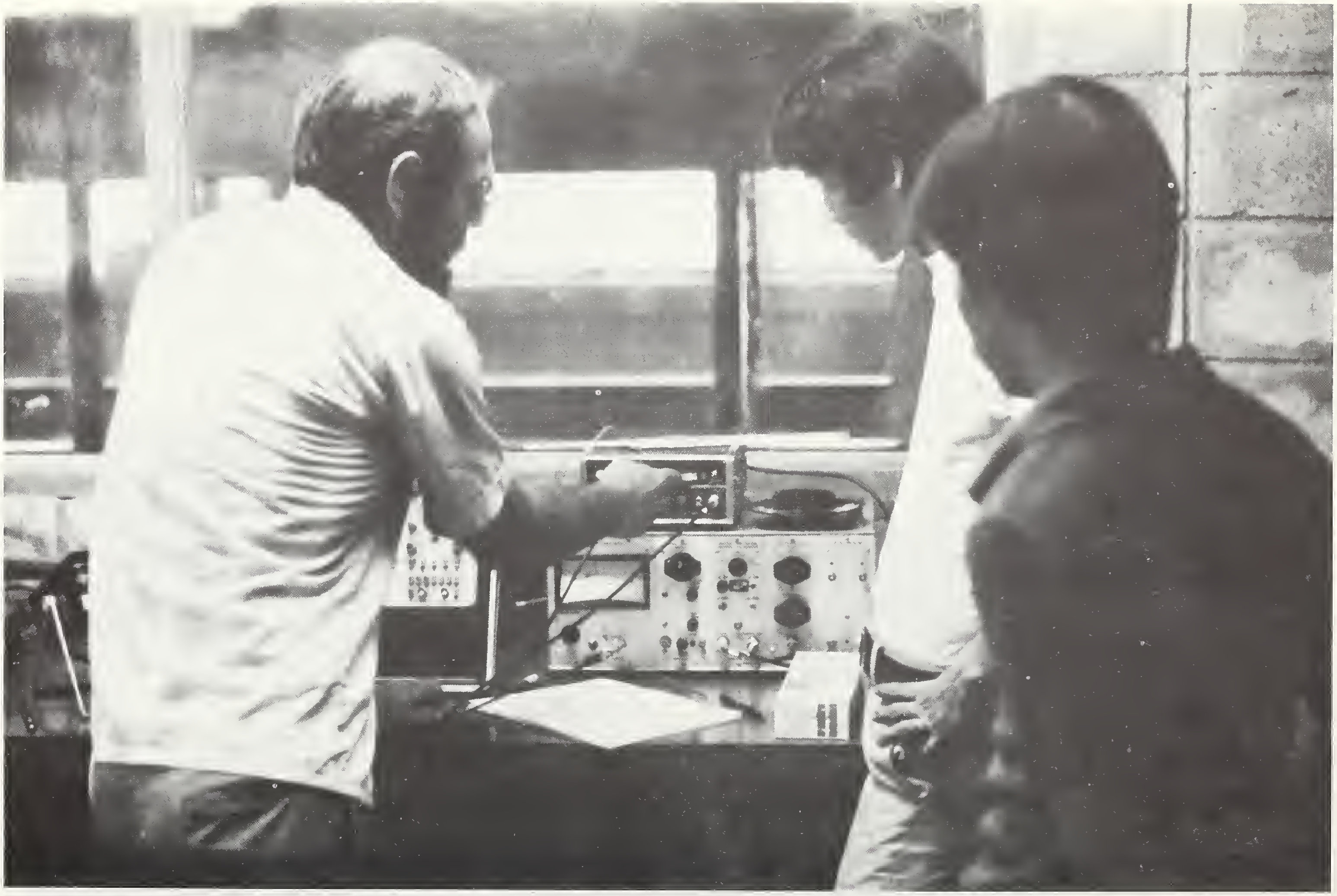


Figure 11 Member of NBS research team instructing staff of the National Center for Hydraulic Research (at the UP) in the operation of wind tunnel test equipment

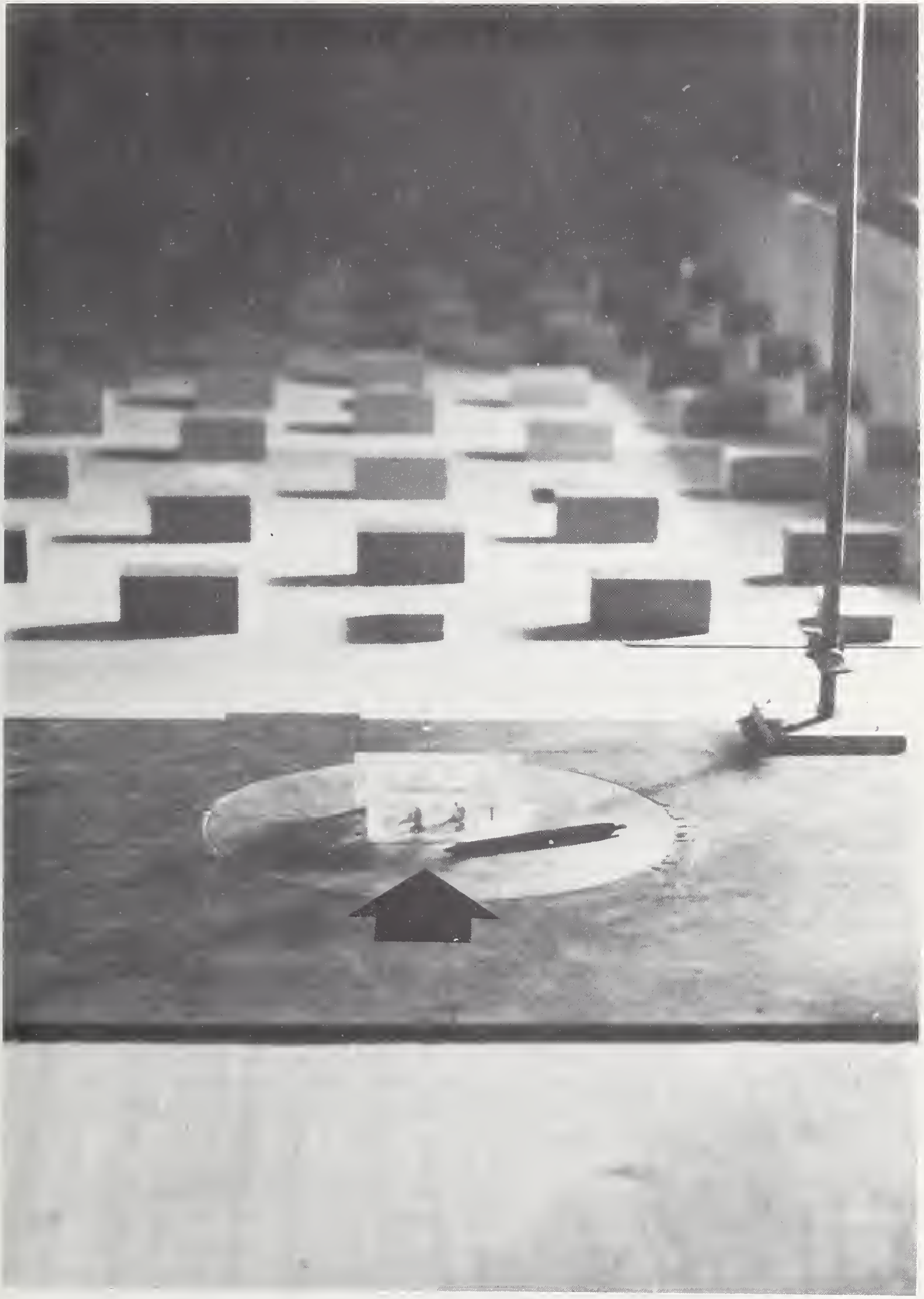


Figure 12 Photograph of 1:80 scale model of field test house installed in UP wind tunnel. This is a view looking upstream. Note ball point pen for scale

The first step in the data reduction process is to record certain key channels, such as wind speed, wind direction and a representative pressure signal on a paper stripchart and subjectively classify the records by degree of stationarity. Those records exhibiting significant trends are eliminated during this screening process. Records which contain redundant information are also eliminated at this time. The remaining records are then viewed on an oscilloscope to determine the approximate maximum or minimum peak values and to verify that the recordings have an acceptable signal to noise ratio and are free of discontinuities. Once the records are determined to be of acceptable quality, they are converted to digital form for analysis.

Analog to digital conversion is accomplished by means of a computer-controlled data aquisition system which scans the analog channels in sequence and converts the voltage levels into binary equivalents. The data channels are multiplexed at a rate of 20,000 channels per second so that the time skew is negligible for the frequency range of interest. The scan rate can be varied but is typically 12 scans per second. Each channel is sampled 12,000 times, resulting in a record length of 1000 seconds (16 min - 40 sec). The multiplexing stage is followed by a programmable amplifier which allows best use of the digital representation (eleven binary bits plus sign). The digital data are entered on a 7-track magnetic tape for subsequent analysis in the NBS Computer Center. This tape also contains header information such as site and tape identification, the time of day when the original data were recorded, and the length of record.

Several programs were developed at the NBS for the analysis of random data. These include; Probability Density Function which determines the peak values (either maximum or minimum) between zero crossings, calculates the mean and root mean square values and plots probability distribution functions; Correlation Analysis which calculates correlation functions and spectral density estimates; and a Summation Program which calculates the area-averaged surface pressures and the drag and uplift forces acting on a structure.

As of May 30, 1974, a total of 8 records were obtained at the Science Garden site, Quezon City, from two storms passing near Manila during October 1973. These records are currently being analyzed. The outputs are expressed in terms of dimensionless coefficients which will be used in developing the design criteria. These coefficients are described in another section of this report.

Data obtained from the wind tunnel are processed "on line" and are not recorded for future reduction or analysis. A hybrid computer allows the direct calculation of auto- and cross-correlation functions as well as probability density and distribution functions. A time domain analyzer is used to obtain direct measurements of mean and rms values. This system has the disadvantage of manual calculation of pressure coefficients, but this is insignificant when compared with the ability to quickly assess the test results and alter the model configuration without waiting for results from a central computer.

e) Assessment, Selection and Application of Climatological Data

A study of the available Philippine wind climate information with a view of assessing its adequacy from a structural engineering viewpoint will continue throughout the life of the project. Records of wind speeds, of typhoon observations and damages due to significant typhoons were collected by NBS through the courtesy of the PAGASA. Out of these records, data were selected which appear to be suitable for analysis. These will be used as input in programs available at NBS for predicting extreme winds corresponding to various recurrence intervals. A listing of the NBS program will be sent to the PAGASA Computer Center for future adoption by the PAGASA as a calculation tool. The Computer Center would assume the task of adopting the program for use in their facilities. NBS would provide appropriate assistance as required.

A parallel study of wind maps including the 1972 National Structural Code for Buildings of the Association of Structural Engineers of the Philippines and tropical cyclone frequency and intensity maps reveal the area of northern Luzon, and perhaps parts of Western Luzon (including Manila) may need to be included in a more intense wind zone area. This topic was discussed with the supervising Meteorologist of the PAGASA Climatological Division who confirmed, on the basis of his studies, the need to update the Structural Code wind map to insure a consistent and more adequate degree of safety for buildings. It is desirable that future editions of the building code differentiate between zones with different exposure (e.g. urban terrain vs. coastal sites). Results from this task will provide the appropriate Philippine code officials with much needed information for incorporation in a new building code. This information will serve as an input to the final report.

International Workshop on Effects of Extreme Winds

An International Workshop held in Manila, Philippines on November 14-17, 1973 addressed the state-of-the-art in mitigating building damages from winds. The workshop was jointly sponsored by AID, the project's Philippine Advisory Committee and the U.S. National Bureau of Standards.

Four themes covering climatology and aerodynamics, structural engineering, socio-economic and architectural considerations, and codes and standards were discussed.

The first two workshop days were devoted largely to presentations of technical papers. During the afternoon of the first day, a visit was scheduled to the field test site at the PAGASA Science Garden site, Quezon City.

Nine papers were presented during the technical sessions and five related reports with time reserved for discussions. The third day was devoted to subcommittee working sessions where 31 recommendations were developed. They were presented and discussed on the fourth day. Approximately 140 individuals from five countries (Jamaica, Bangladesh, the United Kingdom, the Philippines and the United States) attended the workshop.

Subsequent to the workshop the NBS and Philippine Advisory Committee edited the recommendations and combined several and modified others into 14 recommendations. The proceedings of the workshop will be published by the NBS in the summer of 1974. The publication will include the recommendations for improved building practices, the opening ceremonies, and the technical papers and reports.

It was the intent of the workshop to identify deficiences in data gathering procedures, wind effects on buildings, and building practices. The purpose of the recommendations is to upgrade design criteria for low-cost buildings to a minimum acceptable level, and to suggest improvements in the building procedure.

Library Research

As noted in the FY 73 Project Status Report to AID, NBS commenced a task to identify and collect related documents of extreme winds on low-rise buildings. As previously mentioned, two copies of 75 documents of wind effects on buildings and structures were transferred to the Philippine Advisory Committee. This occurred during September 1973. These documents provide the Committee with a fairly complete library of related documents from the U.S., the United Kingdom, Japan, Canada and Australia. They provide a current state-of-the-art on extreme winds. One copy of each document is on file at the University of Philippines Library and the School of Engineering Library.

A list of the documents is presented as Appendix C.

Additional document collection activities are underway. This is an ongoing continuous task throughout the life of the project. Two copies of all additional appropriate wind, socio-economic, structural and codes and standards related documents will be transferred to the Philippine Advisory Committee at appropriate times, usually during Philippine visits.

Information Transfer to Other Wind Areas

Research developed in the Philippines can be directly applied to other geographic areas subjected to tropical storms. In addition to southeast Asia, other wind prone areas include the Indian Ocean countries, the northern Caribbean Islands, and the southeastern coastal regions of the United States.

To ensure the transferability of research results it is important these geographic regions be represented. Effective implementation and dissemination of the projects research results should be accomplished by local individuals who have a working knowledge of their country's and geographic areas housing and climatological conditions. Contacts were established with individuals from Bangladesh and Jamaica. Dr. Jamilur Choudhury, Assistant Professor of Civil Engineering, Bangladesh University of Engineering and Technology is representing the Bay of Bengal countries. Mr. Alfrico Adams, Partner, Douet, Brown, Adams and Associates, Consulting

Engineers, Kingston, Jamaica is representing the northern Caribbean Islands. These individuals, under contract with NBS, prepared a report and participated in the international workshop conducted in Manila during November 14-17, 1973. They identified low-cost housing trends and design problems, socio-economic considerations, information gaps concerning structural systems and connection details, design loads and climatological data.

Appendix D contains the reports prepared by the two consultants. They are entitled "Low-Cost Housing and Extreme Wind-Related Problems in Jamaica and the Northern Caribbean Islands" and "Low-Rise/Low-Cost Housing and Extreme Wind Related Problems in Bangladesh".

In addition, these two reports will be submitted to the National Technical Information Service (NTIS) library upon final acceptance by AID.

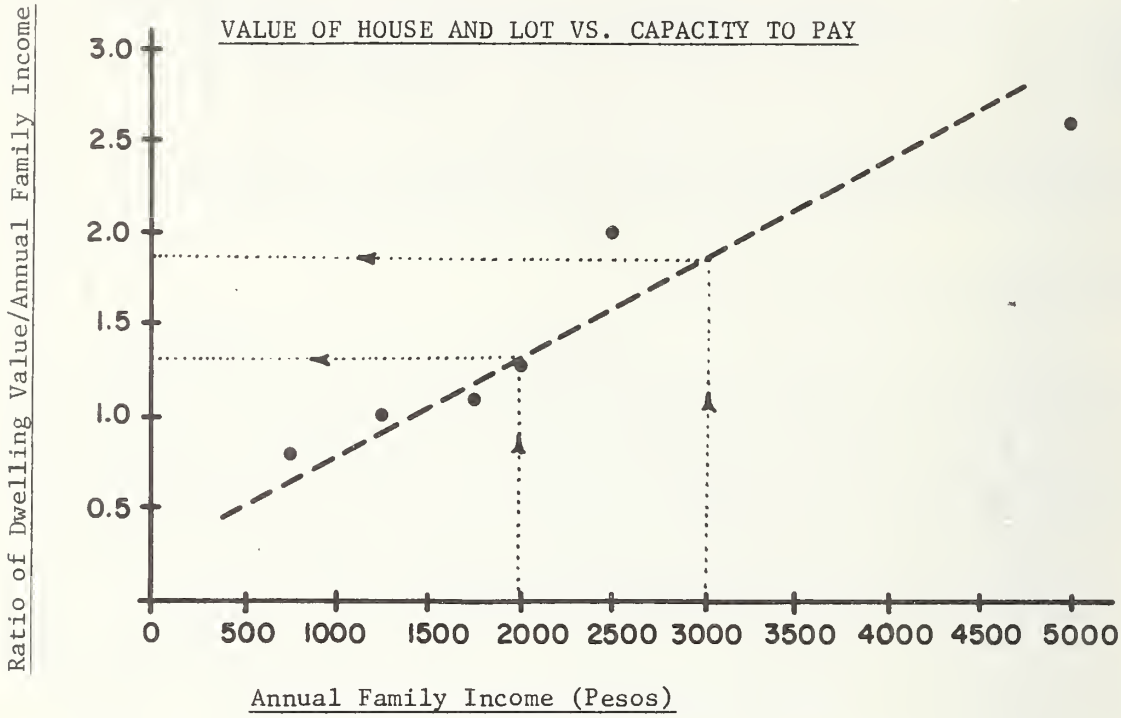
Socio-Economic and Housing Study

An introductory socio-economic and housing study of geographic areas subjected to extreme winds -- Philippines, Jamaica and Bangladesh -- commenced in FY 74. This topic was first addressed during the International Manila Workshop conducted in November 1973. The purpose of this task is to develop an educational document on socio-economic and housing information about the above three countries. This task is based on performing an economic analysis and synthesizing information from previously documented research. Inputs to perform this task will include information from the Bangladesh and Jamaican short term consultants reports, previous NBS research for AID, university research (domestic and international), general facts from appropriate embassies and developing country desks, research reports from relevant developing countries, from the NBS project team interviews and meetings with members from the participating countries and other sources.

An initial effort was conducted under an NBS contract with Mr. Stephen A. Kliment A.I.A. a consulting architect from New York City. His draft report summarizes information from fourteen documents (see Appendix E). The draft document will be reviewed by NBS and AID to decide its final format with attention to; the reader audience, textual message, graphic presentations and tabular layout. After this review the final portions of this task will be adjusted accordingly.

Directly related to this project is a term requiring clarification or resolution -- i.e. what is a low-cost house? Is it one or two times the family annual income? No one single, well accepted, definition is available. Since this project addresses low-cost housing as it relates to a high technology research activity it is necessary for the reader to have a better "feel" or appreciation of the term. An initial attempt was made in FY 74 to better acquaint the reader with this term. This is presented below. During FY 75 an in-depth economic analysis will be performed including an assessment of -- what is a low-cost house.

Mr. Sixto L. Roxas III, President, Bancom Development Corporation delivered a paper titled" Testimony on Low-Cost Housing" before the Philippine Senate Committee on Housing Urban Development and Resettlement in January 1969. In his paper, Mr. Roxas presented some economic information which is graphically presented below.[1] His information establishes a curve based on total family income versus the value of a home and lot which a family is permitted to purchase at 90 percent financing for 25 years at seven percent interest.[2]



A curve was plotted through the points which approximate the data given by Mr. Roxas. The curve suggests a family with an annual income of 2000 pesos can afford a house valued at 1.3 times their annual income (2,600 pesos) or at an annual income of 3000 pesos the family is entitled to purchase a home at about 1.8 times their income. Accordingly, data such as illustrated above could establish a boundary limit for low-cost housing. Just where along the abcissa is the poverty line (which could establish the range of low-cost housing) is unknown. However, as a rough guide the above figure provides the reader with a better impression of the ratio of housing value to family income.

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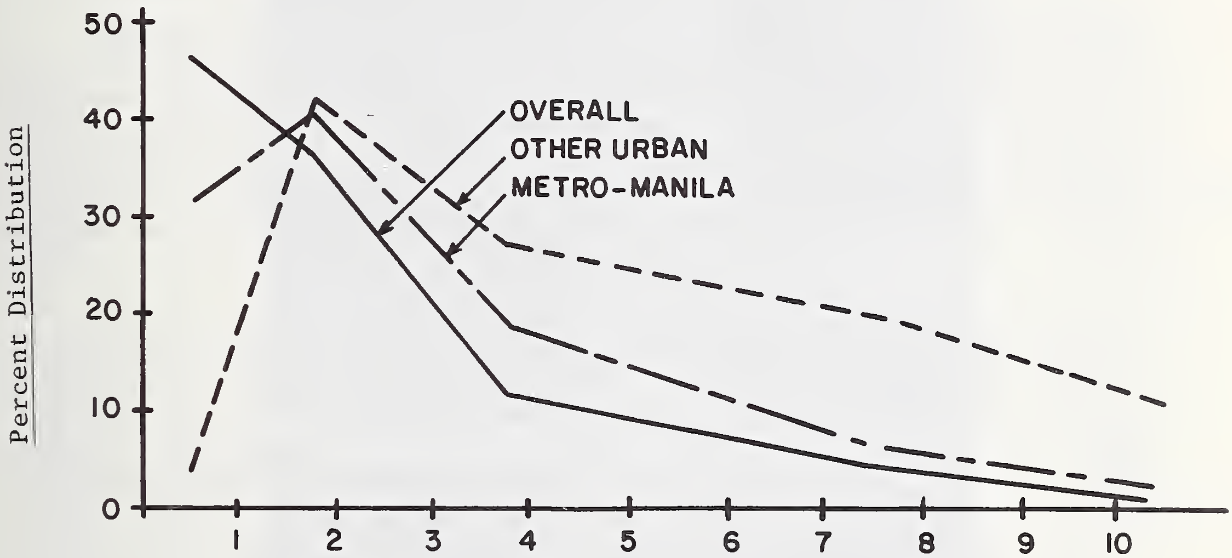
1 Housing in the Philippines - Preparation Material for the Conference on Housing, National Economic Development Authority, Philippines, 1973.

2 Similar information is presented in other documents such as: Housing Program Pre-Investment Survey for the Philippines, USAID Mission, Manila, March 1972; and Research Study of the Socio-Economic Aspects of Low-Cost Housing in the Philippines, Sycip, Gorres, Velayo and Co., Manila, Philippines, 1972

In conjunction with the above, it is important to recognize that income varies throughout the Philippines (and any country for that matter). Mr. Roxas provides income information stratified by 1) Manila metro area, 2) Urban areas other than Manila, and 3) for the entire country. This information is presented below.

INCOME DISTRIBUTION



Annual Family Income (pesos x 1000)

The figure suggests that families living in urban areas other than Manila are generally financially better off.

Information from the above figures provide the reader with boundary constraints leading to the construction of poverty lines and value limits for low-cost houses.

Philippine Housing Construction Practices

In this section of the report some of the construction practices employed in residential housing are examined and their implication with respect to the wind resistant characteristics is considered. The purpose of this is to indicate areas where improved construction practices could significantly improve the wind resistant capabilities.

A typical initial construction operation involves excavation of a shallow trench around the perimeter of the site as shown in figure 13. Since most new houses are constructed on grade without basements the walls are constructed in the trench. Note however that footings are not used and the block walls are laid directly on the ground. Although footings are not needed to compensate for freezing and thawing as in

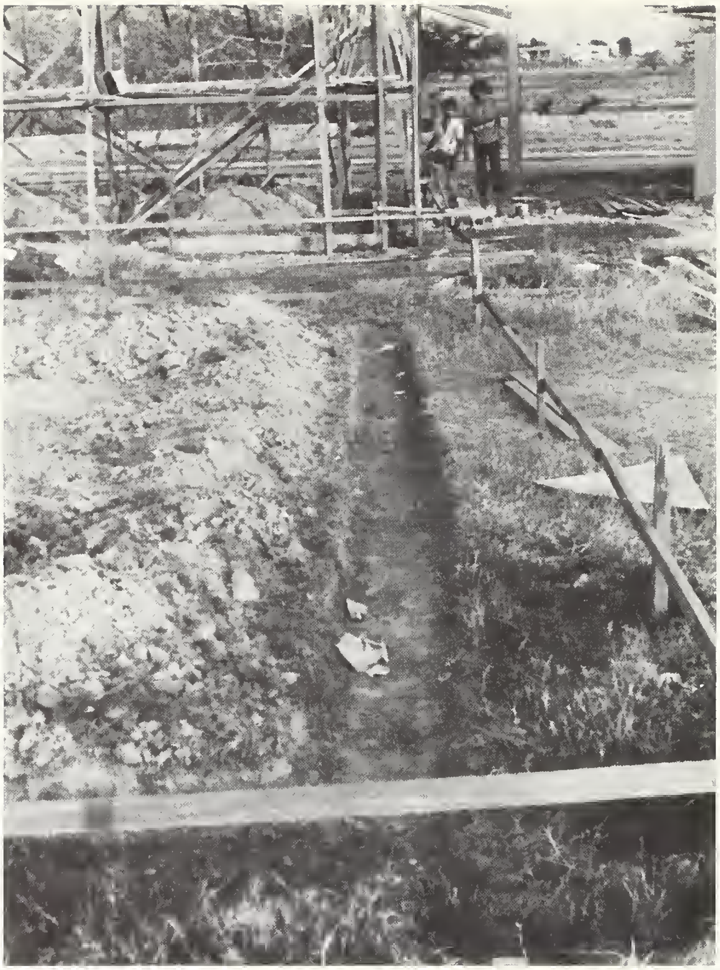


Figure 13   Shallow trench for wall placement

Figure 14   Wall construction quality and window framing details

other climates, placement of the block directly on the ground does not provide an adequate distribution of the wall loads to the soil. High bearing pressures occur under the block which eventually result in unequal settlement. Cracking of the walls as a result of this unequal settlement is a distinct possibility. In addition, this practice does not provide any resistance to uplift forces, other than the dead weight of the structure, for resisting overturning by high winds. Although complete overturning is unlikely, small uplift displacement can result in cracking of the structure.

Figures 14 and 15 illustrate the quality of the wall construction. The poor quality mortar joints and irregular nature of small pieces of block is apparent. In some cases large voids exist in the mortar joints which severely decreases the strength of the wall. The load distribution for the reaction from the roof beam shown in fig. 15 is very irregular resulting in high local stresses. These local stresses cause cracking of the block, settlement of the pier and very little ability to resist lateral load.

Footings are also not used for the corner columns which are major supporting elements for the roof loads, see figure 16. Minimal uplift capabilities and settlement problems exist similar to those discussed for the walls. The lack of a positive connection between the columns and the block do not provide for lateral load; therefore, the two units act independently and the stiffening effect of the walls does not exist.

Details of the connection provided between the supporting columns and the roof members are shown in figures 17, 18, and 19. Minimal anchorage is provided. The long reinforcing bars (the column will be cast-in-place later) shown in figure 17 are bent over the roof member as shown in figure 18 and anchored on the other side as shown in figure 19. This connection provides a very flexible joint which is subject to large displacements under lateral or uplift loads encountered in high winds.

Lack of positive connection between the corner columns and the walls discussed previously is also shown in figure 20. Note the considerable length over which concrete is not present.

Framing details for the window openings are shown in figure 21. The lack of positive attachment between the window frame lintels and the walls are apparent. The irregular filler blocks and large amounts of mortar used provide very little strength. In this case wind loads on the windows would cause the entire window unit including the frame to blow out.

The weaknesses noted above are not apparent following completion of the house. As seen in figure 22, application of finish material covers up these defects. Under wind loading, however, the effects of these weaknesses show up.

As another example, when tieing the roof material to roof trusses, minimal connections are usually provided between the roof sheeting and

Figure 15 Wall pier and roof bearing detail

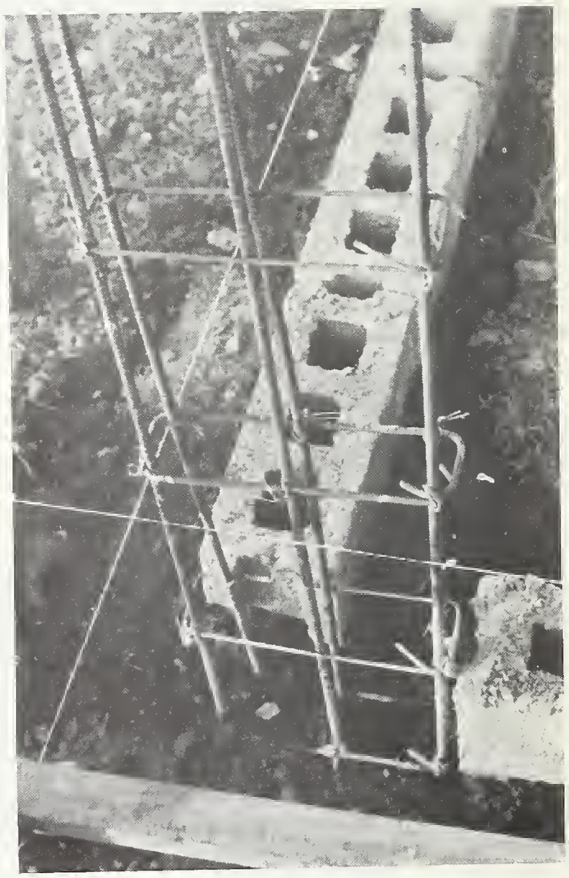


Figure 16 Corner column reinforcement

Figure 17 Column reinforcement anchorage to roof rafters

Figure 18 Completed column and roof anchorage

Figure 19 Roof anchorage detail

Figure 20 Detail of corner column and exterior wall

Figure 21 Window framing detail

Figure 22 Exterior appearance of completed structure

the main supporting members as shown in figure 23. The thin strap provides a very flexible connection subject to large displacments under load. In addition, the eccentric attachment causes torsion of the roof beams and localized bending of the roof sheeting in the vicinity of the bolt hole. Nailing through the thin metal strap reduces its strength and increases the possibility of its tearing under load. It was observed at some other housing construction projects, a "J" bolt replaced the thin strap. While this is an improved connection (rigid connection), the torsion problem remains.

Wind damage to similarly constructed houses by Typhoon Yoling during November 1970 is shown in figures 24 and 25. Referring to figure 24, the consequence of the poor mortar joints and lack of bond strength discussed in figure 14 is apparent. Note that the wall separated from the corner column (upper left hand portion of fig. 24) due to the lack of a positive connection and minimal bond between the column and the wall. Similarly, the window unit completely separated from the wall at its base and toppled in.

The wall failure shown in figure 25 is similar to that in figure 24. Note also the uplift of the roof framing at the connection to the support column. Although complete separation did not occur, the flexible connection detail illustrated in figure 18 permitted substantial displacement.

Figure 23   Roof to truss anchorage detail

Figure 24 Wall damage resulting from Typhoon Yoling, November 1970

Figure 25 Wall and roof damage resulting from Typhoon Yoling, November 1970

B. EXPECTED PROGRESS THROUGH PROJECT COMPLETION

Full-Scale Studies

Full-scale studies will continue during the remainder of the project. Because of the unique opportunity afforded by these field test sites to obtain information that is not available from any other source, it is hoped that the Philippine Advisory Committee will continue to operate these field sites long after completion of the project. This information can serve as a control on wind tunnel test results and can provide considerable insight into the long term effects of wind on structures. An advantage of the test equipment used in this study is that the pressure transducer positions can be easily changed after a storm to study wind pressure distributions on other parts of the test houses, thereby enhancing the value of the data and reducing the amount of redundant information. It is hoped that at least one data tape will be generated at each of the test sites during FY75. However, this depends upon the frequency of storms and the position of the storm tracks; variables that cannot be controlled in the experiment.

Wind Tunnel Studies

As indicated earlier, the primary advantage of wind tunnel studies is that they allow the systematic generation of coefficients required for design criteria. This assumes, of course, that the model results can be scaled up to the prototype case. Test results to date indicate that the coefficients obtained from the models are indeed valid but they will be checked as more full-scale data become available.

It is anticipated that approximately 10 model configurations will be investigated during the next year with roof slopes ranging from 0° to 30° and eaves overhangs ranging from 0 to 1.5 meters (full-scale). Initially, two classes of surface roughness will be used in these studies. If it becomes obvious that one particular roughness creates a "worst case" condition, the remainder of the program will be limited to one surface roughness.

Development of Design Pressure Coefficients

The 1970 edition of the National Building Code of Canada (NBC) provides for risk of occurrence, terrain roughness, height above ground and building geometry in calculating wind pressures,

$$p = qC_eC_gC_p .$$

In this expression, q is a reference mean velocity pressure for a given mean recurrence interval, C_e is an exposure factor which varies with surface roughness and height above ground, C_g is a gust effect factor to provide for surface pressure fluctuations caused by turbulence and localized flow phenomena, and C_p is a conventional mean pressure coefficient. The proper values for C_e will be determined from existing data, full scale wind data and theoretical models of wind speed distributions in typhoons and hurricanes. The coefficients C_g and C_p cannot be developed on the basis of any existing theoretical models and must be determined experimentally. This will be the primary output of the wind tunnel test program with the full-scale test results serving as a control on both the coefficients and final design criteria.

In addition to the above, the full-scale structures will allow some conclusions to be drawn concerning their serviceablility and, if sufficiently high wind speeds occur, their ultimate strength characteristics and performance of structural connections.

Socio-Economic Analysis

A continuation of the socio-economic analysis (a description of the initial attempt is described above) will proceed throughout FY 75. This analysis will focus primarily on the Philippines (based upon the availability of documentation) and will address the two other geographic areas represented by Bangladesh and Jamaica.

The analysis will consist of a study of related documents from the NBS and AID libraries, from a data collection activity of related documents from other groups involved in performing similar research, and data collected from on-site visits to developing countries. The information will be modified, as required, and formatted for input to the final report.

Computer-Generated Motion Picture Film

A computer program will be developed during the summer of 1974 to generate motion pictures depicting the time history of wind loading on Philippine test buildings. These pictures will present the building in various settings and elevations, including a 360° "aerial walk around", which will enable the observer to view the wind loads on building components (roof, eaves and walls).

The input information will consist of wind loading data collected on the test buildings during FY 74 and FY 75. It is envisioned the graphical display will consist of segmented building sections (corresponding to the area located at a pressure transducer) presented as a three-dimensional view of wind forces (negative or positive) acting on the building for various wind directions.

This presentation will assist researchers in analyzing wind load data. Also, the presentation coupled with audio will serve as an educational tool for those interested individuals to view building reactions to various wind loadings.

Regional Conferences

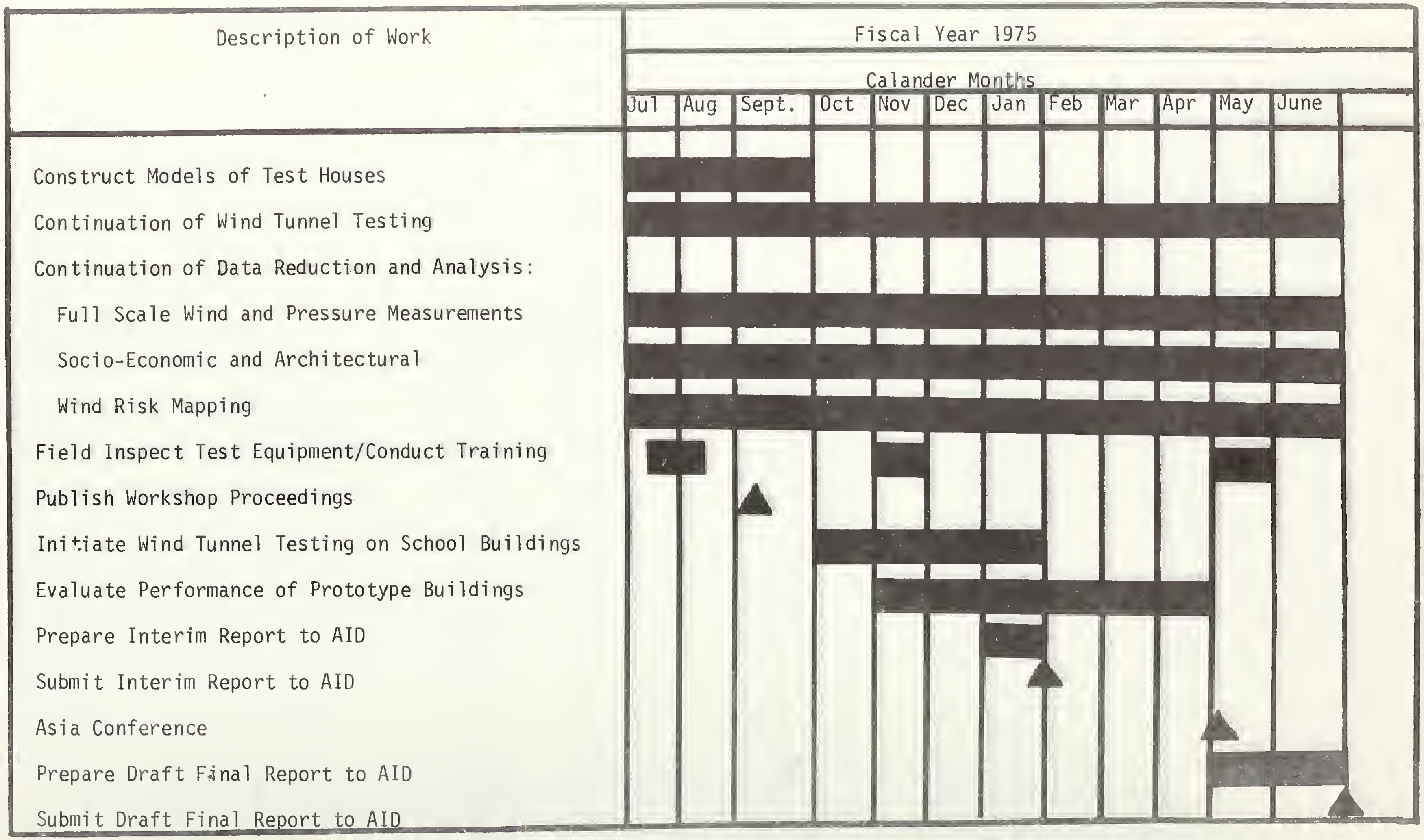
To ensure effective transfer of project results as previously mentioned, members from developing countries (users) are working closely with the NBS team in developing results and transferring them to their appropriate groups. In addition to advisory committee meetings; conferences and workshops provide a mechanism to transfer information to a larger body of individuals. Such was the purpose of scheduling the Manila International Workshop during November 1973 (discussed previously).

By late Spring 1975, many of the tasks outlined above will be completed or nearly completed. At this time a regional conference is expected to be scheduled in Asia to discuss the progress to data. This meeting will afford the opportunity to members from developing countries and the NBS to further establish a cross dialogue for suggesting methods to better structure the final product.

It is anticipated that a draft final report will be prepared for AID's review at the end of FY 75. This report will include all the above including activities associated with wind risk mapping, identifications of off-the-shelf building component connectors, assessment of developing countries ability to fabricate building component connectors, identification and suggested use of selected building connection details and plans for a final regional conference expected to be held in Jamaica. The report will also be aimed at two audiences; the professional and the layman. The AID reviewed draft final report will be discussed and disseminated to professionals attending a regional conference in Jamaica during FY 76.

C. FISCAL YEAR 1975 PROJECT SCHEDULE

The following table presents a Summary of the major activities scheduled for FY 75. The items are presented for illustration purposes and should not be considered complete or inflexible. As activities are initiated the project schedule may be adjusted accordingly to reflect appropriate changes.



FY 75 PROJECT SCHEDULE

APPENDIX A

MINUTES OF THE 1st-6th PHILIPPINE ADVISORY COMMITTEE MEETINGS

MINUTES of the 1st MEETING establishing an ADVISORY COMMITTEE in connection with the research on "DESIGN CRITERIA AND METHODOLOGY FOR CONSTRUCTION OF DEVELOPMENT (Low Cost) BUILDINGS TO BETTER RESIST TYPHOONS AND HURRICANES" Held on 27 April 1973 at the Penthouse, Weather Bureau Office, Development Bank Bldg. Quezon Blvd. Extension, Quezon City

Present: Dr. Richard D. Marshall
Mr. Noel J. Raufaste, Jr.
Gen. Gaudencio V. Tobias
Col. Alejandro R. Kabiling
Col. Alberto R. Sanchez
Lt. Col. Manuel R. Rebueno
Engr. Jose P. Orola
Engr. Modesto D. Soriano, Jr.
Engr. Miguel V. Paala
Prof. Angel A. Alejandrino
Dean Aurelio T. Juguilon
Prof. Geronimo V. Manahan
Dr. Ernesto G. Tabujara
Engr. Ambrosio R. Flores
Archt. Cesar H. Concio
Engr. Andres O. Hizon
Engr. Cesar A. Caliwara
Engr. Rosalio A. Mallonga
Mrs. Magdalena A. Templa
Mr. Romeo G. Cordoba
Mr. Catalino P. Arafiles
Mr. Wellington A. Miñoza
Mr. Manuel C. Bonjoc

1:01 The meeting was formally opened by Mr. Arafiles at 2:55 p.m. After welcoming the group to the meeting which was called to form an Advisory Committee in connection with the research on "Design Criteria and Methodology for Construction of Development (Low-Cost) Buildings to Better Resist Typhoons and Hurricanes", the floor was turned over to Dr. Tabujara who introduced Dr. Richard D. Marshall and Mr. Noel J. Raufaste,Jr. of the U.S. National Bureau of Standards, Washington, D.C. Likewise introduced were all those present.

1:02 Mr. Raufaste presented slides showing the organizational chart, Work Plan, Objectives and Projects of the U.S. National Bureau of Standards. He also stated that there will be an International Organizational Meeting in August or September 1973 in Manila. Other countries proposed to be represented are Bangladesh and Jamaica.

1:03 Engr. Hizon suggested that all information given by Mr. Raufaste be reproduced. Dr. Tabujara replied that the University of the Philippines would do so. A few copies of the reproductions of the slides were distributed.

1:04 Engr. Paala inquired about funding and Mr. Raufaste informed the group that no funds are available from the U.S. National Bureau of Standards.

1:05 Mrs. Templa stated that there must be a formal project proposal.

1:06 Dr.Tabujara suggested that the "fund" need not be in the form of cash but knowledge, paper work, research, equipment and the like.

1:07 Engr. Hizon said that all the results of such efforts should be printed for publication and made available.

1:08 Dr. Marshall said that although they can offer no monetary help, they can offer technology, computer services, and equipment. He also stated that one of the functions of the NBS is to disseminate all information internationally, to exchange information and to have free discussions.

1:09 Gen. Tobias suggested that together with the Advisory Comitee, there should be a coordinating committee with an administrative staff and a secretary to do the job.

1:10 Engr. Hizon stated that before the committee can start the following have to be made available:

a. Materials used and gathered during the UNESCO Seminar.
b. Studies of the Swiss government,
c. and the National Physical Laboratory of England,
d. Studies of Japan,
e. All U.S. studies.

These could be gathered and kept in one agency, such as the U.P.

1:11 Mr. Marshall informed the group that they will supply some materials and instrumentation particularly coming from the NBS.

1:12 The following were resolved:

a. Dr. Tabujara was unanimously selected as the Presiding Chairman of the Advisory Committee.

b. All those present are to be members of the Advisory Committee as formally formed and any other entities willing to be of help may also be represented in the Committee. Those named were NEDA, GSIS, SSS, PHHC, NHC, LHDC, NSDB, UP, WB, PACE, ASEP, PSA, BPW.

   Lt. Col. Rebueno commented that the PHHC need not be a member of the Committee but that they are willing to help, such as having one of their lands as the project site.

c. The U.P. will be the depository for all information and will be in constant contact with the NBS in the U.S.

d. Upon the suggestion of Mrs. Templa a Sub-Committee was formed to do the planning of activities of the Advisory Committee. Gen. Tobias and Dr. Tabujara were unanimously elected Chairman and Vice-Chairman, respectively. After deliberation, the members selected were:

   Dir. Roman L. Kintanar of the Weather Bureau
   Mrs. Magdalena A. Templa of the NSDB
   Engr. Ambrosio R. Flores of the Phil. Stan. Assoc.
   Engr. Andres C. Hizon of the Assoc. of Struc. Engrs. of the Philippines.

   Upon the request of Gen. Tobias, the appointment of Col. Kabiling was accepted by Dr. Tabujara. Col. Kabiling will replace Gen. Tobias in this Sub-Committee.

   The first meeting of the Sub-Committee will be on Friday, May 4, 1973 at 4:00 p.m. at the Suló Hotel, Quezon City.

1:13 The Meeting was adjourned at 4:48 p.m. with Dr. Marshall and Mr. Raufaste thanking the group.

Due to the request of some members of the Committee, additional slides were presented by Dr. Marshall and Mr. Raufaste.

Prepared by:

(Sgd.) Cynthia S. Enriquez
U.P. Building Research Service

NOTED:

(Sgd.) Ernesto G. Tabujara
Executive Officer, U.P.B.R.S.

MINUTES of the 2nd MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DESIGN CRITERIA AND METHODOLOGY FOR CONSTRUCTION OF DEVELOPMENT (Low-Cost) BUILDINGS TO BETTER RESIST TYPHOONS AND HURRICANES".

Held on 9 August 1973 at the Buendia Hall, 5th floor, Bureau of Public Works, Bonifacio Drive, Port Area, Manila.

Present: Dr. Ernesto G. Tabujara, Presiding
Col. Alejandro R. Kabiling
Col. Alberto R. Sanchez
Col. Manuel R. Rebueno
Engr. Jose P. Orola
Engr. Modesto D. Soriano, Jr.
Prof. Angel A. Alejandrino
Prof. Geronimo V. Manahan
Dr. Josefina M. Ramos
Engr. Ambrosio R. Flores
Engr. Andres O. Hizon
Engr. Octavio A. Kalalo
Engr. Rosalio A. Mallonga
Mr. Catalino P. Arafiles

2:01 Before the formal start of the meeting:

1. Engr. Flores suggested that Dean Juinio be designated instead as Honorary Chairman of the Advisory Committee, with Dr. Tabujara as Chairman. This view, which was supported by Engr. Hizon, was accepted by the group.
2. Two (2) members of the Advisory Committee who were unable to attend the 1st Meeting were introduced; namely:
   a. Dr. Josefina M. Ramos, U.P. Building Research Service, and
   b. Engr. Octavio A. Kalalo, President, Association of Structural Engineers of the Philippines.
3. Prof. Manahan was appointed Secretary of the Committee by Dr. Tabujara.
4. Mr. Arafiles informed the body that the new designation of Dr. Roman L. Kintanar is Administrator of the PAG-ASA (formerly Weather Bureau) which stands for Philippine Atmospheric Geo-Physical and Astronomical Services Administration.
5. All those present were re-introduced.

2:02 The meeting formally started at 2:20 p.m. After a brief introduction, and by way of informing the members about recent developments on the research project, Dr. Tabujara read a memorandum of Dean Juinio addressed to U.P. President Lopez requesting support for the project from the University. Pres. Lopez has reacted to this project favorably, but the members felt that clarifications must be made regarding the manner and extent of this endorsement. Prof. Manahan and Dr. Tabujara said that a budget proposal for the operations of the U.P. Building Research Service for next year had been submitted. Dr. Tabujara assured the members that the U.P.BRS is able and willing to coordinate this research project, but stressed that the full backing of each member of the Advisory Committee, whether by individuals or by institutions, is needed.

2:03 Dr. Tabujara referred to the letters and documents he received from Mr. Raufaste, Jr. of the U.S. National Bureau of Standards (NBS) for discussion. (All pertinent papers were either Xeroxed or mimeographed and a set was provided each member.) Dr. Tabujara commented that there were items which had to be answered urgently, considering that the typhoon season had come.

2:04 For expediency, the Advisory Committee confirmed that constructing the experimental house at the PAG-ASA's Science Garden in Quezon City was most convenient. This recommendation was arrived at during the discussions of the Sub-Committee (of six) held on May 4, 1973. Quoting from Mr. Raufaste's letter, at least three (3) test sites would have to be identified by the Advisory Committee, with preferably three (3) experimental houses at each site.

Since the Science Garden was chosen to be one of the test sites, two other sites with different topographic and climatic characteristics would be selected. The PAG-ASA's station at Virac, Catanduanes, was suggested as one of these, but Dr. Tabujara proposed that the final selection be deferred until the Advisory Committee could confer with Dr. Marshall and Mr. Raufaste when they come to the Philippines first week of September.

2:05 As suggested by NBS, at least one experimental house must be ready by the first week of September. To this, Col. Kabiling informed the group that the National Housing Corporation (NHC) could construct one of their prototypes within two (2) weeks. For the first test site at the Science Garden, the NHC was requested to put up two houses and LHDC, represented by Col. Sanchez, would construct another one. Both Col. Kabiling and Col. Sanchez commented that an "official" letter from the Advisory Committee requesting for these donations would be in order. Dr. Tabujara promised to write these letters.

2:06 For the other test sites, Engr. Orola and Engr. Soriano, Jr. of the GSIS, as well as Col. Rebueno of the PHHC, signified their desire to convince their respective entities, to provide the rest of the experimental houses.

2:07 The NHC plans for one house would be picked-up by Dr. Tabujara from Col. Kabiling the day after the meeting, and the former would be responsible in sending these to NBS. The NBS engineers need the plans in order to program the location of the test instruments.

2:08 Mr. Arafiles also confirmed the commitment by Dr. Kintanar that PAG-ASA personnel could double as observers in the absence of any other provision as such. These same people could do occasional maintenance work on the equipment, too. Col. Rebueno offered to assign army men as first-class trainees who would also act as guards at the project site for at least six months. Engr. Kalalo's suggestion that full-time employees be hired for this project was considered premature in view of the uncertainty in the funding. In this connection, Dr. Tabujara stated that some of the professional organizations might be able to help in terms of logistics, to which Engr. Kalalo of the ASEP and Engrs. Soriano and Orola of GSIS gave encouraging answers. Dr. Tabujara answered the direct question of Col. Sanchez that the house to be constructed by LHDC may be needed by the beginning of the year.

2:09 An urgent item was the information contained in a cablegram from Mr. Raufaste, Jr. that full-scale equipment and instrumentation are due to arrive in the Philippines by the end of August. These instruments had been calibrated and tested at the NBS and would therefore be ready to be used upon receipt here.

Col. Sanchez suggested that the US AID, c/o Mr. W. Larson, would be in a much better position to have the equipment released from Clark Air Force Base and consequently these could be turned over to the Advisory Committee. A second alternative was to ask for the help of the U.S. Embassy. If neither of the above was feasible, Dr. Tabujara said that the Advisory Committee could request for the help of Pres. Lopez of the U.P.

2:10 Two lists of equipment were read:
Those instruments which pertain to the experimental house, and those connected with the wind tunnel instrumentation for the U.P. Hydraulics Laboratory. Prof. Alejandrino commented that the wind tunnel at the U.P. has a size of 4 feet by 4 feet. Engr. Hizon inquired

whether the 14-track analog tape recorder could be used directly with the present computer set-ups locally, as for example, the one at the U.P. Computer Center. Prof. Alejandrino replied that at the start of the research, the tapes would be transcribed at Washington, D.C., but expressed hopes that a converter may be provided by NBS to enable these tapes to be processed locally in the near future.

2:11 Engr. Kalalo was appointed the PRO for the project. Dr. Tabujara accepted the responsibility of preparing the first write-up which Engr. Kalalo would publicized.

2:12 Due to organizational difficulties, stated by Mr. Raufaste, Jr., the Advisory Committee welcomed the postponement of the Organizational Seminar until mid-November. Countries to be represented are the Philippines, Bangladesh and Jamaica, but representatives from Hongkong, Japan and other countries be invited also. The Advisory Committee accepted the offer of Mrs. Templa of NSDB for the use of the NSDB Auditorium at Bicutan for this Seminar. Hotel Intercontinental at Makati was cited as convenient for foriegn attendees.

2:13 The NBS confirmed that they would provide assistance on the following: Secretariat, Documentation and Printing, international travel, while the Advisory Committee's responsibility would include: Program, Arrangements (including local transportation, if needed) and Refreshments. Dr. Tabujara appointed the following chairmen:

a. Finance - Mrs. Templa
b. Arrangements - Engr. Orola and Engr. Soriano, Jr.
c. Program, Invitation and Publicity - Engr. Kalalo
d. Reception and Hospitality - Archt. Concio
e. Editorial - Engr. Flores and Dr. Ramos

Each chairman was requested to choose his members and the Advisory Committee will function as the Executive Committee.

2:14 Dr. Marshall and Mr. Raufaste, Jr. wrote that they would be in Manila about the first week of September. They also signified their desire to visit the PAG-ASA's weather station at Virac, Catanduanes. It was suggested that the US AID be alerted of this plan so that they could help in the arrangements. Col. Rebueno volunteered to accompany the two gentlemen, in addition to PAG-ASA's personnel.

2:15 Before the meeting was adjourned, Dr. Tabujara announced the recent promotion of Engr. Mallonga as Regional Director of the Fourth Regional Office of the BPW. In behalf of the Advisory Committee, Dr. Tabujara thanked the BPW through Engr. Mallonga for hosting this Second Meeting.

2:16 The meeting was adjourned at 4:00 p.m. and the Advisory Committee would reconvene sometime first week of September.

(Sgd.) GERONIMO V. MANAHAN
Secretary

EGT:cse

MINUTES of the 3rd MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DESIGN CRITERIA AND METHODOLOGY FOR THE CONSTRUCTION OF DEVELOPMENT (Low-Cost) BUILDINGS TO BETTER RESIST TYPHOONS AND HURRICANES."

Held on 14 September 1973 at the Housing Operations Center, 3rd floor, People's Homesite and Housing Corp., Quezon City

Present: Dr. Ernesto G. Tabujara, Presiding
Col. Alejandro R. Kabiling
Col. Manuel R. Rebueno
Engr. Modesto D. Soriano, Jr.
Adm. Roman L. Kintanar
Prof. Geronimo V. Manahan
Dr. Josefina M. Ramos
Engr. Ambrosio R. Flores
Archt. Cesar H. Concio
Engr. Andres O. Hizon
Mrs. Magdalena A. Templa
Mr. Catalino P. Arafiles

Dr. Richard D. Marshall
Mr. Noel J. Raufaste, Jr.
Engr. Jaime C. Cano

3:01 The meeting started at 1:15 p.m. Dr. Tabujara introduced Engr. Jaime C. Cano of the NHC to the other members of the Advisory Committee. In view of the power uncertainty due to scheduled Meralco brownouts, Col. Rebueno suggested that the order of business be changed to enable Dr. Marshall and Mr. Raufaste to show slides.

3:02 Mr. Raufaste took the floor and reviewed the activities which transpired since the organizational meeting of the Advisory Committee last April. A more comprehensive three-year schedule of activities was presented with emphasis on the conduct and format of the final draft of the report so that the members could be oriented to the general aims and purposes of the project. Field experimentation and wind tunnel phases of the project were clearly defined. The former phase called for seven (7) experimental houses to be constructed at three (3) different test sites within the first year. Mr. Raufaste also showed slides of houses which were proposed for Bangladesh and also for the Carribean area. One type for Bangladesh, proposed and designed by CARE, costs about $1.10 per sq. ft. of area.

3:03 Dr. Marshall showed slides of the various equipment and related instrumentation which will be used in this research. He also explained that preliminary wind tunnel tests have been conducted abroad with the view of continuing these experiments here at the National Hydraulics Center Laboratory. The Advisory Committee was informed that all equipment and accessories necessary to fully instrument one experimental house have been delivered to the Pag-asa's Science Garden. Because of their rather critical and busy schedules, Mr. Raufaste and Dr. Marshall expressed hope that the NHC, under the direct and personal supervision of Col. Kabiling, would be able to put up the first experimental house by Tuesday or Wednesday of the following week. This would enable Dr. Marshall to personally supervise the installation of necessary equipment before he leaves on Sept. 24. Col. Kabiling confirmed that the house will be ready for the installation of sensors and other instruments by Wednesday or Thursday.

3:04 In answer to Mr. Raufaste's question, Dr. Tabujara changed the designation of Engr. Kalalo to Publicity Chairman instead of Public Relations Officer. Engr. Hizon accepted to become member of this important Sub-committee.

3:05 Dr. Marshall further stated that the Wind Tunnel at the National Hydraulics Center Laboratory will perform the wind tunnel tests which will complement whatever tests had been done abroad. The NBS will assist in the modeling techniques and will provide other expertise necessary in order to verify certain findings from the field data.

3:06 Engr. Soriano reiterated GSIS' willingness to donate two (2) houses, possibly the 5th and the 6th house in the program, within the Diliman area.

3:07 Mr. Raufaste described the objectives and the proposed conduct of the November 1973 Workshop, as follows:

A. During the Workshop:
   1. To discuss socio-economic considerations (per geographic area) as they affect the design and acceptance of buildings.
   2. To discuss information gaps concerning structural systems and connection details.
   3. To discuss wind design load requirements.
   4. To discuss climatological data needs.

B. Immediately after the Workshop:
   1. Prepare report on the above.
   2. Elaborate on problems associated with extreme wind loading.

C. Short-term international consultants are requested to:
   1. Identify housing trends and their design problems.
   2. Discuss the influence of socio-economic considerations on housing patterns.
   3. Perform a survey and analysis of housing needs for the next 10 years.
   4. Collect and tabulate available climatogical data on extreme winds.
   5. Collect and tabulate wind damage statistics.
   6. Study the probability of alternative solutions in mitigating losses due to high winds.
   7. Define possible low-cost dwelling design problem areas unique to each consultant's geographic area.

3:08 Instead of being co-chairmen of the Editorial Sub-committee, Engr. Flores and Dr. Ramos were re-designated co-chairmen of the Technical Papers Sub-committee. The Technical Papers Sub-committee will meet together with Mr. Raufaste, and possibly Dr. Tabujara, on Thursday, Sept. 20, 1973. This Sub-committee will have the responsibility of gathering all technical papers, and reviewing each of them prior to forwarding these to the NBS for final review. It was tentatively suggested that:

1. Dr. Marshall would take care of presenting papers corresponding to Items A and B of the tentative program. Prof. Alejandrino would be requested to contribute on this particularly with regards to the National Hydraulics Center Laboratory's capability to support this research program.
2. Prof. Manahan would help out in Item C-1, and the name of Dr. Mary R. Hollnsteiner, Director of the Institute of Philippine Culture, was also mentioned.
3. Engr. Flores and Archt. Concio would discuss Item D, while Prof. de Castro of the U.P. College of Engineering would be able to help in Item B. Pag-asa would discuss Item A-1.
4. Mr. Raufaste would give the suggested format for the technical papers before he leaves Friday of the following week.
5. Mr. Raufaste informed the group that the foreign participants may present papers pertaining to their respective experiences.

3:09 It was decided that the Workshop will be for three-and-a-half ($3\frac{1}{2}$) days. The dates November 14 thru 17, 1973 were selected, and the Workshop will be held at the Paulino J. Garcia Memorial Hall, NSDB, Taft Avenue corner Herran, in Manila instead of at Bicutan as previously recorded. Mrs. Templa immediately offered to make the necessary reservations for the place.

As Chairman of the Finance Sub-committee, Mrs. Templa selected Dr. Tabujara as Co-Chairman with the following as members: Col. Kabiling, Engr. Paala, Engr. Soriano and Engr. Orola. The Finance Sub-committee was scheduled to convene in a luncheon meeting at Sulo Hotel, Q.C., Wednesday, Sept. 19. Mrs. Templa also volunteered to be member of the Sub-committee on Program, Invitation and Publicity, chairmaned by Engr. Kalalo.

3:10 Archt. Concio accepted his appointment as Chairman of the Reception and Hospitality Sub-committee.

3:11 Mr. Raufaste suggested Dir. Niblock of US AID as a probable speaker to deliver the Welcome Address during the Workshop. Other names suggested for the welcome ceremonies were Dean Alfredo L. Juinio as Honorary Chairman of the Advisory Committee, and other high government officials.

3:12 In the selection of the second test site, the Advisory Committee heard the arguments for and against the selection of Virac, Catanduanes. Adm. Kintanar and Mr. Arafiles described the conditions at their new weather station at Daet, Cam. Norte.

1. Dr. Marshall favored the latter considering the problems in the wind tunnel simulation of the actual site topology and other conditions.
2. The logistics problem tend to favor Daet over Virac.
3. The presence of commercial electrical power at Daet makes experimentation more reliable, particularly during typhoons.
4. Both sites are serviced by airstrips although Daet could be reached by land, whereas Virac could not.
5. The slight edge in the frequency of typhoons at Virac as compared to Daet was not considered too significant.

Tentatively, the Advisory Committee preferred Daet pending the report of Dr. Marshall and Mr. Raufaste after their visit there next week. For Site No. 3 the Weather Stattion at Infanta, Quezon and at Baguio were mentioned.

3:13 Dr. Marshall raised the question of whether the Advisory Committee preferred to start the second test site or to expand the present Science Garden site to include two houses by this coming November. The idea was to report back to Washington, D.C. so that pertinent sets of equipment could be prepared and these could be brought here by Mr. Raufaste and Dr. Marshall during their next visit in November. After some discussion, it was decided that a second experimental house at the present first site (Science Garden) would offer more advantages and would be expedient. Dr. Tabujara felt that another type of house must be provided, and the LHDC would be requested to donate this one.

3:14 Mr. Raufaste distributed copies of "Bibliography - Wind Effects on Buildings and Structures." He also informed the Advisory Committee that Dr. Marshall and he brought with them some 50 lbs. of documents which they wish to be entrusted to the U.P. College of Engineering library as agreed upon during the April meeting. These documents will be made available to the members of the Advisory Committee. In the meantime Prof. Manahan promised to reproduce the Bibliography for those who would be interested.

3:15 Mr. Raufaste also advised the members to prepare a list of publications not readily available here which may be of interest; particularly as they pertain to the current research project. The NBS, he said, will try to get these or will suggest the source where said documents may be procured.

3:16 Engr. Hizon was designated to draft a Letter of Acceptance which would serve as the official transfer of equipment and instruments donated by the NBS to the Philippine government through the Advisory Committee. The Pag-asa will be the depository for the field instrumentation and equipment, while the hydraulic equipment will be entrusted to the National Hydraulics Center.

3:17 Finally, the Minutes of the two previous meetings of the Advisory Committee were (officially) approved as corrected.

3:18 Before adjournment, Dr. Tabujara expressed thanks to the PHHC, through Col. Rebueno, for hosting this third meeting. The meeting was adjourned at 4:00 p.m.

(Sgd.) GERONIMO V. MANAHAN
Secretary

(Sgd.) ERNESTO G. TABUJARA
Chairman

Prepared By:

(Sgd.) Cynthia Señoran Enriquez

MINUTES of the 4th MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DEVELOPMENT OF DESIGN CRITERIA AND METHODOLOGY FOR LOW-RISE/LOW-COST BUILDINGS TO BETTER RESIST EXTREME WINDS."

Held on 13 November 1973 at the Penthouse, SSS Building, East Avenue, Quezon City.

Present: Dr. Ernesto G. Tabujara, Presiding
Col. Alberto R. Sanchez
Col. Manuel R. Rebueno
Engr. Jose P. Orola
Engr. Modesto D. Soriano, Jr.
Engr. Miguel V. Paala
Prof. Angel A. Alejandrino
Dean Aurelio T. Juguilon
Dr. Josefina M. Ramos
Engr. Ambrosio R. Flores
Engr. Andres O. Hizon
Engr. Cesar A. Caliwara
Engr. Rosalio A. Mallonga
Mrs. Magdalena A. Templa
Mr. Catalino P. Arafiles
Mr. Wellington A. Miñoza
Prof. Geronimo V. Manahan

Archt. Herminio Golfo
Archt. Avelino de Veyra

Mr. Noel J. Raufaste, Jr.
Dr. Richard D. Marshall
Mr. William Littlewood
Dr. Edward O. Pfrang

4:01 The meeting was called to order at 2:00 p.m. by Dr. Tabujara. The Minutes of the 3rd meeting were read and approved unanimously. He informed the body that since luncheon cannot be served at the NSDB Hall, the Workshop participants will have to proceed to the Alta Vista Buffeteria at the Cultural Center, for the duration of the Workshop. Luncheon will be served there courtesy of various sponsors. The problem regarding the transportation created by the gas shortage was discussed.

4:02 Dr. Tabujara reported that 7 messengers are at the moment delivering the programs and invitations. Mimeographed invitations were sent a few days earlier, and upon the suggestion of Engr. Hizon, telephone follow-ups were made. A total of 174 persons were invited although quite a number of them were courtesy invitations.

4:03 Dr. Tabujara commended the Arrangements Sub-committee for a job well done. Engr. Mallonga informed the body that he bought two flags, that of Jamaica and Bangladesh, the rest were borrowed. Engr. Soriano stated that the streamers, signs and electric fans were all ready.

4:04 For the Reception and Hospitality Sub-Committee, Dr. Ramos reported that the name plates, plastic jackets and lunch tickets were ready. Ten usherettes under the charge of Prof. Manahan and Mrs. C. Enriquez will assist in the Workshop.

4:05 Col. Rebueno reported that there would be 2 NSDB Security guards in the premises during the deliberations although, he believed that this arrangement was not necessary.

4:06 Mrs. Templa stated that the Finance Sub-Committee should have been chairmaned by Dr. Tabujara, since he did all the work of getting sponsors. She, however, promised to see what the NSDB could contribute as soon as Dr. Tabujara submits his finalized draft of proposal for project funding.

4:07 For the program, Invitation and Publicity Sub-Committee, Dr. Tabujara reported that the undertaking has been widely publicized so much so that people were calling and asking if they could attend the Workshop. The body decided that should there be future callers it would be alright to tell them to attend.

4:08 Prof. Alejandrino together with Mr. Raufaste would coordinate the sessions and distribute the audience for the Workshop Sessions.

4:09 Dr. Tabujara reported that Marsteel Corp. would sponsor one luncheon, and specifically requested that no co-sponsor would be necessary. He announced the other sponsors namely: Weldon Construction Corp., Asso. of Structural Engineers of the Phils., National Society for Seismology and Earthquake Engineering of the Phils., Phil. Asso. of Civil Engineers, Engr. Cesar A. Caliwara, Engr. Romeo S. Caparros, Engr. Octavio A. Kalalo, Dr. Fiorello R. Estuar, Engr. Lauro M. Cruz and Engr. Angel Lazaro, Jr.

Engr. Soriano also solicited ₱5,000.00 from the GSIS and P2,000.00 from Philrock Products Inc. Dr. Tabujara suggested that the Advisory Committee should elect a Treasurer. At this point, he welcomed Mr. Miñoza who just arrived from the U.S.A.

4:10 Col. Sanchez reported that there would be a Metrocom escort for the visit to the experimental house at the Science Garden of the PAGASA. He also informed the group that the second experimental house which the LHDC contracted to the NHC was delayed due to the gas shortage, but that he would follow-up its completion so Dr. Marshall could start the instrumentation by Monday, November 19.

4:11 Mr. Raufaste commented that they were very impressed with everything. He then summarized the activities for the next 2 years with the aid of Xerox copies which he distributed. The project started last March 1973; late April 1973 Dr. Marshall and Mr. Raufaste came here and the Phil. Advisory Committee was formed.

... Their second visit was last September when the first house was instrumented and now they would be ready to instrument the second experimental house. The object was to instrument 7 full-scale houses at 3 independent test sites which would relate to 7 wind tunnel scaled-down buildings at U.P.

4:12 The floor was opened for discussion of the third site. Considerations given by Dr. Marshall are frequency of wind effects, logistics and maintenance of equipment. He suggested areas North-east of Luzon. Mr. Raufaste also added that these sites should be statiscally independent of each other, should represent different terrain conditions and should be very hilly. He also reported that during their last visit they were able to make a trip to Daet and take some photographs thru the help of U.S. AID. If the body could decide on the 3rd site Dr. Pfrang and Mr. Noel Raufaste would make arrangements with the U.S. AID to visit it. Infanta, in Quezon, Daet and Sto. Tomas in Baguio were named but due to availability of transportation, manpower and commercial power, Sto. Tomas, Baguio was chosen. Sto. Tomas, Baguio according to Mr. Arafiles is 7,000 feet above sea level and has the same frequency of typhoons as Infanta.

4:13 Dr. Marshall stated that the 3rd house's roof should either be flat, gabled or hipped. If it would be gabled the degree of inclination should be determined, if hipped, the length of the eaves should be from 0 feet to 5 feet. The materials to be used could be asbestos and the truss, wooden with G.I. sheets. According to Dr. Tabujara the usual pitch locally is 1:4.

4:14 It was confirmed by Col. Rebueno that the 3rd and 4th houses to be build before April 15, 1974 would be donated by the PHHC. In accordance to the Minutes of the 3rd Meeting, the 5th and 6th houses would be donated by the GSIS. The 7th house would be from CARE of Bangladesh.

4:15 Mr. Raufaste commended the two or three PAGASA personnel now manning the experimental house at the Science Garden. He inquired if they could be made use of again for future houses. Mr. Arafiles added that the three could train other personnel and could assist at future test sites.

4:16 Dr. Tabujara, on the other hand, commended the NHC for putting up the first experimental house in 3 days' time.

4:17 Dr. Marshall informed the body that enough information was gathered during the last 3 typhoons here and that assimilation could now start. As work evaluation continues at the Colorado State University we will know how to make the right approach with the U.P. wind tunnel facilities. Taking data from a 6' x 6' wind tunnel and modifying or applying these to a 4' x 4' wind tunnel is essential. Hopefully we can use direct geometric scaling on this and get the tunnel and related equipment into operation before Dr. Marshall leaves on December 1, 1973. The final series of wind tunnel testing will hopefully yield the specific needs for the design criteria.

4:18 Prof. Alejandrino stated that although this is the first time the National Hydraulics Research Center will deal with a wind tunnel project, he is very optimistic especially since the Center employs 3 Research Engineers.

4:19 Dr. Marshall stated that he has some more documents with him and equipment like the Wind tunnel hot-wired animometers for measuring turbulance, pitot tubes for measuring wind dynamic pressures, recorders and digital analog analyzer - all of which will go to the U.P. HRC.

4:20 Engr. Hizon suggested that the wind tunnel results be available to interested parties even before its formal publication. A status report is well in line with this.

4:21 Dr. Tabujara has one set of the documents brought by Dr. Marshall and this set was reviewed by the 3 Research Engineers. Another set is at the U.P. Library. He expressed his thanks to the SSS thru Engr. Paala for hosting the meeting and to GSIS for hosting a Sub-Committee meeting.

4:22 Mr. Littlewood and Dr. Pfrang expressed their appreciation and support and wished the project success.

4:23 Dr. Tabujara in return thanked the NBS for its support and expressed his opinion that this project will benefit the Filipinos more than anybody else. He announced that Dr. Kintanar received a Presidential award as one of the most outstanding scientists of the country. It was agreed that Dr. Tabujara would call Mrs. Templa for the services of a professional secretariat for the Workshop.

4:24 It was announced by Mr. Raufaste, Jr. that due to unforseen circumstances the following foreign participants could not come: Mr. Samuel Kramer, Mr. John Gipson, Prof. Sean Mackey, Dr. R.W.R. Muncey and Dr. Sudhindra Nath Senn.
Dr. Pfrang would take the place of Mr. Kramer and Dr. Eaton would then take the place of Dr. Pfrang. Thus, Dr. Eaton would be in Session B and Dr. Pfrang in Session D on Friday.

4:25 There will be cocktails on Saturday evening in honor of the foreign delegates.

4:26 Mr. Raufaste wants copies of the Minutes of Meetings. This can be done except for the Sub-Committee Meetings which has no recorded Minutes since these were all informal meetings.

4:27 Upon the suggestion of Mr. Raufaste the Letter of Acceptance for the equipment would be made at the end of the project so that it would be in lump sum, however, temporary receipts, if possible would be appreciated. The Advisory Committee would accept the equipment and the PAGASA would be its custodian.

4:28 The meeting was adjourned at 4:10 p.m.

(Sgd.) GERONIMO V. MANAHAN
Secretary

(Sgd.) ERNESTO G. TABUJARA, Ph.D.
Chairman

Prepared By:

(Sgd.) Cynthia S. Enriquez

MINUTES of the 5th MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DESIGN CRITERIA AND METHODOLOGY FOR THE CONSTRUCTION OF LOW-COST/LOW-RISE BUILDINGS TO BETTER RESIST EXTREME WINDS."

Held on 18 March 1974 at the Seminar Room, 4th floor, Melchor Hall, University of the Philippines, Diliman, Quezon City.

Present: Dr. Ernesto G. Tabujara, Presiding
Engr. Cesar A. Caliwara
Mr. Manuel C. Bonjoc
Engr. Ambrosio R. Flores
Engr. Andres O. Hizon
Dean Aurelio T. Juguilon
Engr. Rosalio A. Mallonga
Dr. Josefina M. Ramos
Col. Manuel R. Rebueno
Engr. Modesto D. Soriano, Jr.
Dr. Francisco Tamolang
Col. Alejandro R. Kabiling
Dr. Richard D. Marshall
Mr. Noel J. Raufaste, Jr.
Mr. Peter Paul Castro

5:01 Dr. Tabujara opened the meeting at 2:00 p.m. He stated that most of the members would not be able to attend due to the short notice given. Dr. Francisco Tamolang, Commissioner of FORPRIDECOM and a new member of the Committee was introduced to the group.

5:02 A 10-second silence was observed for the late Mrs. Magdalena A. Templa.

5;03 Dr. Tabujara reported on the status of the 2 houses to be erected at Laoag and Daet. Since the donors, GSIS and PHHC, are governed by their respective Boards, their approval had to be obtained first. GSIS, presently have the materials for the 2 houses at the Laoag site. Although one of the NHC's truck was burned while delivering some materials, Engr. Soriano and Col. Kabiling are optimistic that they will beat the schedule for the instrumentation of Dr. Marshall.

5:04 It was decided that Engr. Soriano and Mr. Bonjoc will verify the exact locations of the 2 houses being erected at Laoag since the cables to be used were pre-cut at 50 meters each. It was also decided that since PAGASA personnel were to man the houses, one house at least had to be erected at the PAGASA site. The PAGASA site was found not big enough to hold 2 houses at its compund, making it necessary to ask the CAA to have the other house at its compound which is adjacent to the PAGASA's. Dr. Tabujara would have to get Gen. Singson's permission for this.

5:05 The instruments have to be at an air-conditioned room and since Mr. Bonjoc stated that there was no air-conditioned room at the PAGASA in Laoag, Mr. Raufaste expressed his opinion of either getting an air-conditioning unit or asking the CAA if they have an air-conditioned room at the Laoag CAA Building.

5:06 Dean Juguilon stated that he would be going to Laoag on Thursday, March 21, and so he would be furnished with Dr. Marshall's letter of instructions to enable the Dean to verify the locations of the experimental houses and confer with PAGASA's Mr. Gabuat and Mr. Teofilo Aquino of GSIS.

5:07 Mr. Bonjoc reiterated the permission granted by Adm. Kintanar for PAGASA personnel to instrument the houses at Daet. The PHHC Board approved the putting-up of 2 houses at Daet, however, due to funding problems, Manager Sebastian Santiago decided to include this as part of the housing program planned for Naga which will take sometime before implementation.

5:08 Col. Rebueno reported that Archt. Fernando of PHHC designed 2 houses of 39 sq. mts. each but due to logistic problems he advised Dr. Tabujara to talk with Acting Manager Venago.

5:09 Mr. Raufaste's schedule was as follows:

March	20	at Daet
	22	back to Manila
	26	at the wind tunnel
	27	at Laoag
	30	back to Manila
April	1	leave for Japan

5:10 Messrs. Dapul and Purisima would go with Mr. Raufaste to Daet. Mr. Bonjoc has wired the PAGASA in Daet regarding their arrival. Engr. Soriano will also be there on March 28 to 29.

5:11 CARE, thru its Philippine representative, Mr. Manuel Torres, reiterated their commitment for 1 house which will be the property of the Committee.

5:12 Dr. Tabujara reported on the financial status of the Committee. (Please see attached Financial Report).

5:13 Mr. Raufaste turned-over to the Committee 2 books entitled "Design, Siting and Construction of Low-Cost Housing and Community Buildings to Better Withstand Earthquakes and Windstorms".

5:14 Dr. Tabujara reported that these will be included with the other documents already at the U.P. Engineering Library. Another set was with him and could be availed of by the members of the Committee or any other interested party.

5:15 Dean Juguilon could make arrangements for Mr. Raufaste to tour some parts of the country and take pictures of typical Filipino dwellings.

5:16 Mr. Raufaste distributed copies of the Draft Recommendations of the International Workshop held last November 1973. The members of the Committee were to submit their own comments based on this draft and submit the same to Engr. Flores, Dr. Ramos and Prof. Manahan before April 1, 1974. It would then take 3 months for the NBS to review and print the final recommendations.

5:17 The meeting was adjourned at 4:00 p.m.

(Sgd.) GERONIMO V. MANAHAN
Secretary

(Sgd.) ERNESTO G. TABUJARA
Chairman

Prepared By:

MINUTES of the 6th MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DEVELOPMENT OF DESIGN CRITERIA AND METHODOLOGY FOR LOW-RISE/LOW-COST BUILDINGS TO BETTER RESIST EXTREME WINDS."

Held on 1 April 1974 at the 4th floor, Melchor Hall, University of the Philippines, Diliman, Quezon City.

Present: Dr. Ernesto G. Tabujara, Presiding
Dean Aurelio T. Juguilon
Dir. Angel A. Alejandrino
Mr. Manuel C. Bonjoc
Mr. Catalino P. Arafiles
Engr. Modesto D. Soriano, Jr.
Prof. Geronimo V. Manahan

Dr. Richard D. Marshall
Mr. Noel J. Raufaste, Jr.
Engr. Jaime Cano
Mr. Rod Dapul
Mr. Peter Paul Castro
Mr. Enrico Gregorio

6:01 The meeting started at 2:15 p.m. with Dr. Tabujara introducing Mr. Rod Dapul, technician of the PAGASA who together with Mr. Ignacio Purisima worked very closely with Dr. Marshall and Mr. Raufaste. These two PAGASA personnel will instrument the remaining 3 test houses. They went to Laoag with Dr. Marshall and Mr. Raufaste and with additional instructions could instrument the houses. Mr. Raufaste was all praises for the two and he also expressed his appreciation to Messrs. Arafiles and Bonjoc and the PAGASA.

6:02 Likewise introduced was Engr. Jaime Cano of the NHC. Engr. Cano assured the body that he would check on the materials used for the GSIS houses at Laoag. He would also talk with Col. Kabiling regarding the painting and floor tiles of the houses at the Science Garden.

6:03 Mr. Raufaste reported that they visited Daet and Laoag. They were able to instrument the PAGASA house at Daet which is a one-storey building made of concrete hollow blocks, G.I. sheet roofing, wooden trusses and a hip-roof. It also has an air-conditioned room which is essential for the instruments. Mr. Raufaste expressed their optimisim regarding the construction of the second house at Daet by PHHC.

6:04 On the Laoag site, Mr. Raufaste reported that the CAA building is actually the PAL Building. One test house is already up and instrumented and the second test house is under construction. The 2 houses are oriented at 90% to each other. The second house is within the CAA Compound. Mr. Raufaste informed the group that the CAA should be informed of cables placed 6 inches beneath the ground and runs from the tower to test house No. 1 since a road will be constructed here in the near future. He also mentioned that one air-conditioning unit is needed for the test house.

6:05 Mr. Arafiles reported that there is no water nor toilet facilities at the Laoag test house. To this, Engr. Soriano replied that the plumbing fixtures are already at the site and only the spetic tank is needed. Engr. Soriano also stated that the ₱30,000.00 donation of the GSIS is not sufficient for the two houses and he had to get some of the materials. Dr. Tabujara informed Engr. Soriano that since the Committee has some money, this could be used for things like this.

6:06 Mr. Raufaste stated that the CARE house is now in Manila according to CARE representative Manuel Torres. Dr. Tabujara read Mr. Torres' letter giving U.P. full ownership and responsibility of the CARE house. Dr. Tabujara would reply that ownership would be to the Philippine government and the custodian will be the Phil. Advisory Committee.

6:07 Dr. Marshall reported that field studies covered 80% of his time and that 2 units were already instrumented. Although they had some equipment problems for the Wind Tunnel facilities, the people there can now carry on with constant communication between them. He also expressed his desire for a bigger model than the present 1:80 scale. He expressed his appreciation for the time and money spent by the University and made mention of the air-conditioning unit supplied for the wind tunnel instruments.

6:08 Dr. Tabujara commended the 2 graduate engineers assigned to the Wind tunnel project, namely Peter Paul Castro and Enrico Gregorio. Dr. Tabujara stated that Dean Juguilon's report on Laoag would be put into record and he expressed his appreciation for the Dean's help.

6:09 Dr. Marshall would probably be back on July or August 1974. Mr. Raufaste's telephone number is 301-921-3233 or 34 and Dr. Marshall's 301-921-3475. For emergencies they could be contacted "collect". Mr. Raufaste stated that any material, information or plan of typical Filipino houses that the Committee could give him would be highly appreciated. He also commented how impressed he is on the Philippines.

6:10 Engr. Soriano, on the other hand, commented on how impressed he was on Mr. Raufaste and Dr. Marshall who worked very hard on instrumenting the two houses at Laoag. Mr. Raufaste then reported on how he even had to hold the plane at Clark Air Base for the instruments could not be located prior to their departure for Laoag.

6:11 Dr. Tabujara thanked Engr. Soriano for all his help. The meeting was adjourned at 4:15 p.m. with Mr. Raufaste reminding the body of their comments based on the draft recommendations distributed during the last meeting.

(Sgd.) GERONIMO V. MANAHAN
Secretary

Prepared By:

(Sgd.) Cynthia S. Enriquez

APPENDIX B

"SIMULATION OF ATMOSPHERE FLOWS IN SHORT WIND TUNNEL TEST SECTION"

SIMULATION OF ATMOSPHERIC FLOWS IN SHORT WIND TUNNEL TEST SECTIONS

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LIST OF FIGURES

LIST OF SYMBOLS

X,Y,Z	Wind Tunnel Coordinate System
Y_{ref}	Reference Height for Profile Nondimensionalization
Y_o	Effective Roughness Length
U	Local Mean Velocity
U_{ref}	Mean Velocity at Height Y_{ref}
U_{RMS}	Root-Mean-Square Velocity
$\overline{u'v'}$	Second Order Velocity Correlation
ΔX	Separation Distance for Velocity Correlations
X_o	Zero-Crossing for Autocorrelation Functions
$R(\Delta X)$	Normalized Longitudinal Velocity Space Correlation
L_x	Eulerian Integral Scale
n	Frequency in Hz
F(n)	Velocity Spectral Function
δ	Boundary Layer Thickness

I. INTRODUCTION

1.1 Scope of the Study

The design for wind effects on buildings has traditionally been performed in a highly empirical manner. However, within the last decade modeling techniques have been developed which permit the rational design of structures for wind resistance--Cermak (3,4) and Davenport et al. Recent design approaches rely on the availability of wind pressure information derived from measurements on small-scale models placed in an "appropriate" wind tunnel.

The realization that wind tunnels can be used as an effective tool in designing buildings against wind damage has caused considerable thought and effort to be directed toward determination of what constitutes an "appropriate" wind tunnel. A decade of research on turbulent boundary layers formed over rough surfaces in a long (30-40 m) test-section wind tunnel has demonstrated that a wind tunnel of this type is indeed satisfactory and "appropriate"--Cermak (4). Unfortunately, long test-section wind tunnels are costly to build and require large buildings for housing with the result that very few are now in existence--the major facilities are located at Colorado State University and the University of Western Ontario. On the other hand, many aeronautical wind tunnels (short test-section type) exist throughout the world at universities, government operated laboratories and industrial laboratories. Although considerable effort has been expended in adapting these short test-section wind tunnels to the modeling of atmospheric flows (Section 1.2), there is not a clear indication at this time that satisfactory simulation can be achieved. Jensen (15) has demonstrated that uniform flow or boundary-layer flows with the wrong turbulence scale can lead to incorrect pressure distributions; therefore, the pressure data from short test-section wind tunnels must be viewed with caution. Development of a thick turbulent boundary layer in a short test-section wind tunnel requires initial stimulation of the boundary layer by some system of momentum sinks. Although devices such as graded screens, grids, vortex generators, spires, roughness plates, etc. have yielded reasonable vertical gradients of mean velocity, no definitive study has been made to determine how realistic are the resulting turbulence structures.

The purpose of this study was to develop an optimum system for generating thick turbulent boundary layers with a proper integral scale to simulate the atmospheric boundary layer in a short test-section wind tunnel. In particular, a system was to be developed which could be adapted to the 4 x 4 ft by 12 ft long test section of the University of the Philippines wind tunnel to study wind pressures on buildings resulting from typhoons.

1.2 Review of Previous Modeling Techniques

The need for wind tunnels to study atmospheric flow phenomena has prompted a number of investigators to convert existing short test-section wind tunnels or to build wind tunnels with test sections significantly shorter than required by a natural boundary layer development. Most of these have been reported rather recently, since 1968.

Methods of generating turbulent shear flow have been known for many years. Lawson (16) provided a review of those techniques and their possible use for atmospheric flow simulation. Cowdrey (12) showed a technique for designing horizontal rods to provide desired mean velocity profiles. Cockrell and Lee (5) used horizontal rods designed with

Cowdrey's technique and also used solid "mixing wedges" on the tunnel floor to simulate a neutrally stable atmospheric flow. Their technique required a fairly long test section (approximately 40 duct heights) before the boundary-layer settled down to an equilibrium condition.

An early use of vortex generators at the test section entrance to simulate atmospheric flows was reported by Armitt and Counihan (1). Their triangular wedge shape resulted in excessive organized longitudinal vorticity at their test station. Further development of the vortex generators with appropriate roughnesses has been performed by Counihan (7-11). His development has resulted in what he claims to be an acceptable simulation of a neutrally stable boundary-layer flow four and one-half boundary-layer heights downstream of the generators. Because he presented no data upstream or downstream from his measurement station, it is not possible to determine whether or not the boundary-layer was in a reasonable state of equilibrium. Triangular vortex generators were used by Sundaram et al. (22) in combination with a trip fence to demonstrate the technique of shortening the development length. Their limited data showed some promise of successful simulation.

The Canadian National Research Council has had a program to develop flow modeling in a short test section for several years. An early attempt, Templin (23), used a grid of horizontal bars with little success. Later attempts have used spires at the test section entrance. Standen et al. (20), Standen (21), and Wardlaw (26) described the technique and compared pressures measured on a structure with measurements in a conventional naturally developed boundary-layer and with field measurements. While the extent of comparison was not sufficiently extensive to demonstrate complete acceptability, the technique did show promise. Approximately six boundary-layer heights were required to establish equilibrium. Some of their data indicated a possibility of undesirable organized vorticity in the outer portions of the boundary-layer. A spire-generated boundary-layer was also used by Dreher and Cermak (14) at Colorado State University. However, the mean velocity profile showed distortions characteristic of too small a surface-roughness height.

Two investigators have used a coarse grid covering the entire cross section combined with a two-dimensional barrier fence across the floor either upstream or downstream of the grid. Barrett (2) used an upstream barrier with grid to develop the boundary layer and to even out nonuniformities from a high-angle diffuser a short distance upstream. Significant nonuniformities in the approach flow did not permit a good evaluation of the boundary-layer-generation technique. Cook (6), using a barrier downstream of his grid developed a boundary layer simulating the lower one-third of the atmospheric boundary layer with a realistic integral scale. However, his roughness elements were spaced sufficiently closely that a large effective wall displacement occurred.

Fluid barriers or trips have been used by several investigators. Teunissen (24,25) used an array of jets pointing in the direction of the main flow to provide turbulence structure and mean velocity defect to simulate atmospheric flow in an 8 x 8 inch duct. He found it necessary to include a two-dimensional solid fence to trip the flow and carefully selected floor roughness to properly simulate an atmospheric flow. The simulation was very encouraging; however, scale-up to a facility large enough to accomodate a model at 1:200 to 1:400 has not yet been demonstrated. Schon and Mery (19) used a jet blowing perpendicular to the main flow at the leading edge to thicken their boundary layer. They were limited in the thickness of the boundary layer they could develop by this technique. Morkovin et al. (17) used a row of counter-jets at floor level directed upstream at various angles to the flow. They did not measure sufficient turbulence properties to indicate acceptability of their simulation. Nee (18) has recently completed a wind tunnel which will use lateral jets to control the flow properties.

II. WIND SIMULATION FACILITIES

2.1 Wind Tunnel

The study was performed in the Industrial Aerodynamics Wind Tunnel at Colorado State University (Fig. 1). The test section is 6 x 6 ft in cross section with a length of 36.5 ft and contraction ratio of 4:1. An axial-flow blower driven by a 75 hp constant speed motor provides wind velocities up to 65 ft/sec. Continuous variation of wind speed is accomplished by varying the fan blade pitch.

2.2 Spire and Roughness Arrays

The intent of the study was to determine a combination of disturbance devices and roughnesses to simulate a neutral atmospheric flow for two classes of roughness defined by mean velocity power-law exponents in the ranges 0.14-0.20 and 0.28-0.35. A location 18 ft downstream in the test section was selected as the cross section at which the boundary-layer simulation would be targeted. This location was scaled to the end of the 12 ft test section of the University of the Philippines wind tunnel. In order to provide a flow in which models as large as 1:50 could be used, as deep a boundary layer as possible was desired, even to the point of modeling only the lower portion of the atmospheric boundary layer.

With the present status of expertise in generating artificially stimulated boundary layers outlined in Section 1.2, spires with a roughened floor were selected as the most likely means of obtaining an acceptable simulation. Spires used in a previous study (14) provided a starting point for spire geometry. A number of spire geometries and roughness heights were tried. Two combinations of spires and roughness were found which met the power law velocity-exponent criteria. The spire and roughness array geometries are shown in Fig. 2. Configuration 1 yielded a profile in the 0.28-0.35 range while Configuration 2 provided a profile close to the 0.14-0.20 range. Photographs of Configurations 1 and 2 are shown in Fig. 3.

2.3 Instrumentation and Data Acquisition

During the initial stages where spire and roughnesses were selected, most mean velocity profiles were obtained with a pitot tube with pressure differences measured with an MKS Baratron pressure transducer. For final data (including all data presented in this report), velocity data was taken by hot-wire anemometer. Data associated with Configuration 1 was taken with a Thermosystems Model 1054B constant temperature anemometer on loan from National Bureau of Standards for checkout purposes. The remainder of the data was taken with a DISA model 55D01 constant temperature anemometer.

Autocorrelations, space correlations and spectra were obtained for selected locations. Autocorrelations for Configuration 1 were obtained using a Saicor Model SAI-43A Correlation and Probability Analyzer which was on loan from National Bureau of Standards for checkout. The remaining correlations were obtained on a Princeton Correlator. Spectra were obtained by Fourier transform of the correlations. Each correlation was digitized at two millisecond intervals (300-350 points per correlation) and transformed by a Fast-Fourier-Transform algorithm on the CSU CDC 6400 computer.

Six measurement stations were defined in the wind tunnel, two each at three downstream positions. The three longitudinal positions were at X=14, 18 and 28 ft from the spires at the test-section entrance (see Fig. 2 for coordinate system). At each of these distances, measurement stations were located on the centerline of the wind tunnel and 1/2 spire spacing off the centerline. At each of these six stations, data was taken along a vertical line. Mean velocity and turbulence data were taken at all stations on a vertical traverse spanning the entire boundary-layer thickness. Correlations and spectra were taken at selected locations chosen to show certain features of the turbulent structure.

III. RESULTS

3.1 Mean Velocity

The mean velocity profiles for the two desired power law exponent flows are shown in Fig. 4. The data is nondimensionalized with respect to the velocity U_{ref} measured at a height Y_{ref}. These reference values are not intended to represent the edge of the simulated boundary layer flow but a convenient position for nondimensionalization. The best value to use for the simulated boundary-layer thickness will depend on the scale of models to be placed in the flow. This scale should not be selected until the turbulent properties of the flow have been examined. A value of Y_{ref} of 52 inches was selected to nondimensionalize all data since all mean velocity profiles measured obeyed a power law to that height. Some profiles had a power law profile to a height of as much as 58 inches before effects of the ceiling boundary layer were felt. The solid lines in Fig. 4 represent a least squares fit of the data to a power-law velocity profile. The exponents were found to be 0.312 and 0.138.

An important criterion in the simulation of atmospheric flows is the effective roughness length. Significant difficulties were encountered in this study in that excessively large values tended to occur. This difficulty was also evident in several of the reviewed publications. The final solutions for the present simulation represent reasonably acceptable values. Logarithmic plots of the data from Fig. 4 are shown in Fig. 5. As expected, a large portion of the boundary layer followed a logarithmic relationship. Roughness lengths Y_o determined from the graph are 0.884 inches for Configuration 1 (n=0.312) and Y_o=0.01 inches for Configuration 2 (n=0.138). The corresponding prototype roughness lengths range from 22 to 88 inches for model scales of 1:25 to 1:100 for Configuration 1 and from 0.25 to 1.0 inches for Configuration 2. These values fall within the range of field values expected for the power law profiles given.

One of the greatest difficulties in developing a boundary layer with artificial stimulation has been that of generating a flow which is in equilibrium. Only the spire configuration used by the National Research Council (20, 21) and the multiple jet facility reported by Teunissen (25) have demonstrated some measure of equilibrium. The Canadian study required six spire heights to establish equilibrium--a condition which, for this study with a short test-section length available, would limit spires (and consequently boundary layer height) to less than half the wind tunnel height. Teunissen had such a small range of frequencies between the peak of his spectrum and viscous dissipation that his boundary layer reached equilibrium more quickly--about 4½ tunnel heights downstream. The desire for equilibrium in three tunnel heights (4.1 Y_{ref}) in the present study represents a severe requirement. A necessary (but not sufficient) condition for equilibrium is a mean velocity profile invarient with longitudinal position. Figure 6 shows the mean velocity profiles for the three longitudinal measurement positions for both Configurations 1 and 2, plotted on log-log scales to show the power law relationship of the profiles. The solid lines are least square fits for the exponent n. The variation in exponent for Configuration 1 was from 0.336 to 0.245 from X=14 ft to X=28 ft. While the variation was not exceedingly large, equilibrium has certainly not been indicated in the strictest sense. The profiles for Configuration 2 show a variation with downstream extent sufficiently small to indicate the possibility of a fully developed flow.

An equilibrium boundary layer maintains itself by balancing the production of turbulence which is influenced by the roughness with the dissipation of that turbulent energy in viscous effects. The decay in exponent for Configuration 1 indicates that, for the given roughness, the boundary layer was seeking an exponent lower than those shown in Fig. 5 as it approached closer to equilibrium. It also indicates that larger roughness elements would be required in the region from X=14 to 28 ft to maintain an exponent in the range of 0.28-0.35 desired for a solution in Configuration 1. However, it was found that, for a particular spire, the roughness required to force a power-law variation in mean velocity was fixed--that is, one is not free to arbitrarily select a roughness to vary the exponent. A particular spire demands a particular roughness to obtain a power-law variation in mean velocity and together they define an exponent which may vary with downwind position. This need for a particular roughness has been noted before and was most clearly shown by Standen (21). His profiles showed two distinct power-law regions with incorrect roughness leading to the concept that the spires controlled the profile shape in the outer region of the boundary layer and the roughness controlled the profile shape in the inner portions. This concept, however, oversimplifies the mechanism. The roughness actually affects the profile over the entire height as is demonstrated in Fig. 7. Four mean velocity profiles are shown representing the solution profile for Configuration 1 and three alternate roughness heights. The data shows that the effects of spires and roughness interact so strongly that they must be considered together in their effect on the flow. This makes the design of a spire and roughness array to obtain a particular result (say a desired power-law exponent) a difficult task since one cannot, for example, determine the effect of varying spire width without also trying a series of roughnesses with each spire width. It is thus not evident from the data shown in Figs. 4 and 5 what variations in spires and roughness would result in a mean velocity profile more stable in longitudinal variation than the data for Configuration 1.

It was found during the early testing that the spires followed by a roughness of uniform height did not produce a power law profile at the X=18 ft measurement station as readily as a roughness which was higher near the spires than farther down the test section. The effect of the roughness height gradation used for Configuration 1 appears to have the same effects as the barriers used previously by a number of investigators (2, 6, 7-11, 22, 25).

One concern resulting from the use of spires was the spanwise variation of flow properties. Figure 8 shows the comparison of the centerline mean velocity profile with the profile located 1/2 the spire span laterally from the centerline. Data is shown for Configurations 1 and 2 for all three longitudinal measuring stations. The agreement is generally within the measurement tolerance and no indication of a wake effect is evident in the mean velocity profiles. A more stringent test of lateral uniformity is the comparison of turbulence intensity profiles discussed in the next section.

3.2 Turbulence Intensity and Shear Stress

Turbulence intensity profiles showing longitudinal variation on the tunnel centerline for Configuration 1 are shown in Fig. 9. The vertical distance has been scaled by the distance Y_{ref} as was done for the mean velocity profiles. The magnitude of turbulence intensity is realistic for simulation of an atmospheric boundary layer. The decay of intensity with longitudinal position is consistent with the decay of exponent noted above and provides further evidence that the flow was not in equilibrium but was seeking a profile of lower power-law exponent and lower turbulence intensity than was reached by 28 ft downstream. Figure 10 shows the lateral variation at the three measurement stations. Since turbulence decays at a slower rate than velocity defect in a wake flow, these profiles should be more sensitive to any remaining wake effects of the individual spires than the mean velocity profiles. An acceptable lateral uniformity is thus indicated for all three stations.

Longitudinal variation of turbulence intensity for Configuration 2 is shown in Fig. 11. The indication from the mean velocity profiles (Fig. 6) was that little or no change in profile shape was occurring with downstream position. The turbulence profiles, however, show a steady decay of turbulence intensity indicating that the boundary layer was not in equilibrium. Within therange of X=14 to 18 ft, the turbulence variation was small and could represent a flow sufficiently close to equilibrium for many measurement purposes. The overall level of turbulence intensity was somewhat below that expected for an atmospheric flow with the same power-law exponent. Figure 12 shows the lateral variation at all three measurement stations. The uniformity is acceptable.

Figure 13 demonstrates the absolute magnitude of the turbulence by referencing the rms velocity to the constant velocity U_{ref} at height Y_{ref}. Configuration 1 has a turbulent intensity approximately constant up to about 1/3 of the Y_{ref} height. Configuration 2 shows a roughly constant, but smaller, value to approximately 1/4 Y_{ref}.

Shear stress profiles for Configuration 1 are shown in Fig. 14. Both variation with longitudinal position and lateral displacement are shown. Good lateral uniformity is demonstrated but is to be expected from the turbulent intensity results. The lateral uniformity results are a good measure of the precision of the measurements. A steady decay of shear stress magnitude is shown with increasing longitudinal distance. This variation reflects the decay shown in power law exponent and turbulent intensity discussed above. It is difficult to define a region of solidly constant shear stress, but the region from the top of the roughness elements to about 1/3 of the Y_{ref} height could be considered to be a region of reasonably constant stress.

Shear stress results for Configuration 2 are shown in Fig. 15. The lateral uniformity again is good. Decay of shear stress with longitudinal position is consistent with the turbulent intensity results and confirms that the boundary layer was not in equilibrium in the longitudinal range considered.

3.3 Correlations, Integral Scales and Spectra

Longitudinal velocity correlations were taken at several heights above the wind-tunnel floor at all three measurement stations for both spire and roughness configurations. In addition, several correlations were taken at locations laterally spaced from the centerline to check for possible nonuniformities. Two correlations obtained at X=18', Y=13" on the centerline for Configuration 1 are shown in Fig. 16. The curves are in the form of a normalized longitudinal space correlation and are typical of all correlations measured. The solid line was obtained by an autocorrelation of a single hot wire and using Taylor's hypothesis $(\frac{\partial}{\partial t} = V \frac{\partial}{\partial x})$ to convert to a space frame. The correlation has an unusual feature: a long negative tail extending past 100 inches (or about 1/2 second in time). When integral scales were computed from this and other correlation curves by the formula

$$L_X = \int_0^\infty R(\Delta X)\, d\Delta X \quad , \tag{1}$$

it was found that the positive area was nearly balanced by the negative area causing the calculated integral scale to be unrealistically small, and in some cases negative. Since the use of formula 1 to obtain integral scales from an autocorrelation requires that Taylor's hypothesis is valid, a check of the validity of that hypothesis was made by obtaining the correlation of physically spaced hot wires. The results of that investigation are shown in Fig. 16 as circles. The larger the distance that the circles fall below the solid curve, the less is the accuracy of the hypothesis. The reasonable agreement shown is an indication that, while not precisely correct for this flow, the hypothesis is acceptable for the computation of integral scales. It is possible that the long negative tail of the correlation is, in fact, due to the already demonstrated lack of equilibrium in the flow. All correlations measured showed this same characteristic tail although those from Configuration 2 were not as long.

Integral scales were finally obtained by use of the formula

$$L_X = \int_0^{X_o} R(\Delta X)\, d\Delta X \tag{2}$$

where X_o is the first zero crossing of the correlation function. This provides an estimate of the integral scale which should be fairly close to the correct value. The error in an estimate of this type should be such that the scale is slightly overestimated. This calculation procedure is rather common, especially for atmospheric measurements, so that the values obtained should be useful for comparison of the boundary layer with atmospheric flow. The variation of integral scale with height and longitudinal position in the boundary layer for both configurations is shown in Fig. 17. The scale increases with height--as in the atmosphere--over the lower portion of the boundary layer but decreases again at larger heights. This decrease with height above the lower levels is a characteristic of most wind-tunnel simulations with a short test-section. The absolute magnitude of the integral scale compared to the atmosphere must be considered with the scale of the model to be employed. This will be discussed in Chapter IV.

The variation of integral scale with longitudinal position is shown in Fig. 17 at a constant elevation. Since the height chosen was near the peak scale for both configurations and because the tunnel boundary-layer thickness varied little with downstream distance, the trend of the integral scale is an indication of real development within the boundary layer. Again the indication is that, within the test region investigated, the boundary layer was seeking but had not quite attained, an equilibrium condition.

A longitudinal velocity spectrum is shown in dimensional form in Fig. 18a. The location is at 18 ft downstream and at 25 percent of the reference height for Configuration 1 at a point where the integral scale is still increasing with height. The important feature is the slope of the curve in the inertial subrange. A slope of -1.46 was obtained which is significantly different from -1.67 slope expected from a turbulence in equilibrium. A comparison of the spectra for several locations in the flow for both configurations is shown in Fig. 18b to illustrate the vertical and longitudinal variations. It can be observed that the slopes, in general, tend to approach closer to the -1.67 value with increased longitudinal position and decreased turbulence intensity. This data further confirms statements made above relative to the equilibrium of the flow.

Figure 19 shows the velocity spectrum of Fig. 18a in nondimensionalized form. The location of the peak in amplitude and position in the frequency domain was similar for the other spectra. The slope in the decay region was also similar although, as noted above, the slopes tended to be steeper for some situations. The frequency scale is commonly nondimensionalized in the form nL/U where L is some characteristic length such as the integral scale and U is the velocity at the elevation of interest. Since these values are related to the scale of the model involved, a discussion of the location of the peak referenced to these variables will be delayed until Chapter IV.

IV. CONCLUSIONS

Wind-tunnel simulations of atmospheric boundary-layer flow were obtained for two power law exponents at a station located three tunnel heights downstream of the test-section entrance with a 6 x 6 ft cross section wind tunnel. Spires extending the full height of the test section and appropriate roughness were used to generate a 52 inch deep boundary layer. Mean velocity profiles followed power-law relationships over virtually the entire height. Turbulence intensities were reasonable for the case with $\alpha=0.3$ but slightly low for the case with $\alpha=0.14$. Shear stress profiles were within an acceptable range although the depth of the roughly constant stress layer was not as large as might be desired.

The equilibrium of the boundary layers was examined using mean velocity, turbulence and shear stress profiles, integral scales and velocity spectra. The indications were that the boundary layers were not in equilibrium as far downstream as 4.7 wind-tunnel heights. Sufficient evidence is not presently available to demonstrate whether or not the flows were sufficiently close to equilibrium that errors in measurements on or about a model placed in the flows would be acceptably small. It is likely that such errors would be reasonably small.

The size of model which could be tested in the boundary layers generated in this study can be determined by examining the integral scales, the peak of the nondimensional spectra and the effective roughness length. Integral scales in the atmosphere generally run from about 400 to 700 ft. However, in typhoons the scales can be in the neighborhood of 200 ft. Using 200 ft as a reasonable target for wind simulation tests which would be of interest for the Philippines area, the 0.4 and 0.6 ft scales measured in the two boundary layers give model scales of 1:300 to 1:500, say 1:400 as an average. Using an atmospheric boundary-layer thickness of 1000 and 1600 ft for the cases δ = 0.14 and 0.30. The wind tunnel boundary-layer thickness for this scale would be Y_L = 2.5 ft and 4.0 ft--within the depth established for the two boundary layers.

Nondimensionalization of the velocity spectrum frequency scale by the term $n\delta/U$ tends to collapse atmospheric data to a single curve (23). The factor δ represents the atmospheric boundary-layer thickness. The peak of the spectra occur at $n\delta/U = 0.35$ with the ordinate in the form $nF(n)/U_{rms}{}^2$. Applying this criteria to the wind tunnel flows where the peak in the spectrum occurred at $n = 2$ (Fig. 19), values of δ were calculated to be 3.8 ft and 5.0 ft for Configuration 1 and 2 respectively. Assuming full scale values of δ of 1200 ft and 900 ft for the two power law profiles leads to wind tunnel scales of 1:300 for Configuration 1 and 1:180 for Configuration 2.

At scales of 1:300 and 1:180, the effective roughness lengths of .884 inches and 0.01 inches for α = 0.3 and 0.14 respectively are 22 ft and .15 ft in the prototype. The value for Configuration 1 is large by a factor of three or more. While a zero-plane displacement could be used to reduce the roughness length, it involves a rather arbitrary assignment of a displacement which would not improve either the logarithmic or power-law description of the mean velocity profile. At scales of 1:300 and 1:180 the integral scales for the prototype become 180 ft and 72 ft for Configurations 1 and 2. These are somewhat small.

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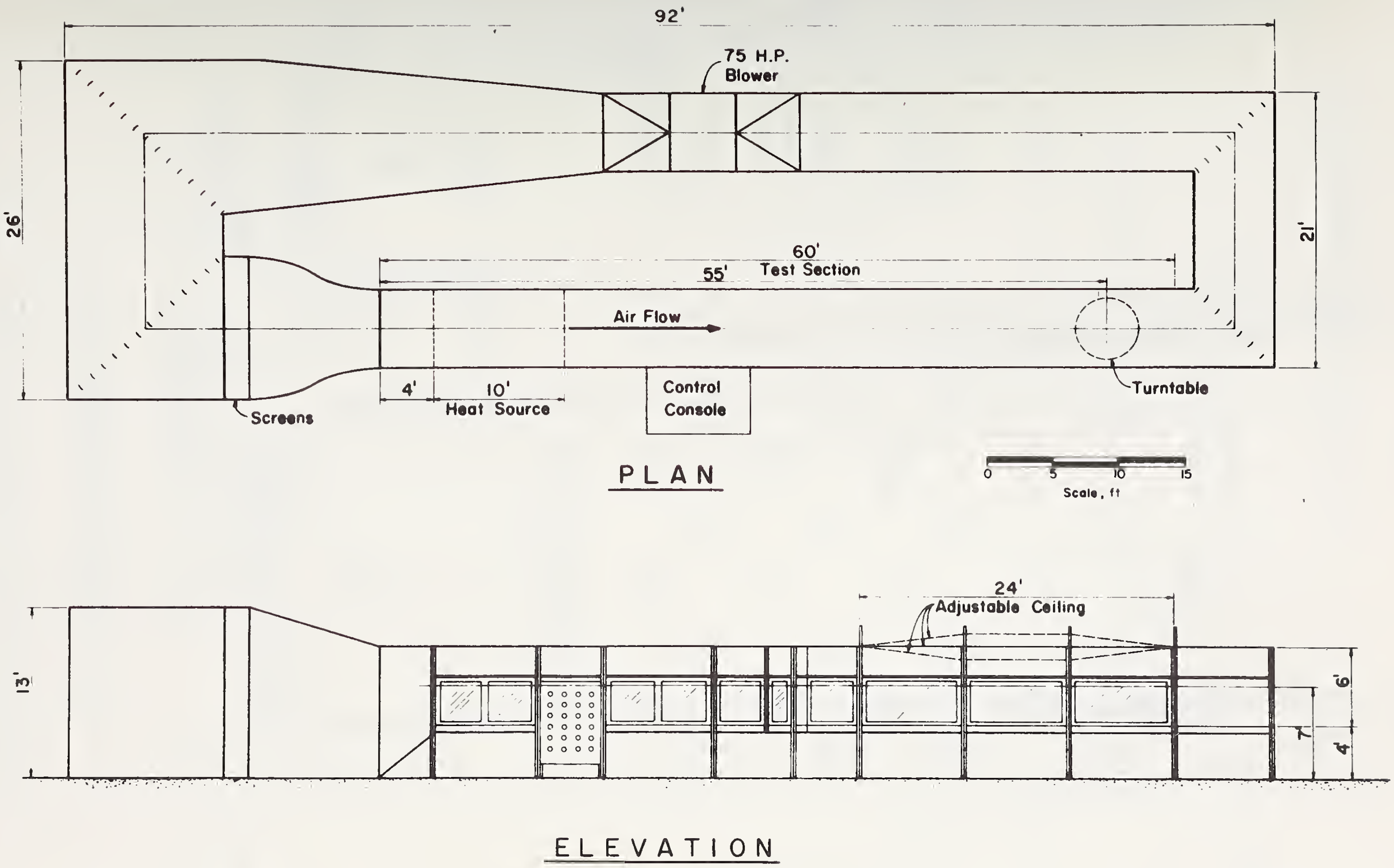


Fig. 1. Industrial Aerodynamics Wind Tunnel
Fluid Dynamics & Diffusion Laboratory
Colorado State University

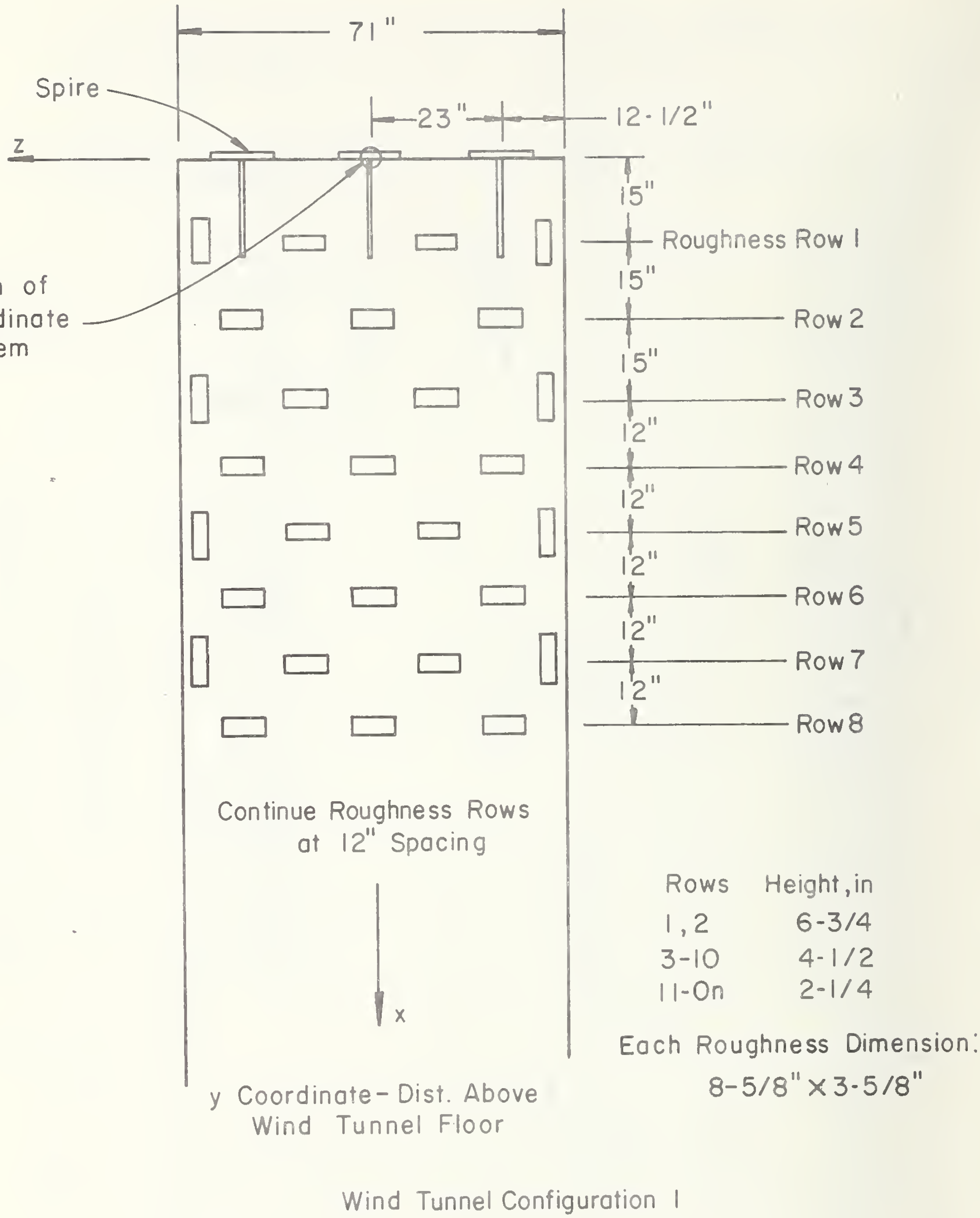
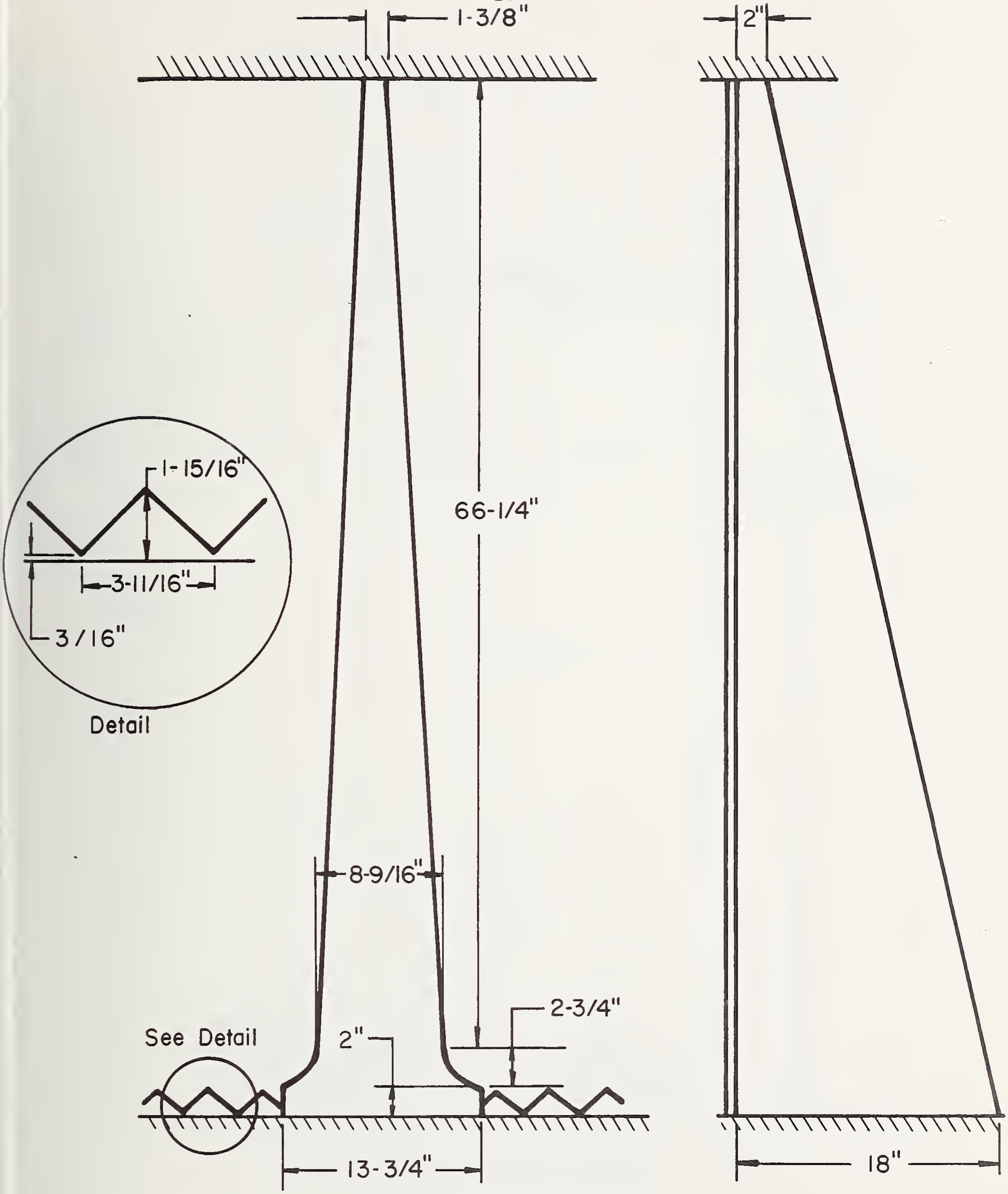
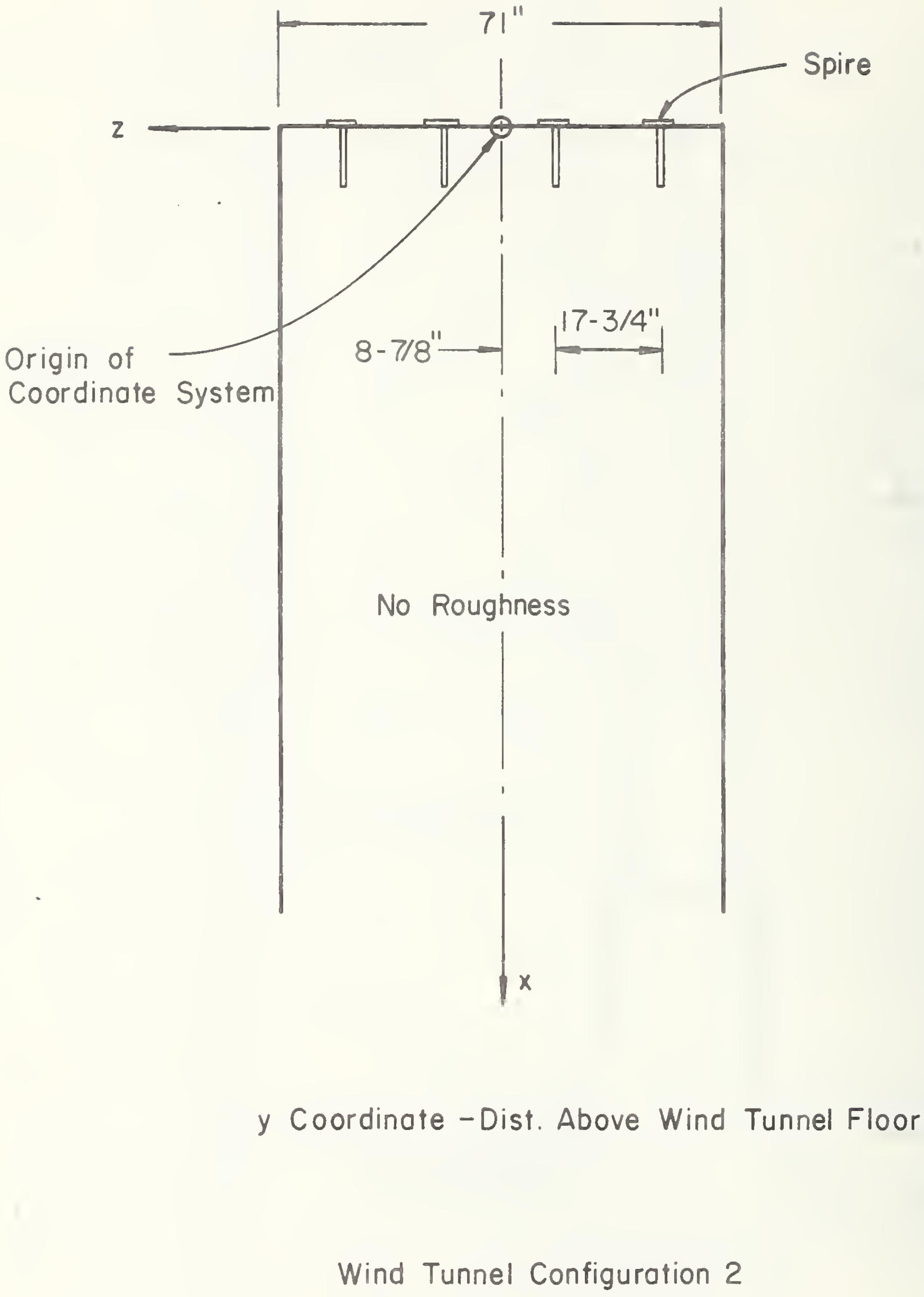


Fig. 2. Spire and Roughness Arrays



Spire for Configuration I

Fig. 2. Spire and Roughness Arrays (continued)



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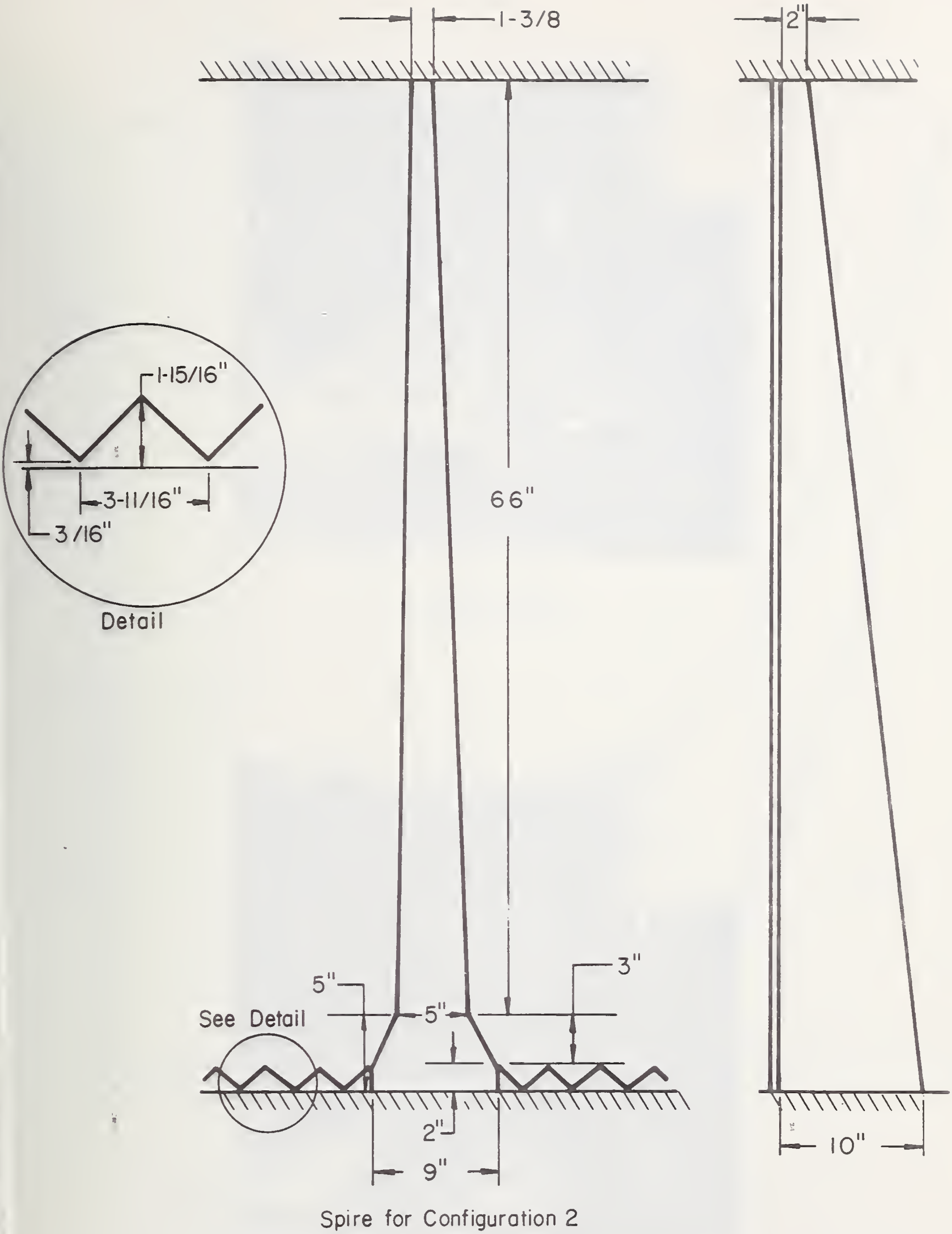
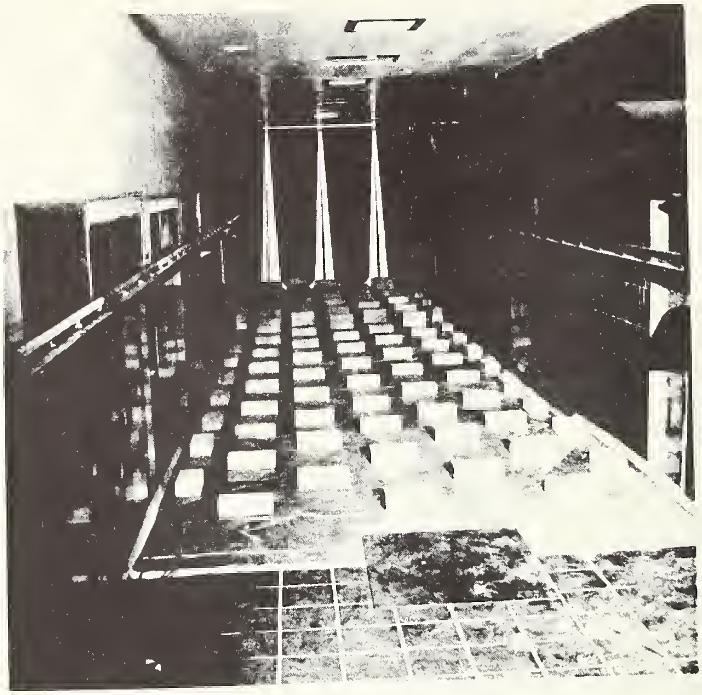
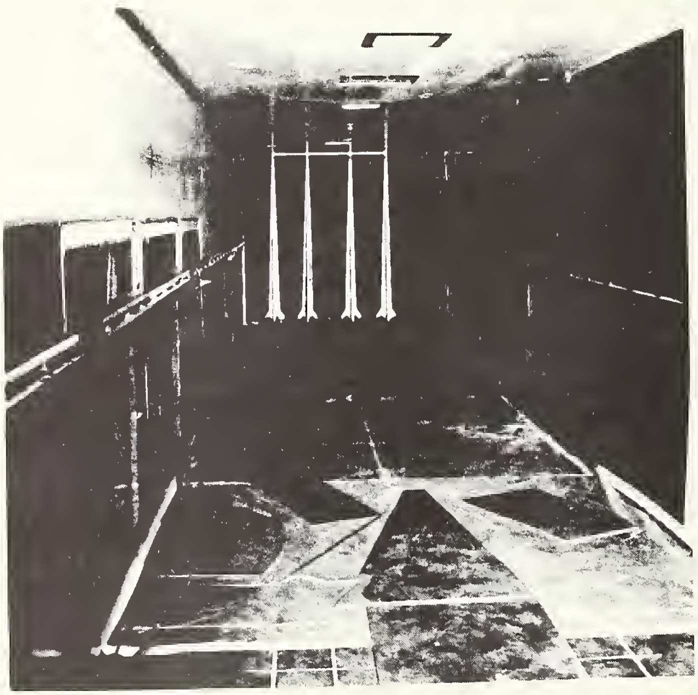


Fig. 2. Spire and Roughness Arrays (continued)



Configuration 1



Configuration 2

Fig. 3. Spire and Roughness Arrays

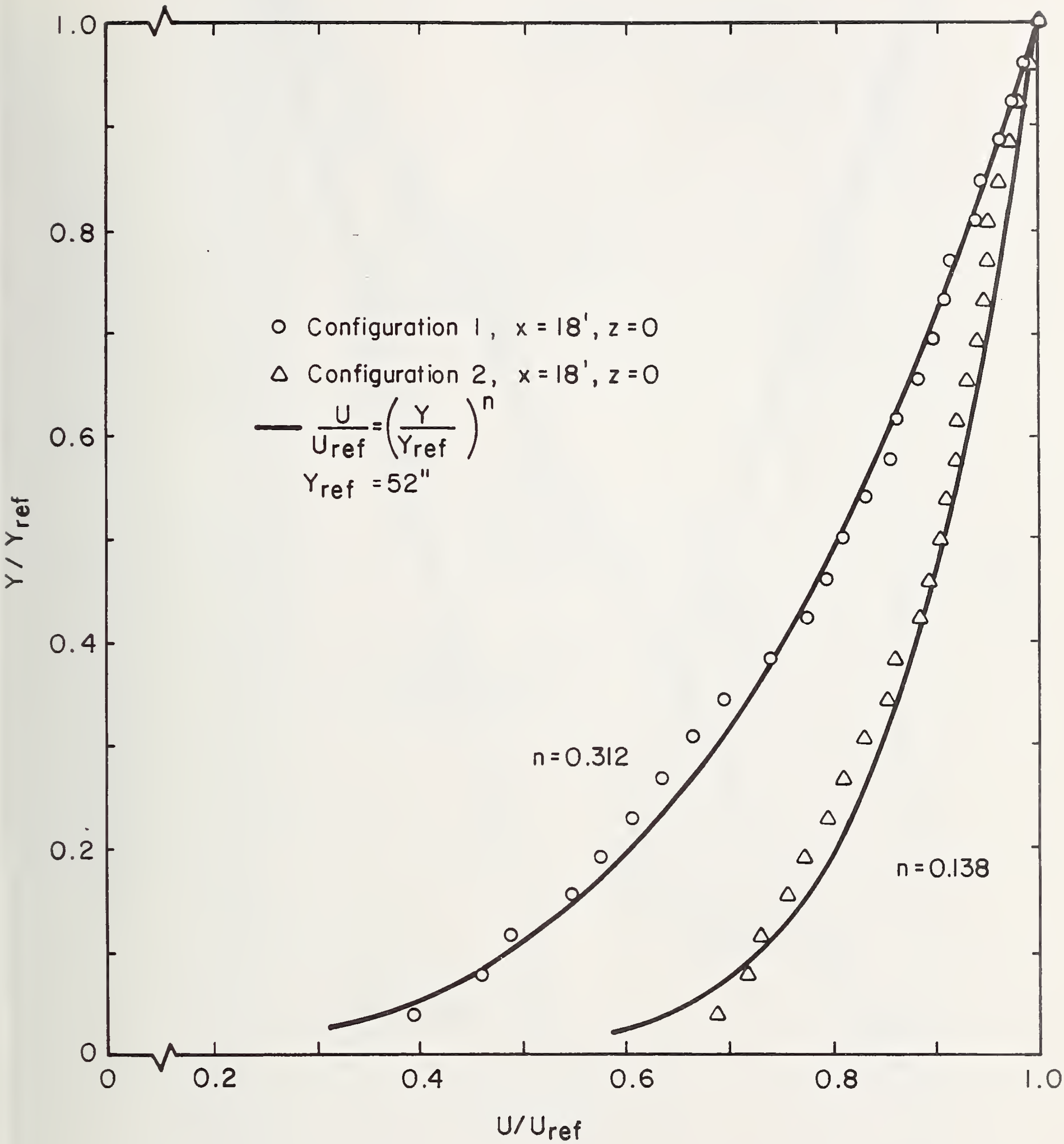


Fig. 4. Mean Velocity Profiles--Rectilinear Form

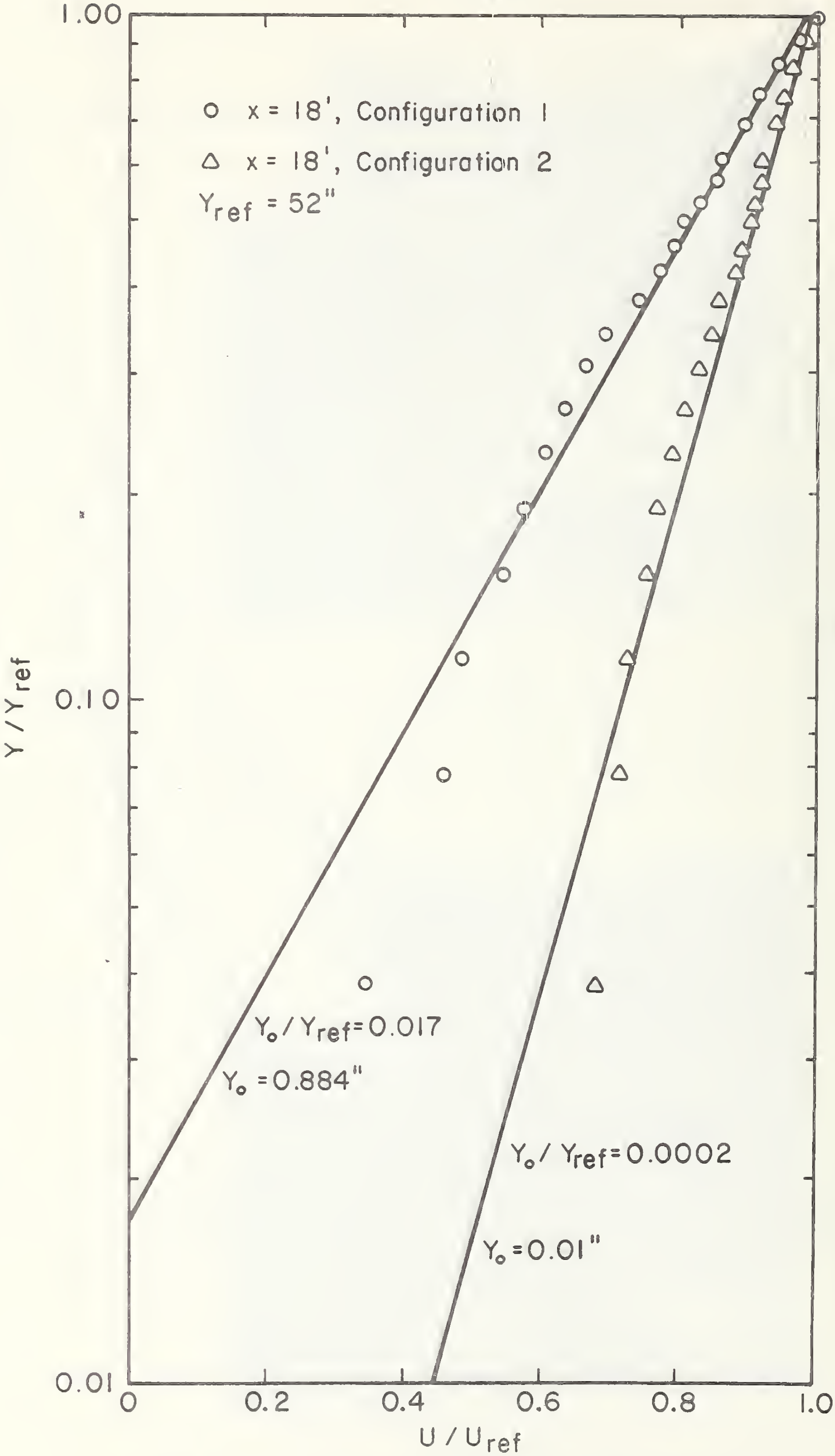


Fig. 5. Mean Velocity Profiles--Logarithmic Form

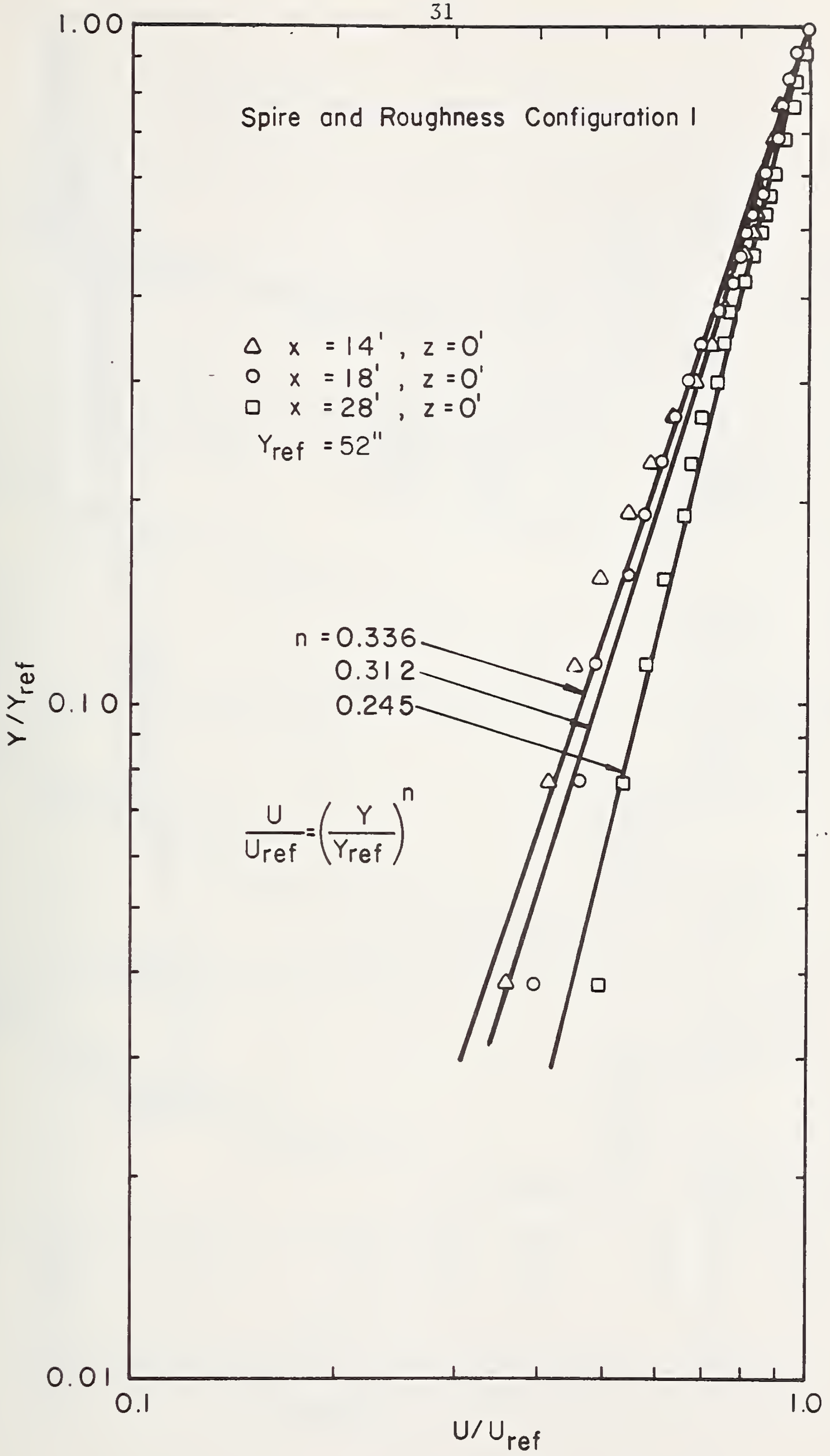


Fig. 6. Mean Velocity Profiles--Power Law Form--Variation with Longitudinal Position

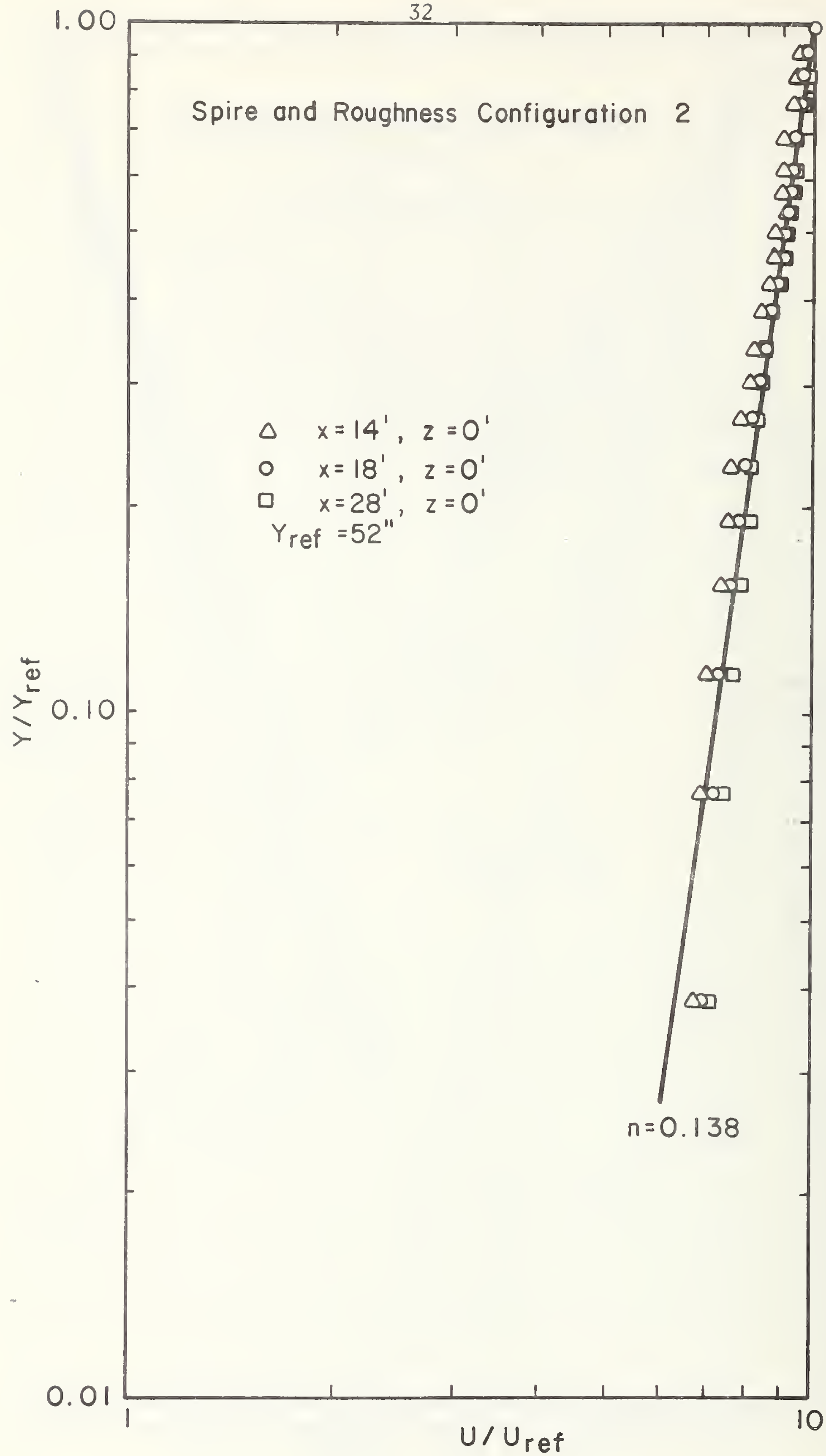


Fig. 6. Mean Velocity Profiles--Power Law Form--Variation with Longitudinal Position (continued)

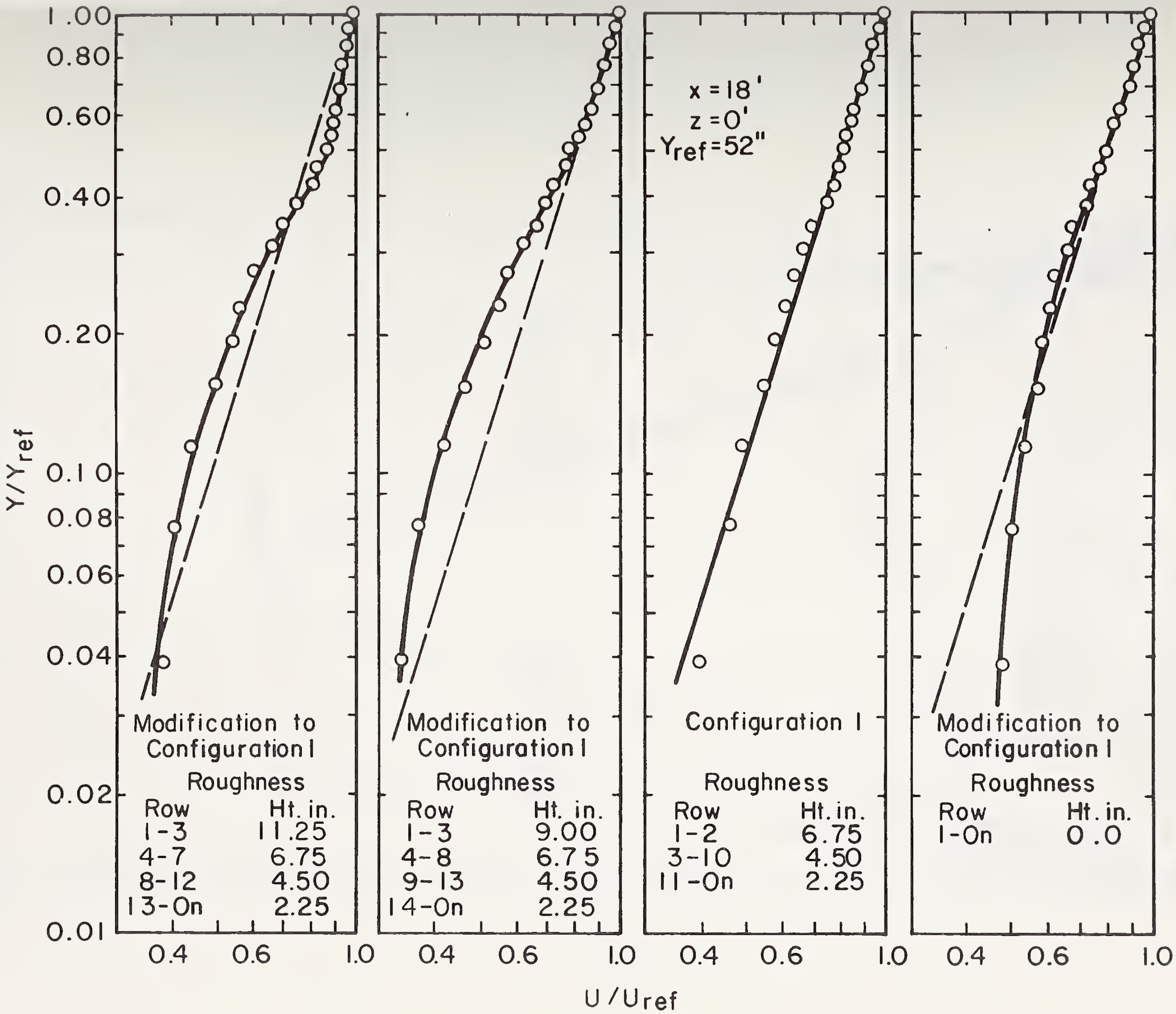


Fig. 7. Mean Velocity Profiles--Variation with Roughness Height

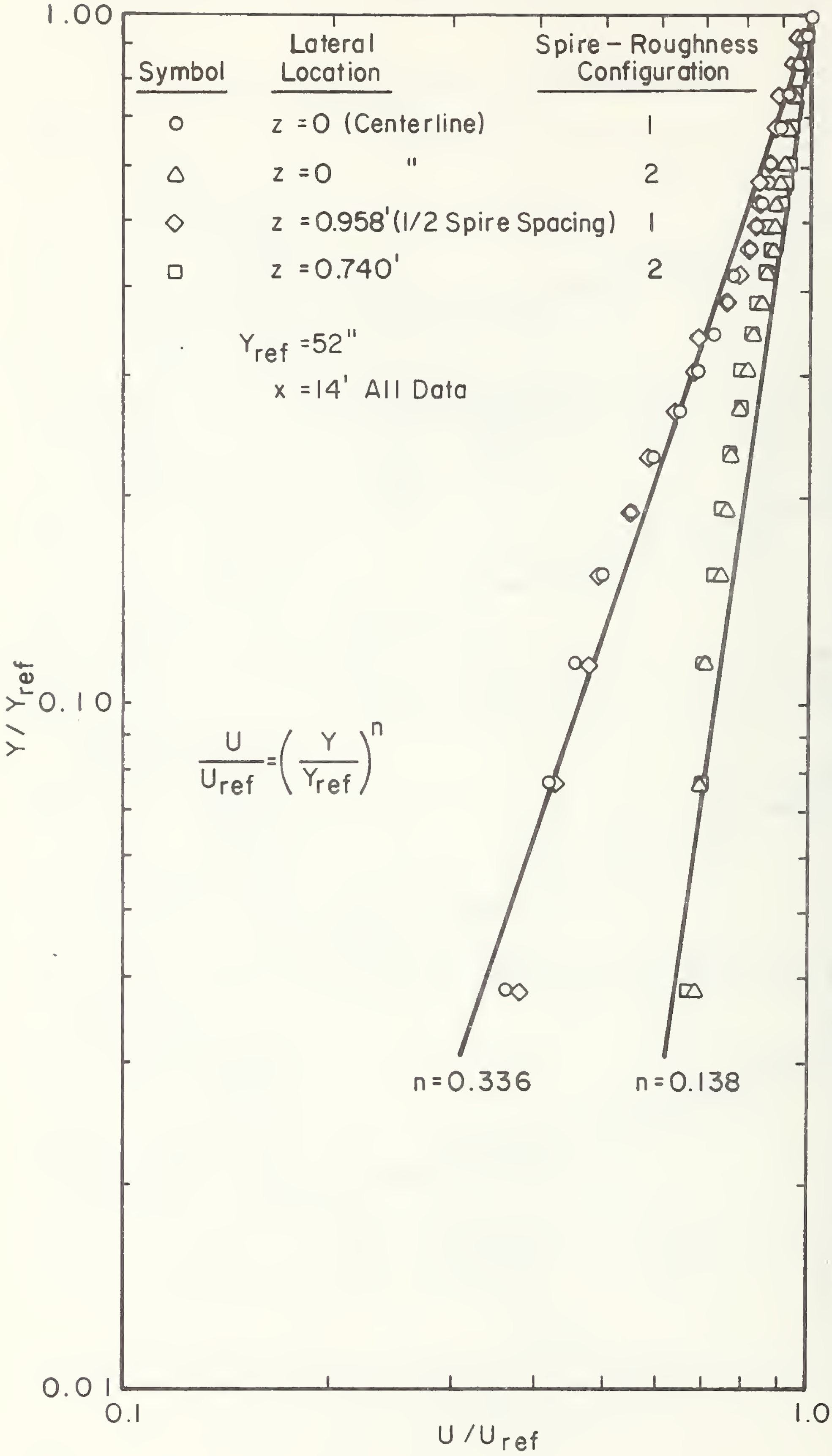


Fig. 8. Mean Velocity Profiles--Variation with Lateral Position

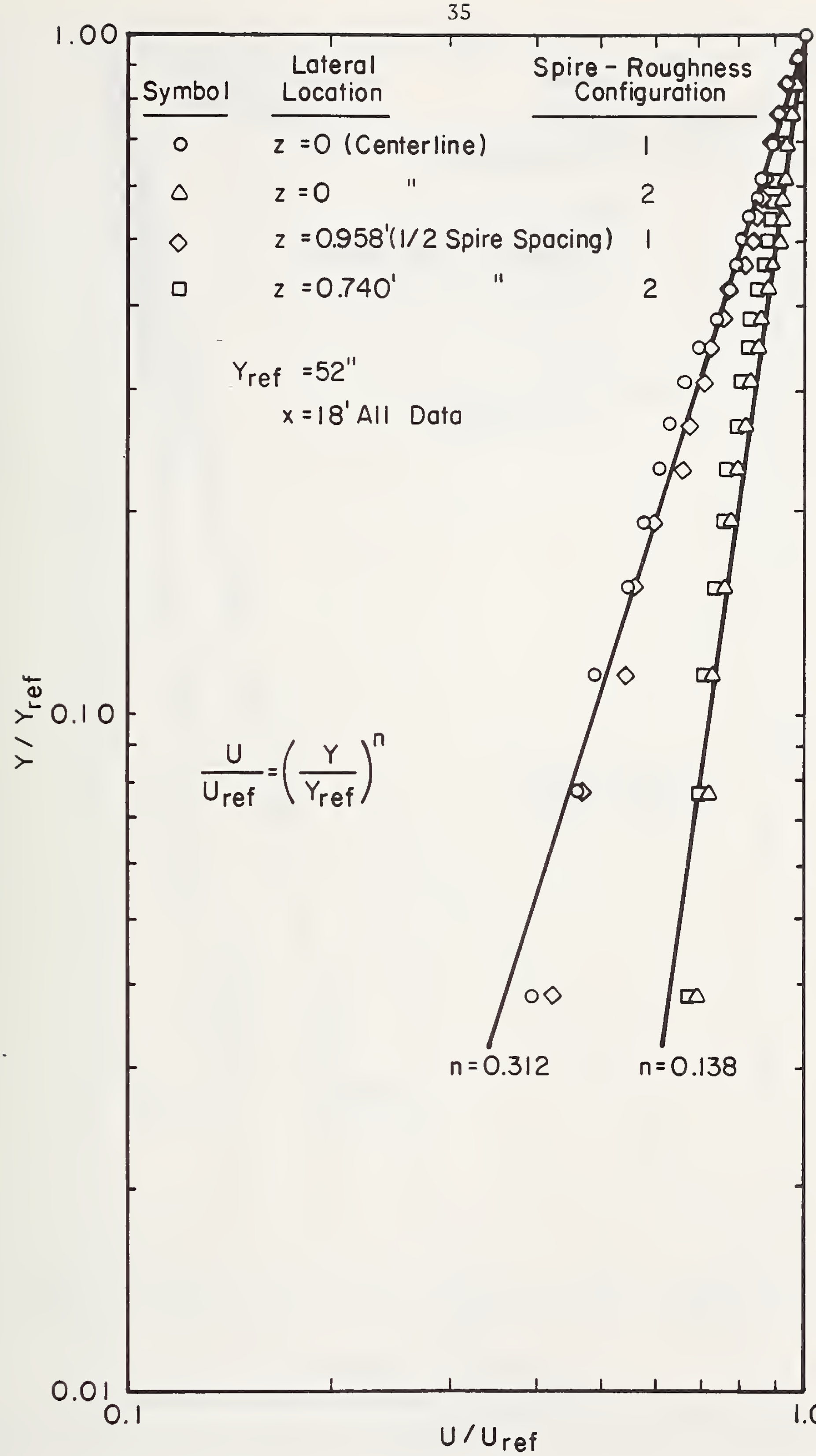


Fig. 8. Mean Velocity Profiles--Variation with Lateral Position (continued)

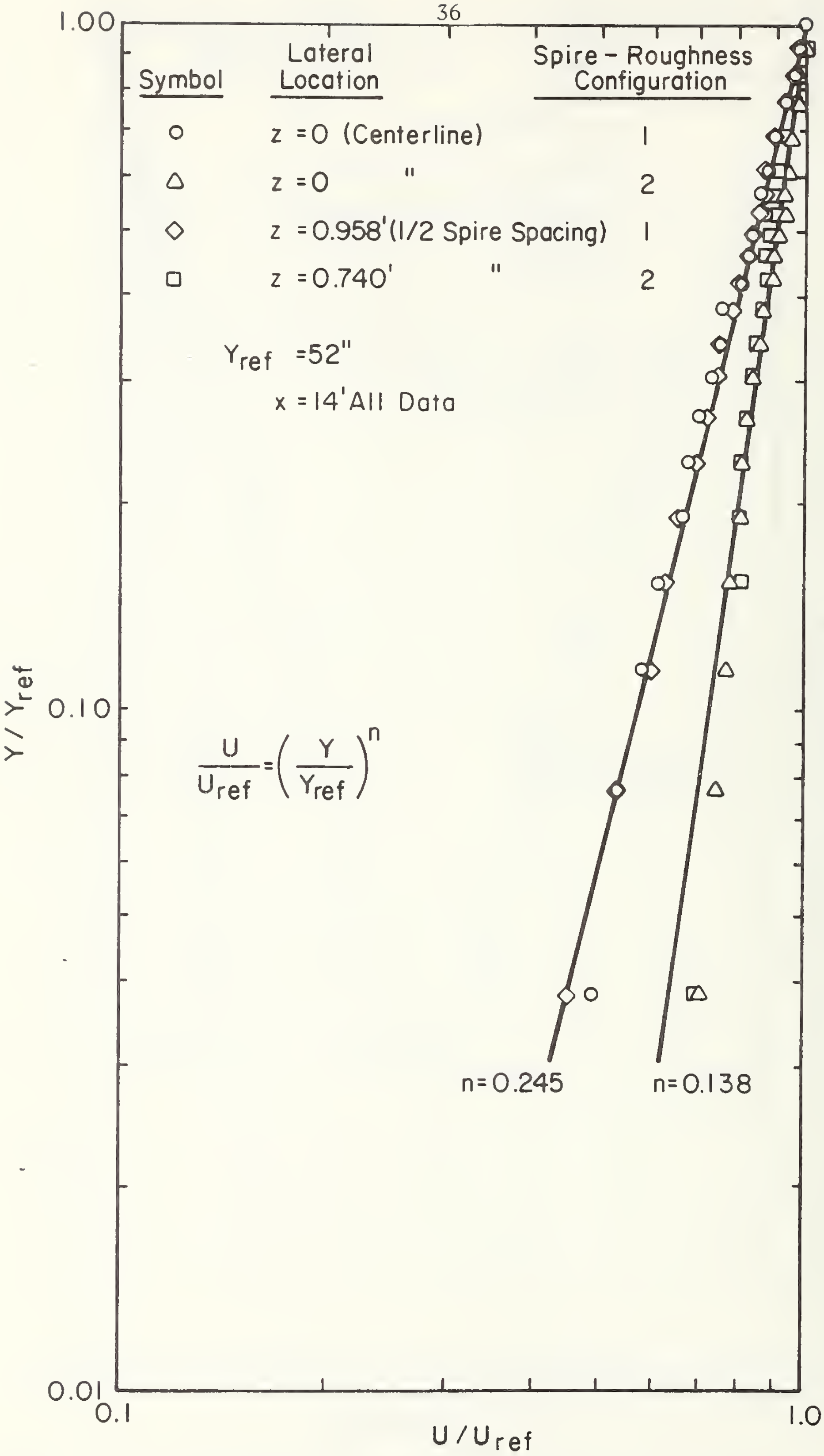


Fig. 8. Mean Velocity Profiles--Variation with Lateral Position (continued)

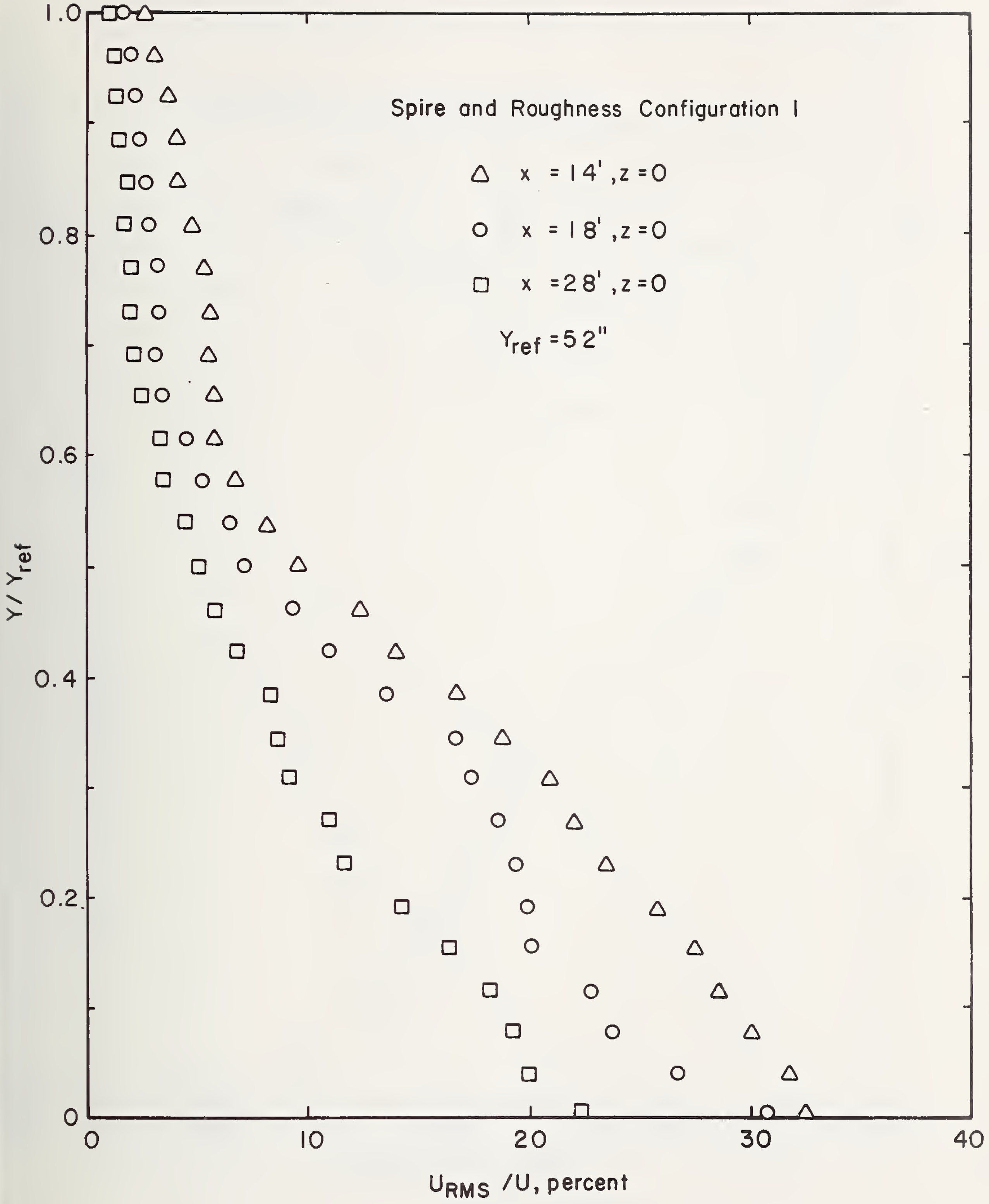


Fig. 9. Turbulence Intensity--Variation with Longitudinal Position--Configuration 1

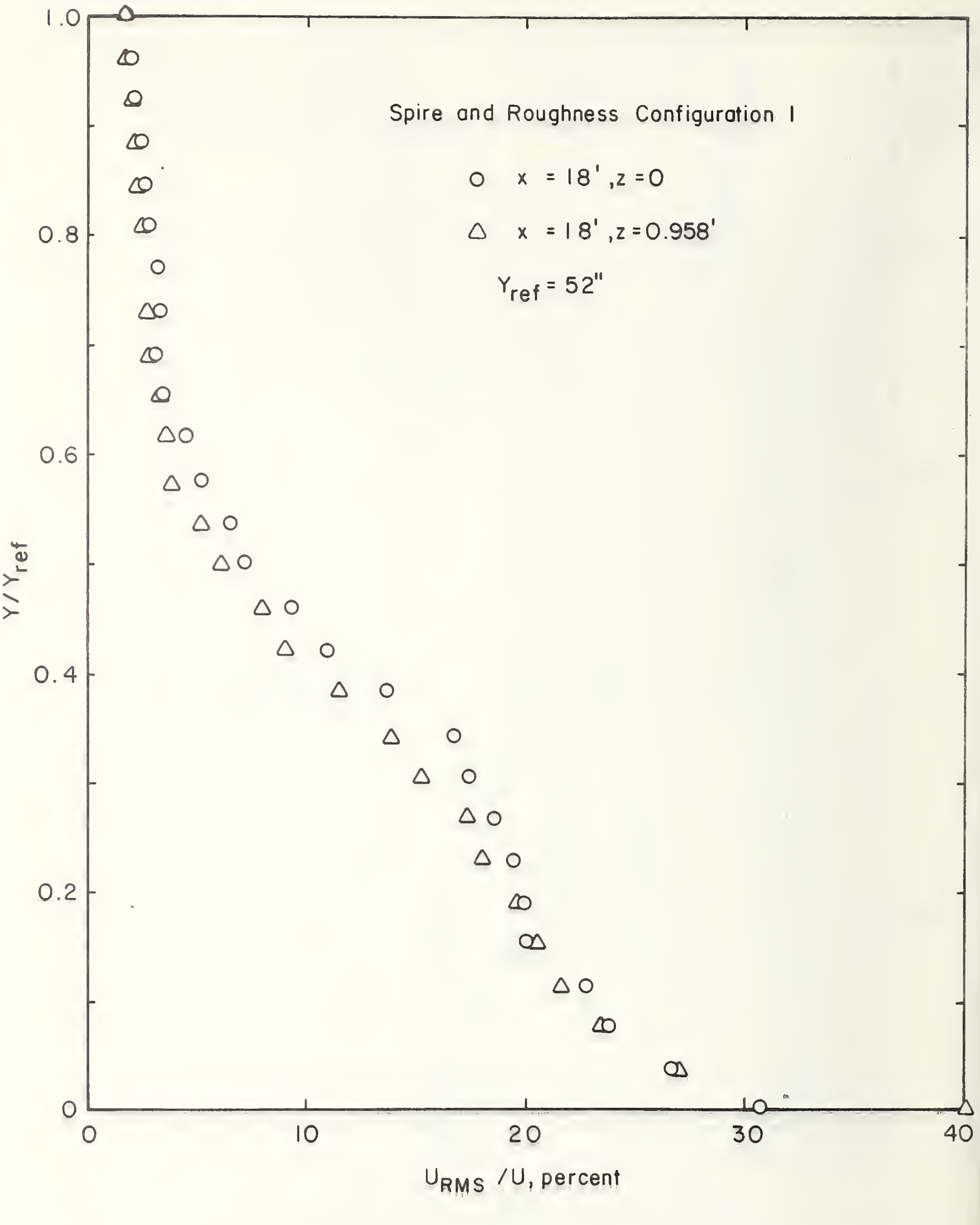


Fig. 10. Turbulence Intensity--Variation with Lateral Position--Configuration 1

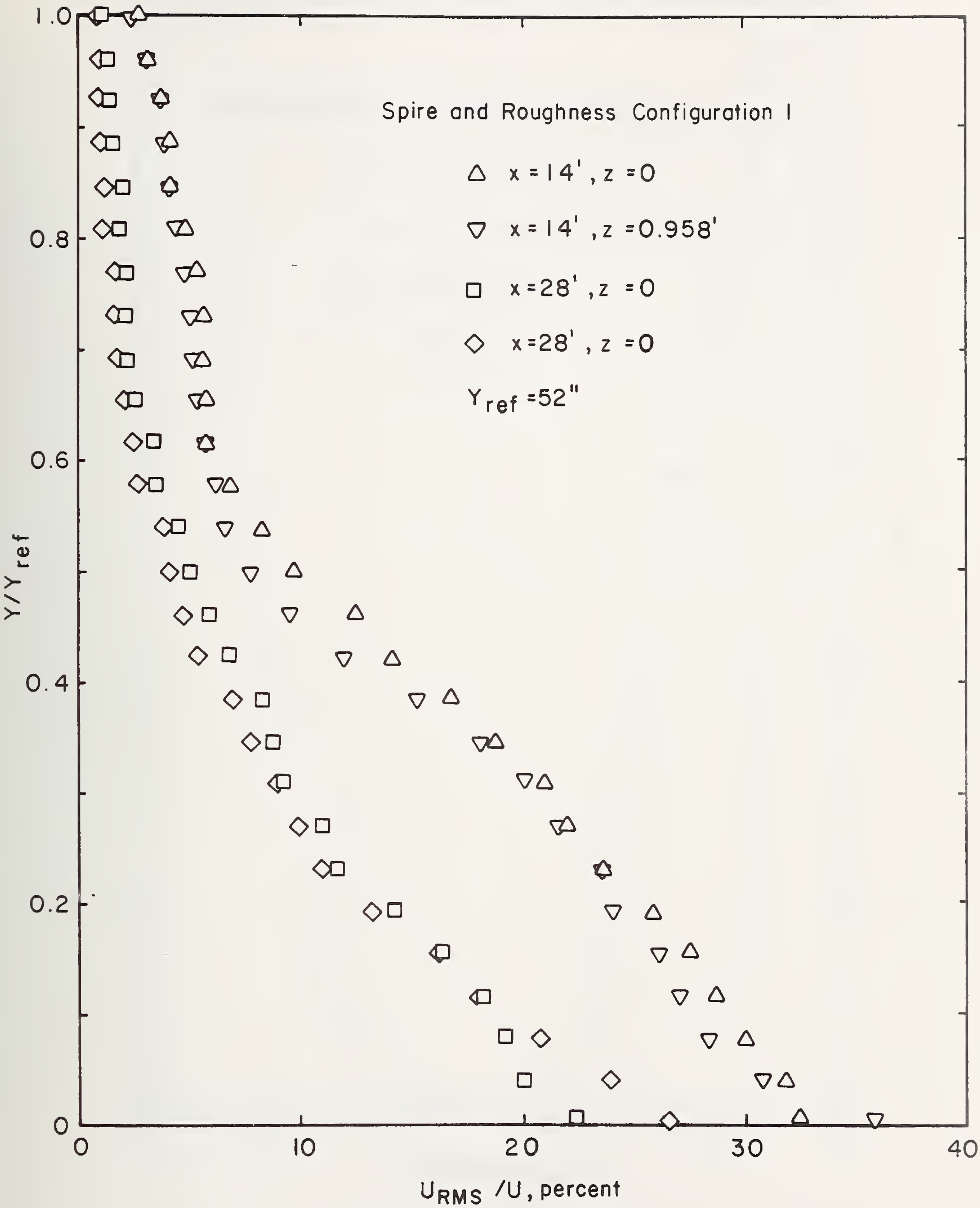


Fig. 10. Turbulence Intensity--Variation with Lateral Position--Configuration 1 (continued)

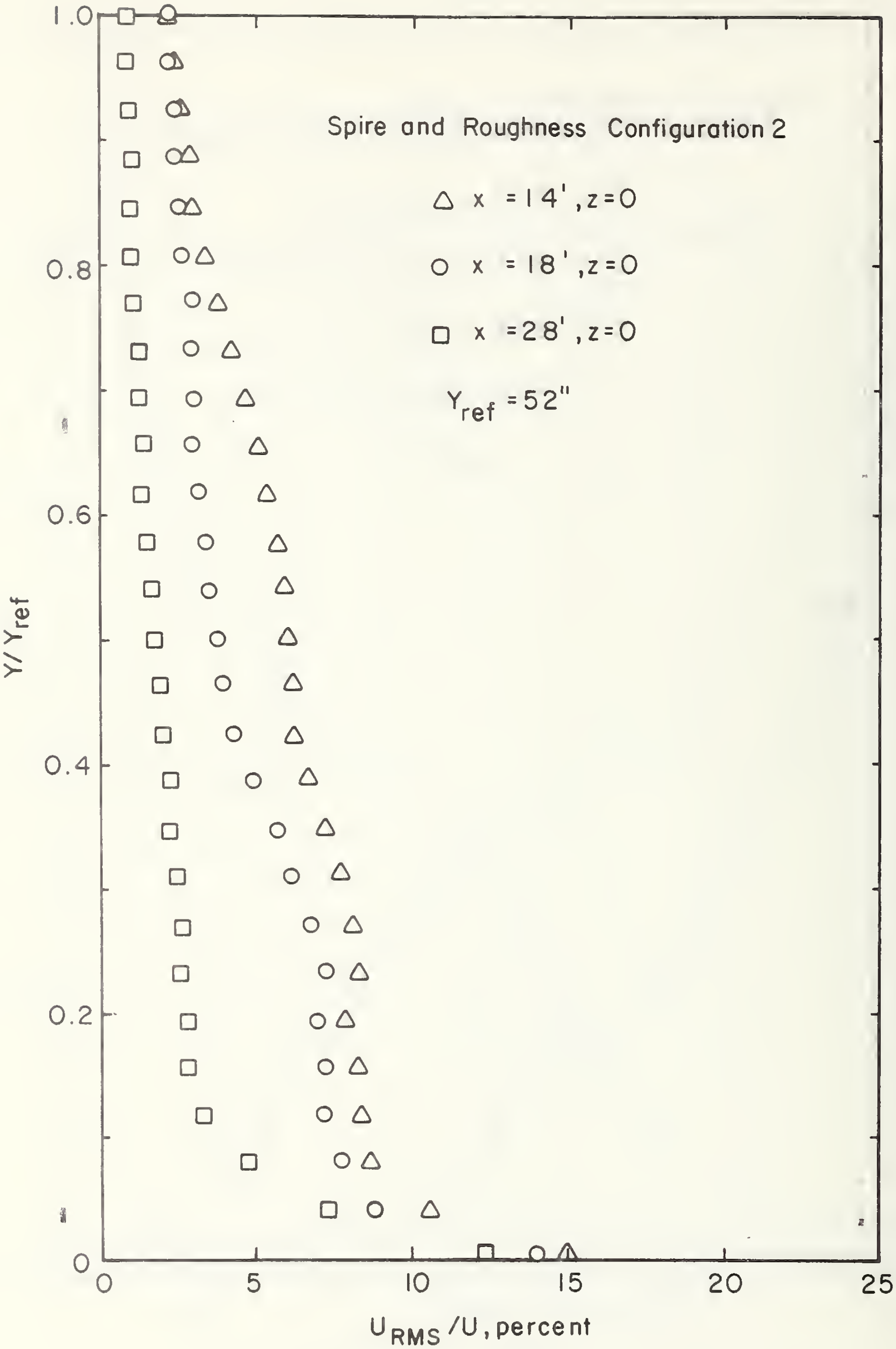


Fig. 11. Turbulence Intensity--Variation with Longitudinal Position--Configuration 2

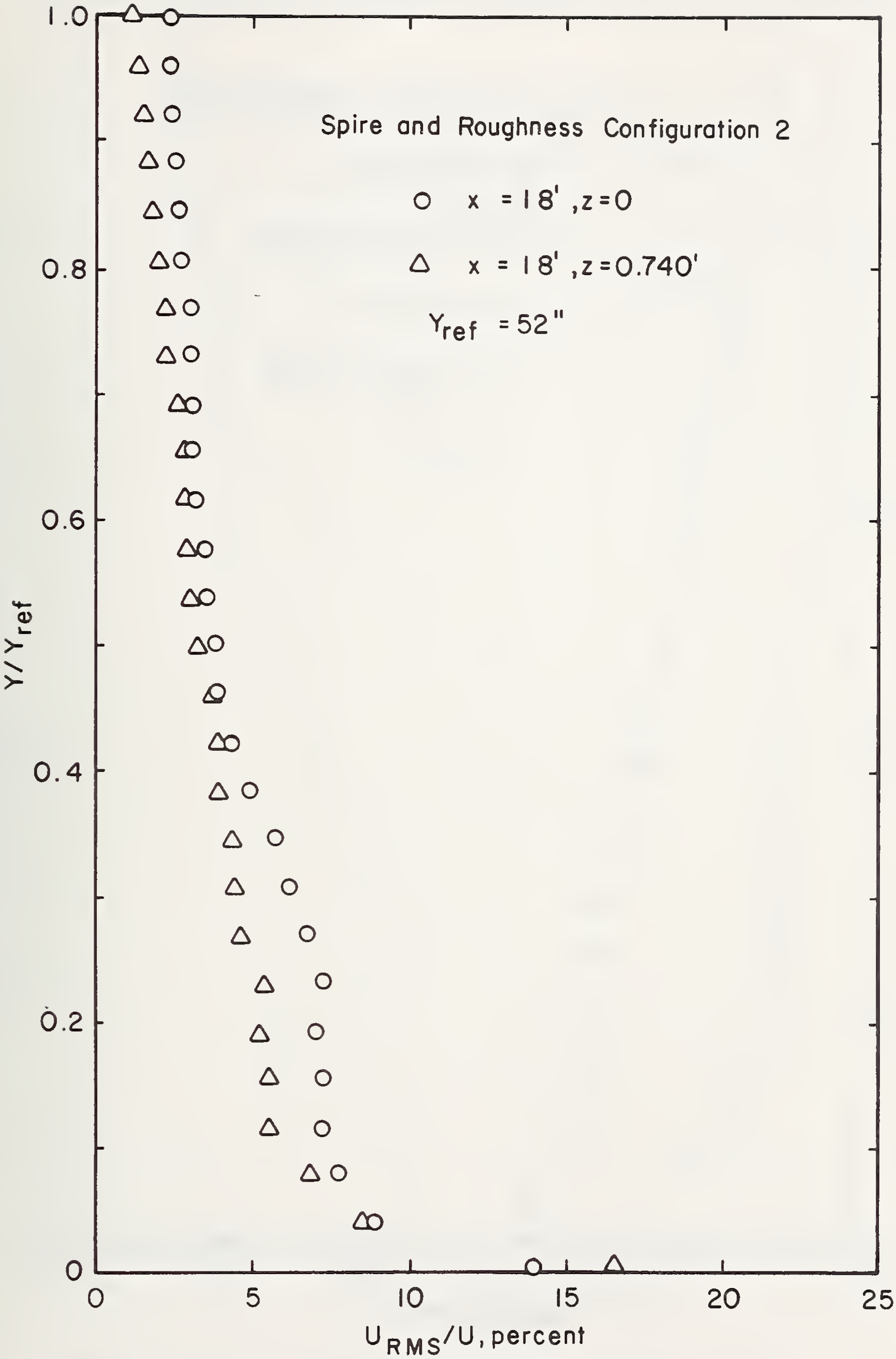


Fig. 12. Turbulence Intensity--Variation with Lateral Position--Configuration 2

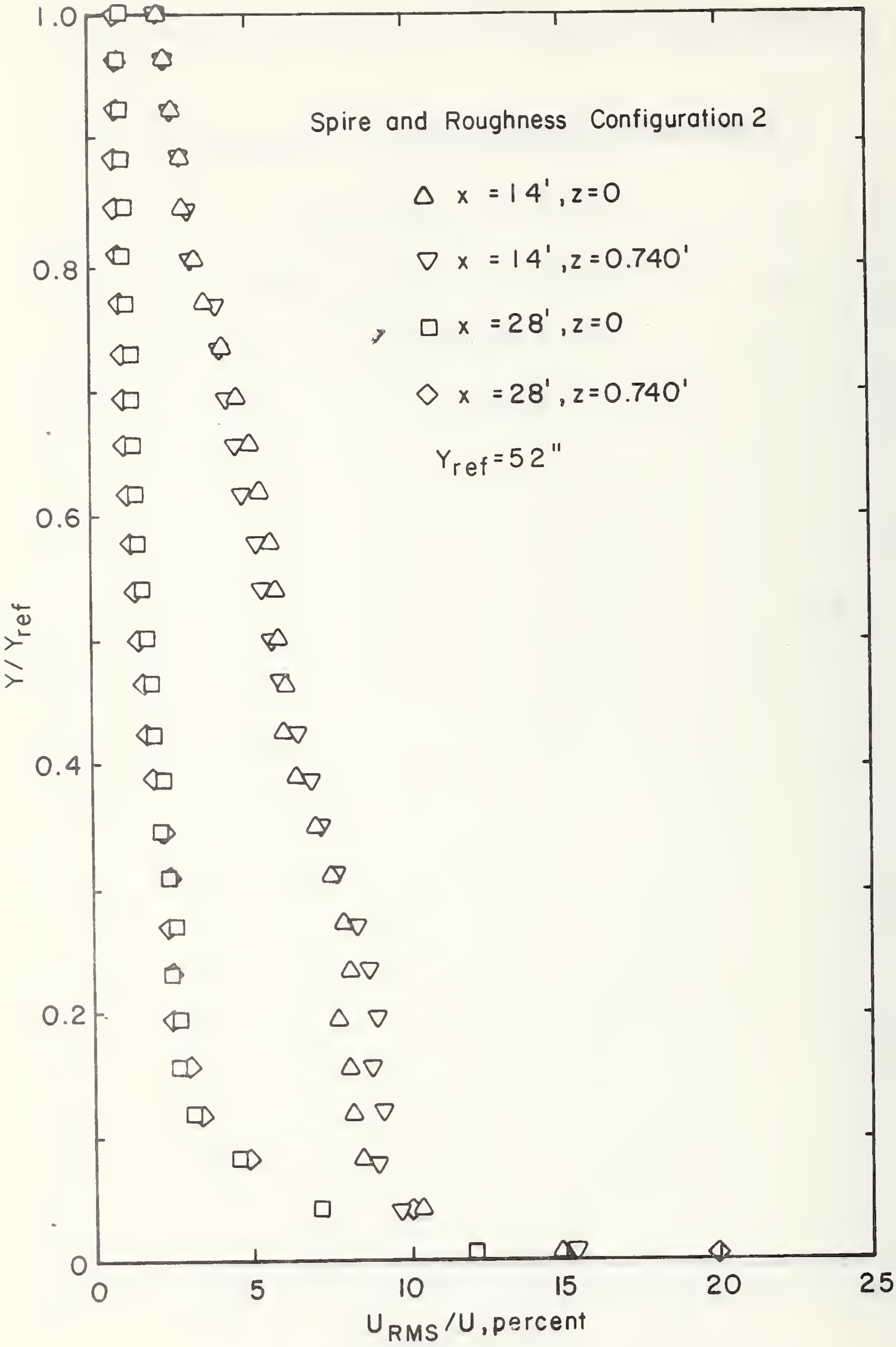


Fig. 12. Turbulence Intensity--Variation with Lateral Position--Configuration 2 (continued)

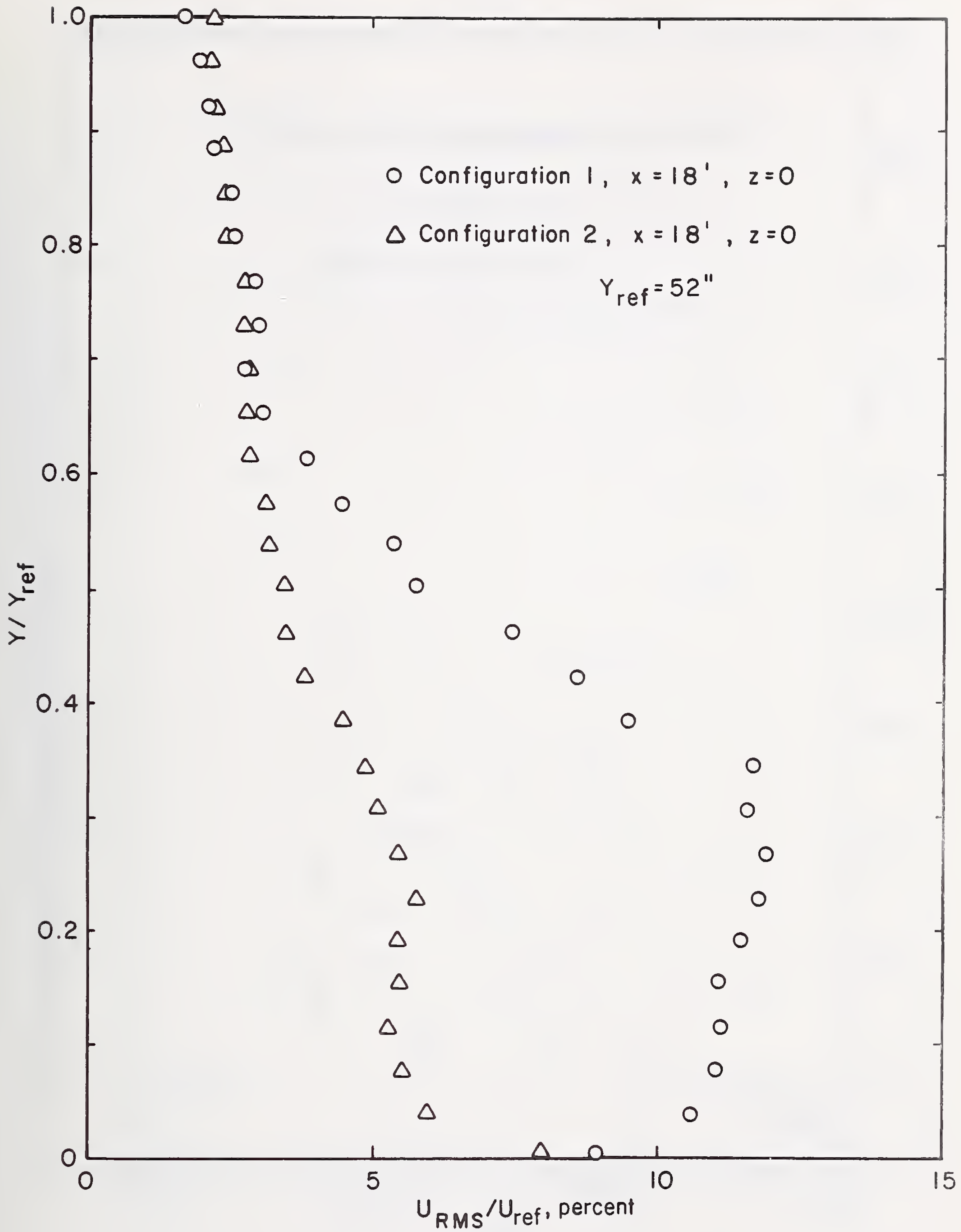


Fig. 13. Turbulence Intensity--Referenced to U_{ref}

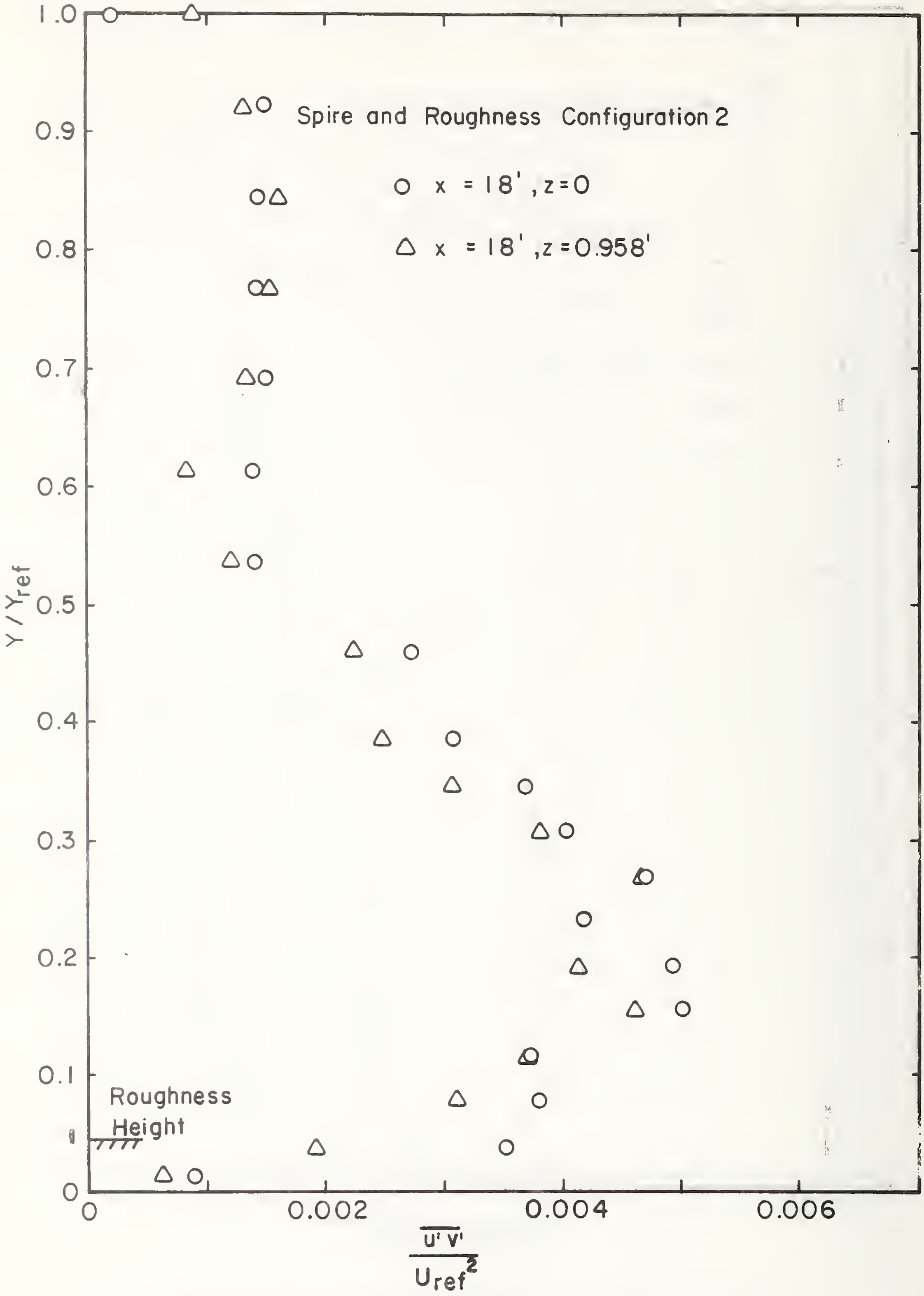


Fig. 14. Shear Stress--Configuration 1

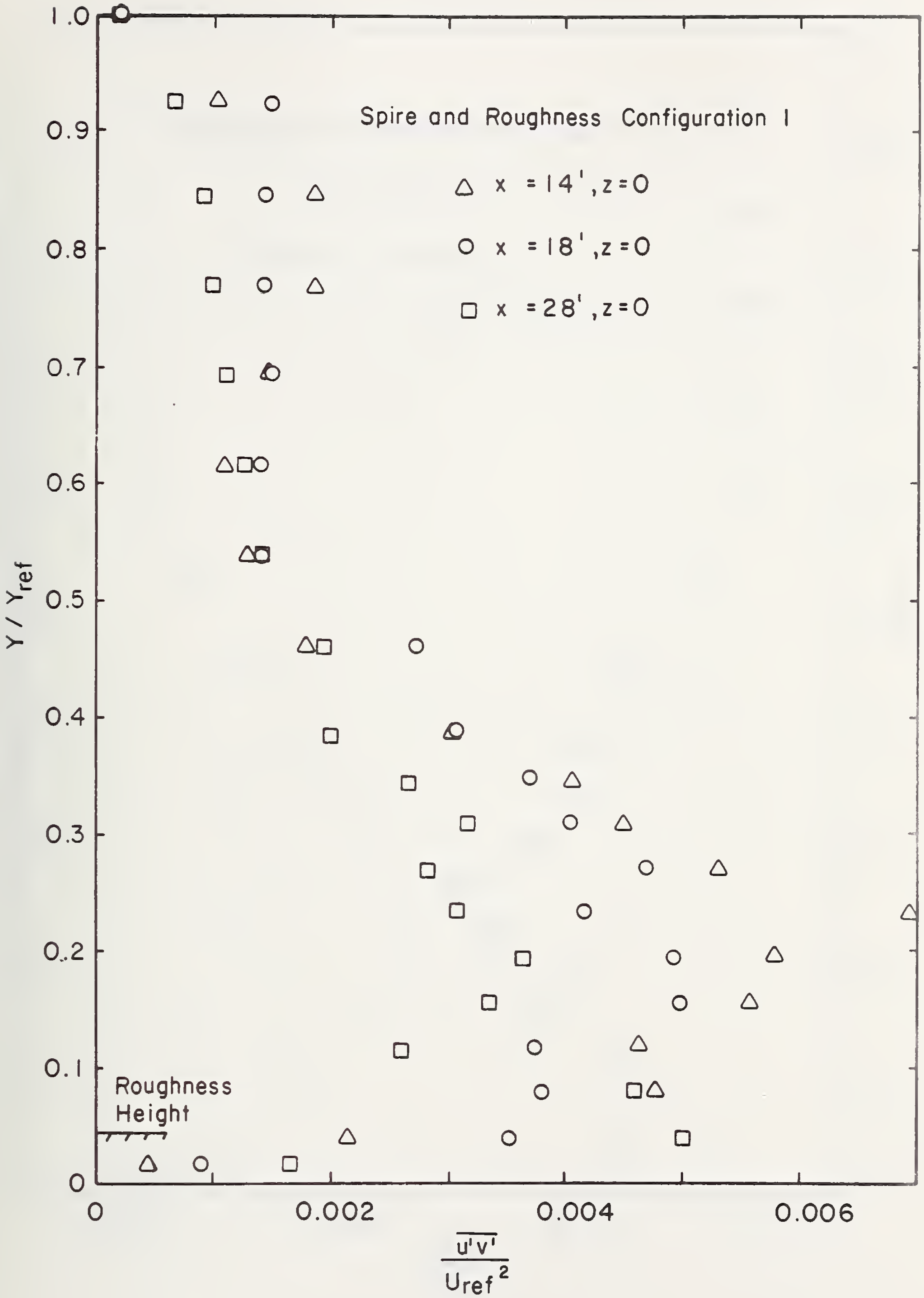


Fig. 14. Shear Stress--Configuration 1 (continued)

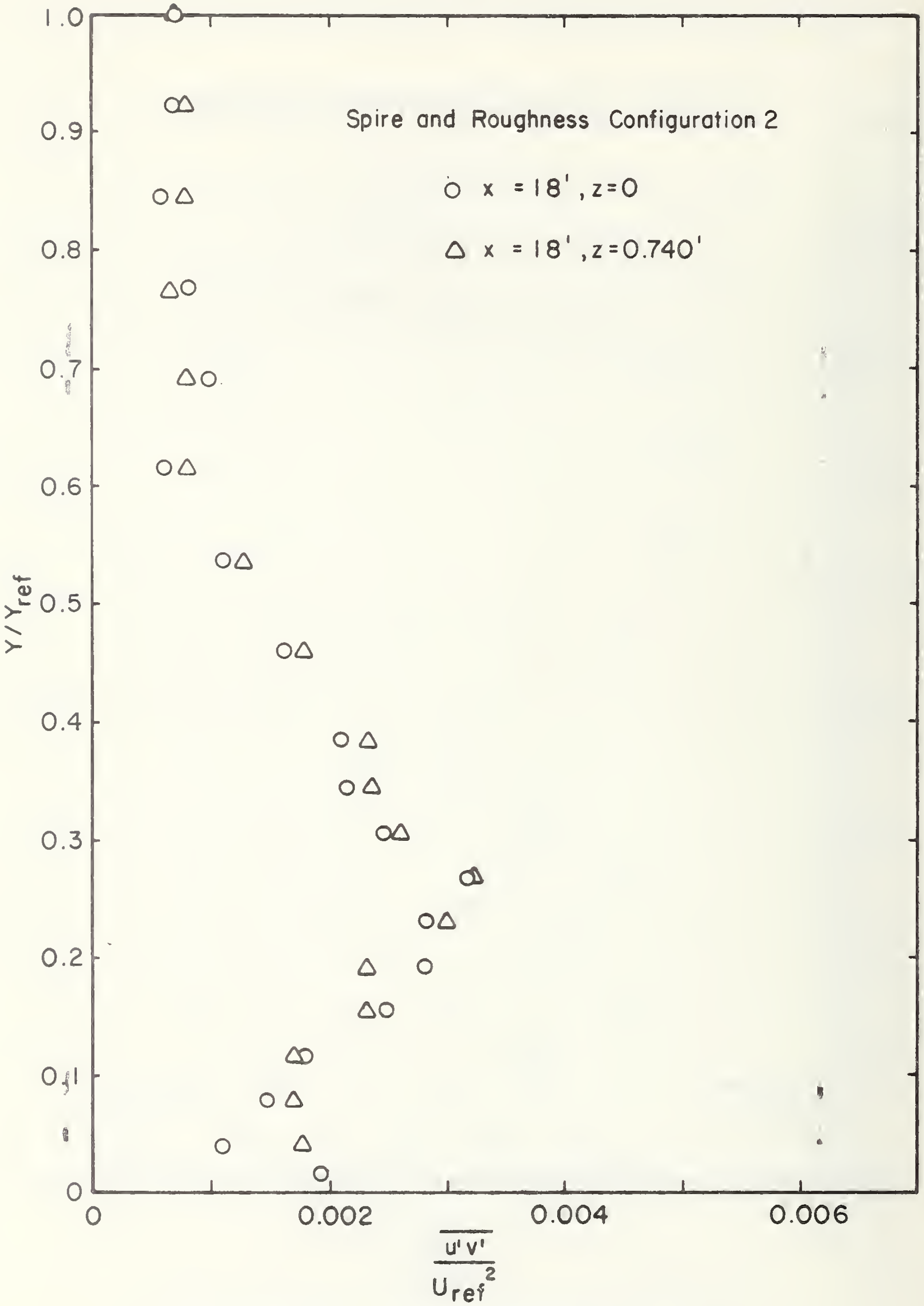


Fig. 15. Shear Stress--Configuration 2

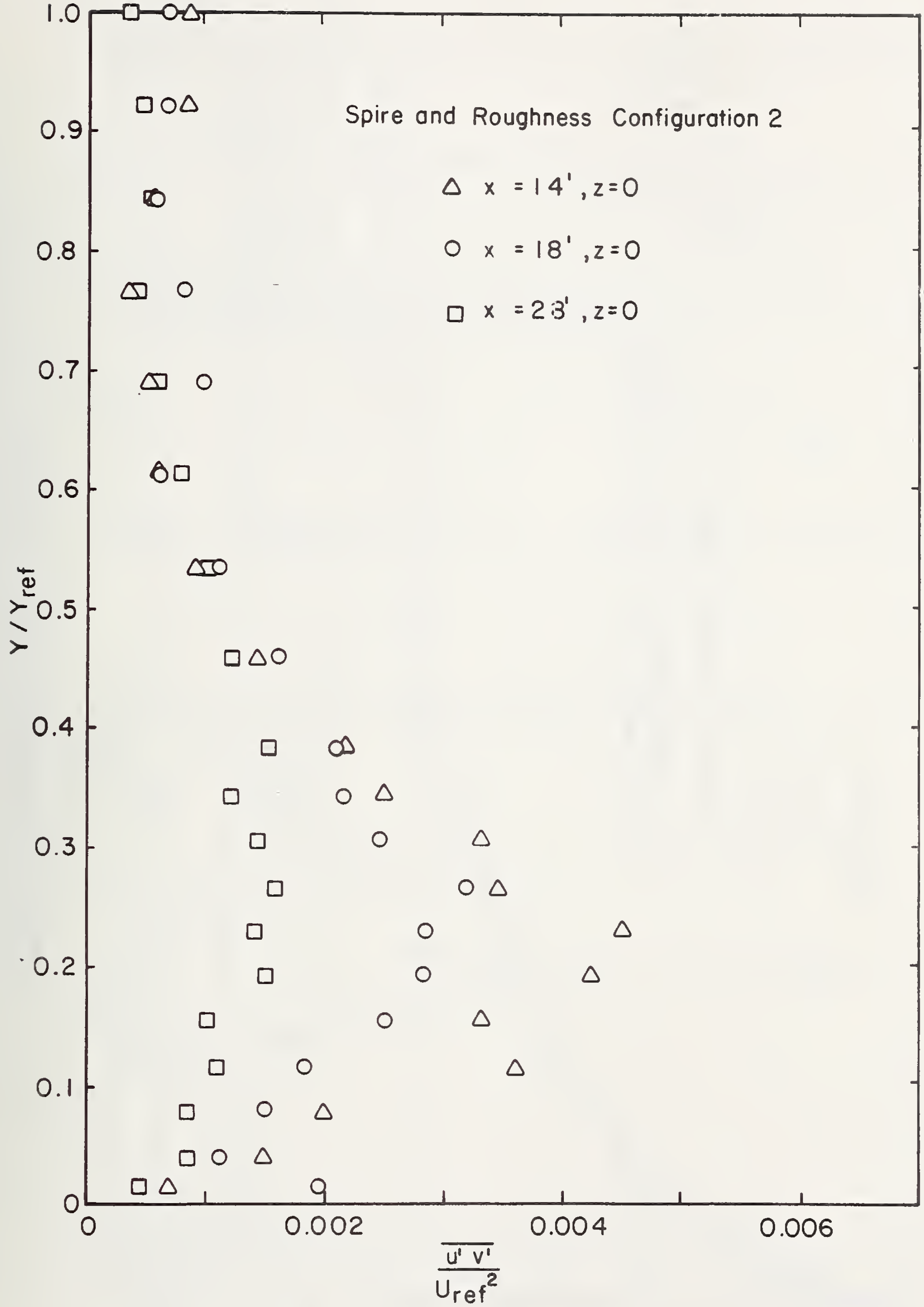


Fig. 15. Shear Stress--Configuration 2 (continued)

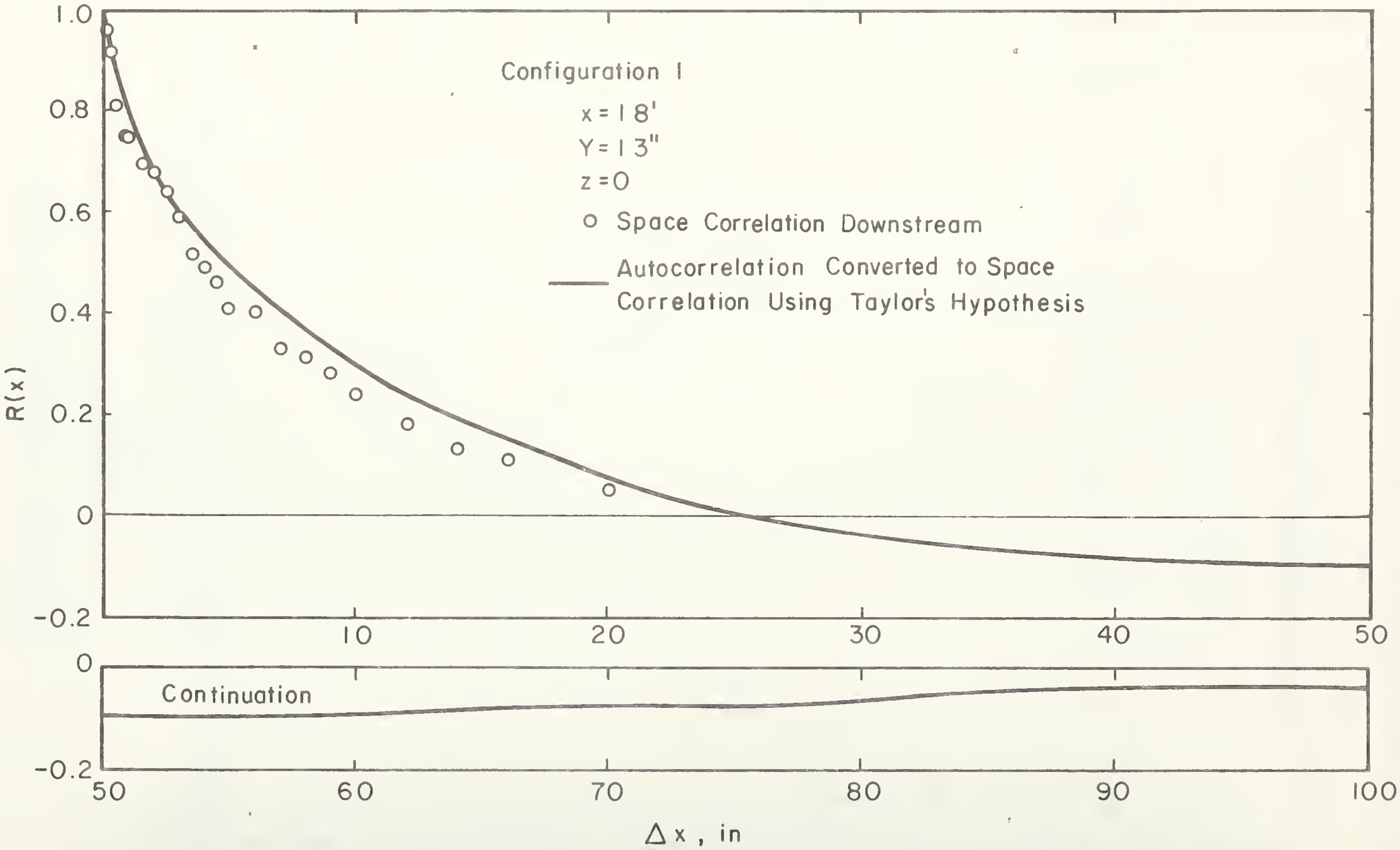


Fig. 16. Longitudinal Space Correlation

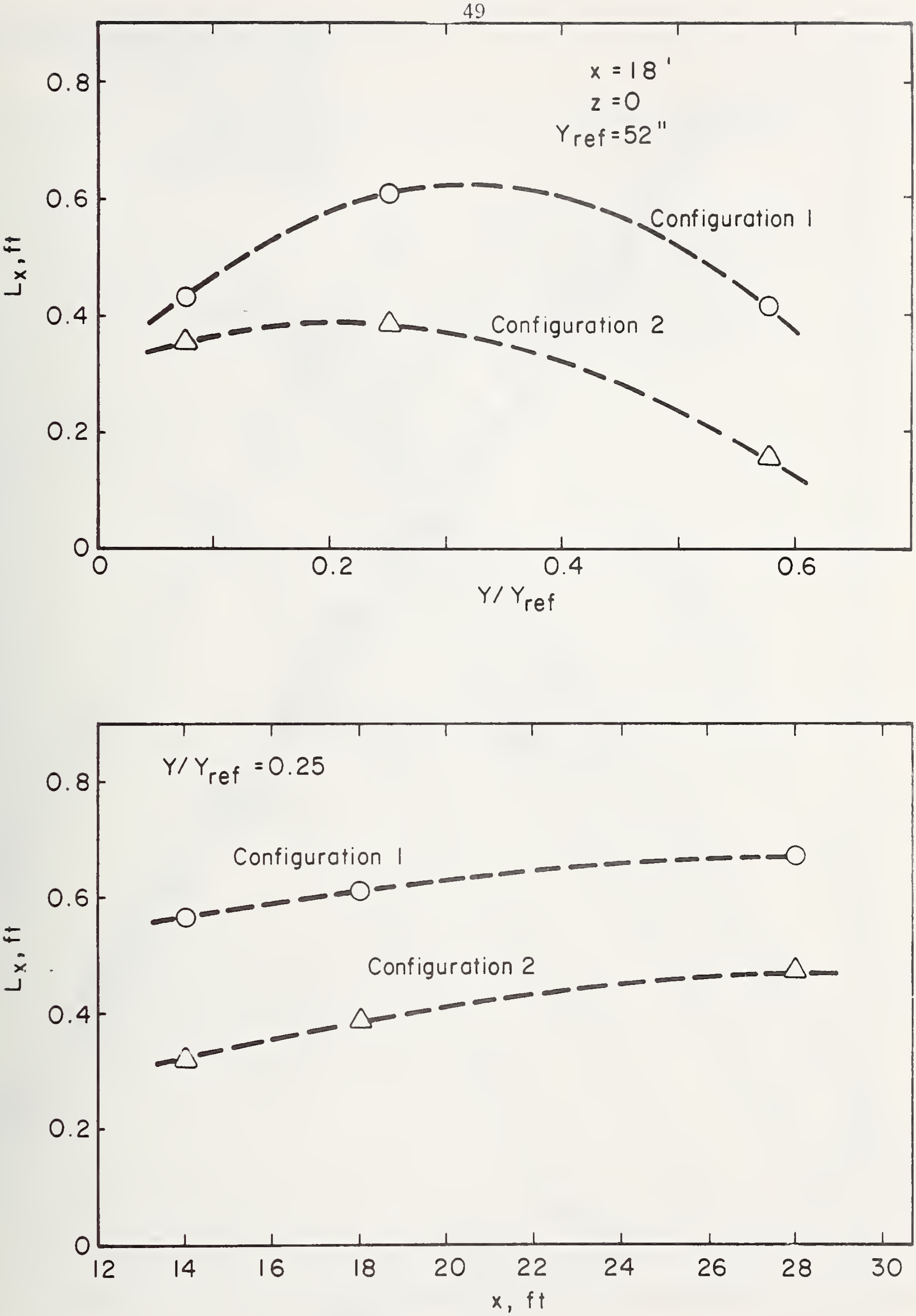


Fig. 17. Integral Scales

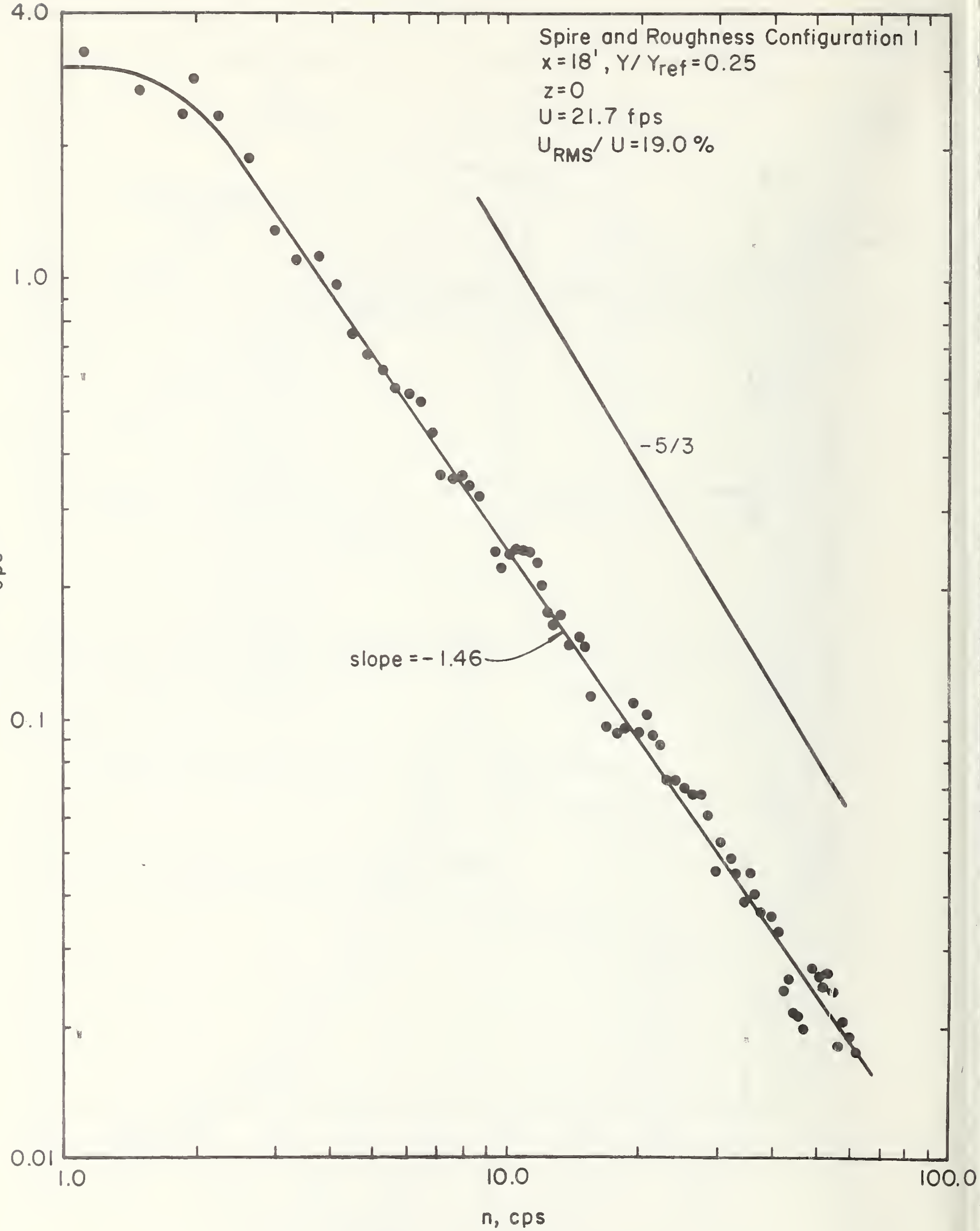


Fig. 18. Velocity Spectra

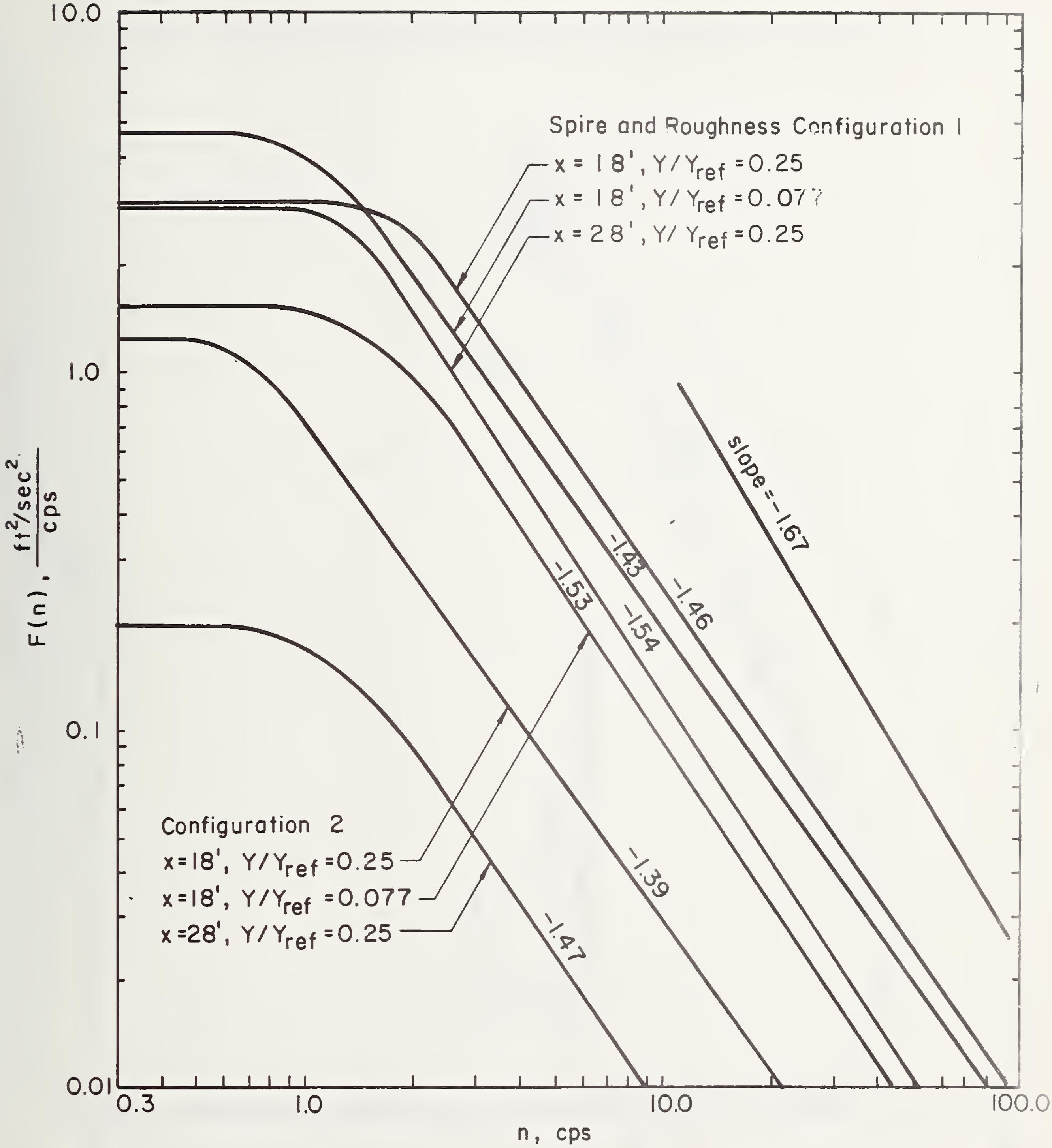


Fig. 18. Velocity Spectra (continued)

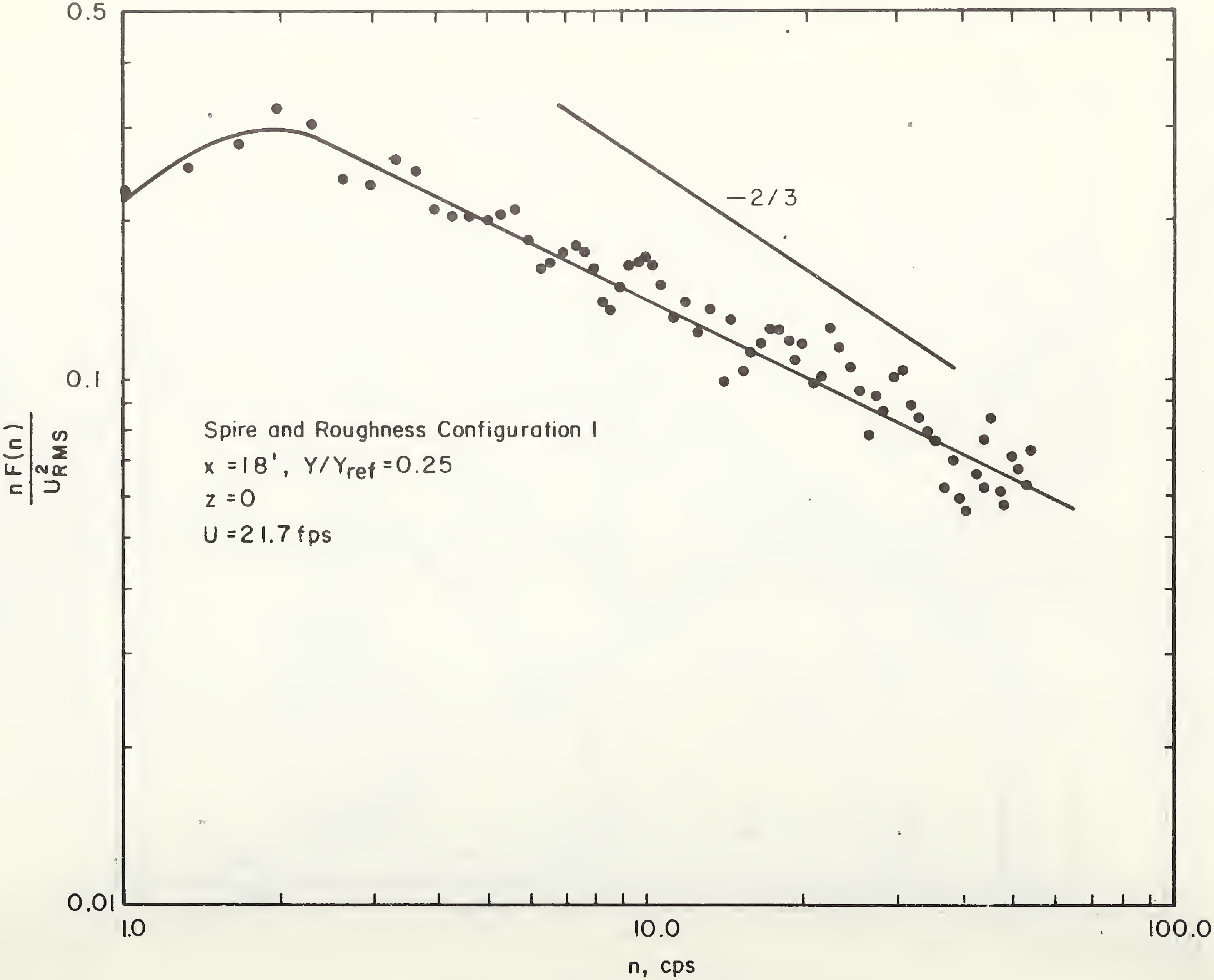


Fig. 19. Normalized Velocity Spectrum

APPENDIX C

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APPENDIX D

HOUSING AND WIND PROBLEMS IN THE NORTHERN CARIBEAN AND INDIAN OCEAN COUNTRIES

LOW-COST HOUSING AND EXTREME WIND-RELATED PROBLEMS IN JAMAICA AND THE NORTHERN CARIBBEAN ISLANDS

REPORT

FOR

NATIONAL BUREAU OF STANDARDS

AND

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

'INVESTIGATION OF WIND RESISTANCE OF LOW-COST HOUSES'

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LOW-COST HOUSING AND EXTREME-WIND-RELATED PROBLEMS IN JAMAICA AND THE NORTHERN CARIBBEAN ISLANDS

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1.0 SCOPE

This report identifies low-cost housing trends and their design problems in Jamaica and the Northern Caribbean and discusses the influence of socio-economic considerations on housing patterns.

It also presents an analysis of housing needs in the next ten years.

It tabulates climatological data on extreme winds and wind damage statistics and also studies the applicability of alternative solutions for mitigating losses from high winds.

Finally, it defines possible low-cost building design problem areas unique to Jamaica.

2.0 LIMITATIONS AND ASSUMPTIONS

2.1 General

This is the second of two reports. It attempts to restrict consideration to those aspects of housing specifically related to wind resistance. More general information is introduced only where it is intended to fill some gap in the Report No. 1 which is attached as Appendix I.

2.0 LIMITATIONS AND ASSUMPTIONS CONTD.

2.1 General contd.

Problems of communication have severely restricted the gathering of data on the other Northern Caribbean Islands. However, the other English speaking Caribbean Islands have similar socio-economic and technical background to Jamaica and can be assumed to have generally similar conditions with respect to low-cost housing except where specifically stated otherwise.

2.2 Building Size Considered

Following decisions reached at the Workshop Conference on "Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds", held in Manila in November, 1973, consideration has also been restricted to 'low-rise' buildings.

3.0 LOW-COST HOUSING TRENDS AND THEIR DESIGN PROBLEMS

3.1 Trends in Low-Cost Housing

There is a continuing trend towards building "low-cost" single storey houses in hollow concrete-block masonry and with corrugated metal roofing on timber rafters. The structural systems are described in detail in Appendix I, page 5.

For two and three storey buildings, masonry construction is equally popular but the roofing systems are quite often of reinforced concrete slab.

Large panel precast concrete systems do not at present fall within any accepted definition of "low-cost housing" but are capable of doing so where increased density and a lower standard of finishes and amenities is accepted. This system is being used in increasing numbers.

3.0 LOW-COST HOUSING TRENDS AND THEIR DESIGN PROBLEMS CONTD.

3.1 Trends in Low-Cost Housing contd.

The following tables show the classification of total dwellings by materials of the outer walls taken from a 1970 survey[27].

There is no breakdown of these figures into low-income housing and others. However, the same survey shows that over three quarters of all dwellings were of three room or less and over half (63%) were two rooms or less.

TABLE 3.1.1 - DWELLINGS CLASSIFIED BY MATERIAL OF OUTER WALLS

(JAMAICA)

Total Dwellings	MATERIAL OF OUTER WALLS						
	Wood	Concrete	Stone	Brick	Nog	Wattle/ Adobe	Other
420,159	155,197	182,349	9,354	3,571	49,417	16,908	3,363

3.0 LOW-COST HOUSING TRENDS AND THEIR DESIGN PROBLEMS CONTD.

3.1 Trends in Low-Cost Housing contd.

TABLE 3.1.2 - PERCENTAGE DISTRIBUTION OF DWELLINGS BY TYPE OF MATERIAL OF OUTER WALL (JAMAICA)

Material of Outer Wall	Total	Urban	Rural
TOTAL	100.0	100.0	100.0
Concrete	43.4	59.3	30.4
Wood	36.9	30.4	42.2
Nog	11.8	7.2	15.5
Stone	2.2	0.7	3.5
Wattle/Adobe	4.0	0.7	6.7
Brick	0.9	1.3	0.5
Other	0.8	0.4	1.1

3.2 Design Problems

Design problems are related mainly to the provision of roof fixings to resist high 'local' wind effects.

These and other problems are also discussed in detail in Appendix I, page 14.

4.0 THE INFLUENCE OF SOCIO-ECONOMIC CONSIDERATIONS ON HOUSING PATTERNS

4.1 The Influence of Tradition and Social Changes

In Jamaica, traditionally, homes for low-income groups in urban areas were mainly high density apartment buildings or "tenements", consisting of terrace-houses or small groups of closely clustered houses. There would generally be a communal yard with shared facilities.

4.0 THE INFLUENCE OF SOCIO-ECONOMIC CONSIDERATIONS ON HOUSING PATTERNS CONTD.

4.1 The Influence of Tradition and Social Changes contd.

On the other hand, the middle income group invariably preferred detached houses, with the greater privacy this offered. The aspirations of all upwardly-mobile members of the low-income group, therefore, tended toward the middle income preferences i.e. detached houses.

With the widespread introduction of mass housing development some ten to fifteen years ago, this preference has forced developers to build detached houses and often to make lots very small in order to achieve a low selling price.

The continuing pattern of low-cost housing, therefore, has been urban housing developments consisting of hundreds of closely spaced single-storey, detached dwelling-units.

It should be noted that in the middle income group, a developing counter-trend is toward a preference for self-contained "apartment type" dwelling units often in blocks of flats.

This is a reaction arising partly from fear of increasing urban crime and thus seeking safety in more compact numbers.

This phenomenon does not affect the lower income group to the same extent, but it is observed that aspiring members of this group tend to follow the lead of the middle income group. It is felt, therefore, that we may be about to experience a change in the preferences of this lower income group which will now show greater acceptance of multi-storey and terraced mass-housing.

4.0 **THE INFLUENCE OF SOCIO-ECONOMIC CONSIDERATIONS ON HOUSING PATTERNS CONTD.**

4.1 The Influence of Tradition and Social Changes contd.

On strictly economic grounds, this should rationalise the use of limited financial resources and might accelerate the present rate of low-cost housing construction.

As far as wind resistance is concerned, the relevant aspect of all thie is that the current pattern of large clusters of closely spaced single storey concrete buildings, with pitched lightweight roofs, will probably soon be joined by an increasing number of low-rise and high-rise rectangular concrete buildings with flat roofs.

4.2 Other Relevant Socio-Economic Considerations

Jamaica's population is approximately two million persons with a rate of natural increase of approximately 27 persons per 1000[5].

Out of a total labour force exceeding 800,000, approximately 20 - 25% are unemployed[5].

The construction and installation industries employ approximately 7% of the employed labour force[5].

At the end of 1972, the personal income per head of population was approximately J$500 (US$550)[5]. Examples of daily wage rates in the construction industry are:-

Unskilled labourers	- J$5.00 (US$5.50)[20]
Skilled workers e.g. Carpenters, Operators	- J$7.00 - J$9.00 (US$7.70 - US$9.90)

The following are statistics obtained from a survey in 1970[27] and refers to the total housing stock:

4.0 THE INFLUENCE OF SOCIO-ECONOMIC CONSIDERATIONS ON HOUSING PATTERNS CONTD.

4.2 Other Relevant Socio-Economic Considerations contd.

TABLE 4.2.1 - DWELLINGS CLASSIFIED BY TYPE (JAMAICA)

Total Dwellings	TYPE OF DWELLING								
	Separate House	Flat/ Apartment	Barracks	Out-Room	Part of Commercial Building	Other Private	Group Dwelling	No Fixed Abode	Not Stated
420,159	327,656	67,083	3,223	4,069	11,765	3,886	247	65	2,165

TABLE 4.2.2 - PERCENTAGE DISTRIBUTION OF DWELLINGS NO. OF ROOMS (JAMAICA)

No. of Rooms	Total	Urban	Rural
TOTAL	100.0	100.0	100.0
1	32.7	42.3	24.9
2	26.3	19.6	31.7
3	16.1	11.7	19.7
4	8.5	7.5	9.3
5	5.3	5.9	4.9
6	2.8	3.3	2.4
7	2.6	3.4	1.9
8 or more	5.8	6.3	5.3

4.0 THE INFLUENCE OF SOCIO-ECONOMIC CONSIDERATIONS ON HOUSING PATTERNS CONTD.

4.2 Other Relevant Socio-Economic Considerations contd.

TABLE 4.2.3 - PERCENTAGE DISTRIBUTION OF DWELLINGS BY TYPE OF TENURE

Type of Tenure	Total	Urban	Rural
TOTAL	100.0	100.0	100.0
Owned	52.4	29.7	70.8
Leased	2.5	3.9	1.4
Rented	36.5	59.9	17.6
Rent-Free	7.9	5.8	9.6
Squatted	0.4	0.5	0.3
Other	0.3	0.3	0.3

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS

5.1 Projected Housing Needs

The housing situation has always been characterised by the inadequacy of new housing to meet the growing demand. It is estimated that between 1960 and 1970 some 32,200 new units were added for an increase in households of some 60,000[5].

A projection of total housing needs for the next ten years is as follows:-

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS CONTD.

5.1 Projected Housing Needs contd.

TABLE 5.1.1 - PROJECTED HOUSING NEEDS 1975 - 1985[13]

TYPE OF NEED	1975-1980	1980-1985
New Households	9,700	10,800
Obsolescence (replacement)	4,700	5,200
Total average annual need	14,400	16,000
Total housing at end of period	519,000	571,000

The above total projected housing needs are based on an estimated population increase of 195,300 persons and 216,500 persons for the periods 1975-1980 and 1980-1985 respectively and an average household size of 4.0 persons per household. It is also estimated that total housing stock at the end of 1975 will be about 470,000.

No precise figures exist on the current existing housing stock but in 1970, this was estimated to be between 420,000[26] and 434,000[13].

The problem of housing shortage is greatest in the urban areas, mainly due to population increase and internal migration. It has been observed[26] that between 1960 and 1970, the rural population has remained approximately the same in numbers, while population increases have been concentrated in urban areas. Overall, the population increased by 16% during this period, while the number of dwellings increased by only 5%.

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS CONTD.

5.2 Housing Programs

5.2.0 Housing is provided by both the public and private sectors but by and large, the private sector provides housing for middle and upper income groups, while the Government restricts its activities to constructing houses for lower income groups.

Even so, only a small percentage of the Government's efforts were directed at the very bottom of the lower income scale and families in this category were often forced into squatting, shanty towns or overcrowded households.

5.2.1 Sites and Services Project

In 1972-3 the Ministry of Housing developed a programme to cater to the needs of families with an income of J$1,200 or less per annum (between 60-70 per cent of the population). Since 1973 this income ceiling has been increased to J$1,500. This programme, called the Sites and Services Project, provides basic infrastructure development and community facilities, and a minimum 'core' dwelling unit.

In addition, it provides for the development of community organizations, employment and skill training programmes and the maintenance of stable property values[5].

This project aims at providing 6,000 serviced lots during the next three years. Two-thirds of these will be located in the Kingston Metropolitan Area and the remainder shared between the smaller urban centres.

Lots are available in three options[28]:-

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS CONTD.

5.2 Housing Programs contd.

5.2.1 Sites and Services Project contd.

Option 1

To be provided with lot-servicee and connections for electricity, water-supply and eewerage and materiale for core shelter and encloeure. The core comprises toilet, shower and kitchen epace.

Option 2

To be provided with lot-services and connectione, a built core and materiale for shelter and enclosure of the remainder of the houee. The sheltered area will be approximately 180 equare feet.

Option 3

To be provided with lot-services and connections, a built core and shelter and materials for conetruction of an encloeure for the rest of the houee.

Thie idea is to harnese the eelf-help capabilities and inclinations of the prospective home-ownere who are also largely under-employed.

Ownership of serviced lote will be on a leasehold baeis. However, an inheritance clauee will form part of the leaeehold agreement.

Selling prices of the various options will vary between J$1,900 and $2,600. Loans for materials will be available through credit unione.

This project is administered by a epecial division within the Miniatry.

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS CONTD.

5.2 Housing Programs contd.

5.2.2 National Housing Corporation, Jamaica

In 1973, the National Housing Corporation, a statutory body, was formed with the purpose of executing "profit-earning" middle-income housing projects and to undertake renewal and land development projects. The Corporation's eventual profits, would revert to the Ministry of Housing and could be used for low-income housing. The first project by this Corporation, consisting of 1,050 two and three bedroom units costing between $14,000 and $18,000 will commence in June, 1974.

5.2.3 Other Government Housing Schemes

The emphasis in the Government's low-cost housing programs is being shifted to the Sites and Services project mentioned above. However, the Five-Year Plan for 1970 proposed certain Government Housing Schemes concentrated in the low-income areas for persons not able to afford private housing.

For the 1970/71 - 1974/75 period, these are summarised as follows (Figures in parentheses show number of units completed between 1970 and 1973)[29] :-

(a) Government-built Housing - Provision of low-cost housing, either for sale on 5% deposit and 25-year mortgages or to be rented at subsidised rates, to be built, by private contractors under the supervision of the Ministry of Public Utilities and Housing, on government owned land in both urban and rural areas. Selling prices have been between $2,000 and $3,000 excluding subsidies. Total units: 3,125 (1902).

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS CONTD.

5.2 Housing Programs contd.

5.2.3 Other Government Housing Schemes contd.

(b) Owner-Occupied Schemes - Loan assistance to persons in rural areas who own or have long-term lease on land and who can afford to pay for their homes; a capital subsidy of up to one-third is offered and no deposit required; administered by the Ministry of Public Utilities and Housing. Costs have been about $2,600 excluding subsidies. Total units: 3,600 (829).

(c) Urban Renewal - Urban renewal and rehousing to alleviate the problem of overcrowding and sub-standard houeing in Kingston; administered by the Ministry of Public Utilities and Housing. Total units: 4,876 (619).

(d) Rural Housing Project - Provieion of adequate housing to farmers through construction of new units and additions and repairs to exieting unite with subsidies of 50% and $33^1/3$% and the balance of cost to be repaid by the farmer; to be adminietered by the Ministry of Rural Land Development. Costs have been about $360. Total units: 4,880 (960).

(e) Indigent Housing - Houeing units erected free of charge on land owned by the allotee and grante made to improve exieting dwellinge; adminietered by the Ministry of Local Government. Prices have been about $500 excluding subsidies. Total units: 2,250 (1272).

(f) Aided Self-Help Scheme - Response to thie program has been unenthusiaetic and it has been decided to phase it out.

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS CONTD.

5.2 Housing Programs contd.

5.2.3 Other Government Housing Schemes contd.

(f) Aided Self-Helf Scheme contd.

Assistance was furnished to organizations whose members had been saving for housing with Government acquiring land, providing infrastructure, housing materials and technical assistance, and the labour to be contributed by the prospective residents. Few or no units are expected to be developed during the plan period.

(g) Assistance to Housing Co-operatives - Official policy is to encourage growth of co-operative housing ventures and the Mutual Housing Services Company, a non-governmental, non-profit organization, has the power to acquire, hold and dispose of land, enter into contracts, receive and disburse funds, and organise and manage co-operatives housing societies. Its activities are expected to attract to the field of low-income housing some of the investment that normally flows to higher income developments. Prices to date range between $4,000 and $7,000. Total units: unknown.

The total number of the government-built or aided units described above under Section 5.2.3 is about 18,700 for the 1970/71 - 1974/75 period which, against a total of 58,000 units required for the country, leaves a balance of 39,700 units to be constructed by the private sector if a new house is to be provided for every new household and obsolescent units replaced. The average annual number of government units projected for the five years is about 3,750, a substantial increase over the 1969/70 figure of 858 units and 1968/69 figure of 1,354 units acutally built.

5.0 HOUSING NEEDS AND PROGRAMS FOR THE NEXT TEN YEARS CONTD.

5.2 Housing Programs contd.

5.2.3 Other Government Housing Schemes contd.

(Note: The actual performance for 1970-73 has been 1,937 units per annum)[29].

Government programs which provide assistance in improving existing dwellings as well as private rehabilitation may reduce the deficiency in the replacement of obsolescent housing.

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS

6.1 Topography of Jamaica and its Effects on the Wind Climate

6.1.1 Topography[23]

Of a total land area of about 4,400 square miles, almost half of Jamaica is over 1,000 feet above sea level and about 40 square miles above 5,000 feet.

The three main types of land forms of the island are:-

(1) The interior mountain ranges
(2) The dissected limestone plateaux and hills
(3) The costal plains and interior valleys.

The interior mountain ranges form the spine of Jamaica and are highest and most rugged in the east where the Blue Mountains attain over 7,000 feet (See Figure 6.1.1).

6.1.2 Climate

The Northern Caribbean lies between the sub-tropical high pressure and equatorial low-pressure belts of the Atlantic where the north-east winds blow regularly throughout the year.

TOPOGRAPHY

of

JAMAICA[23]

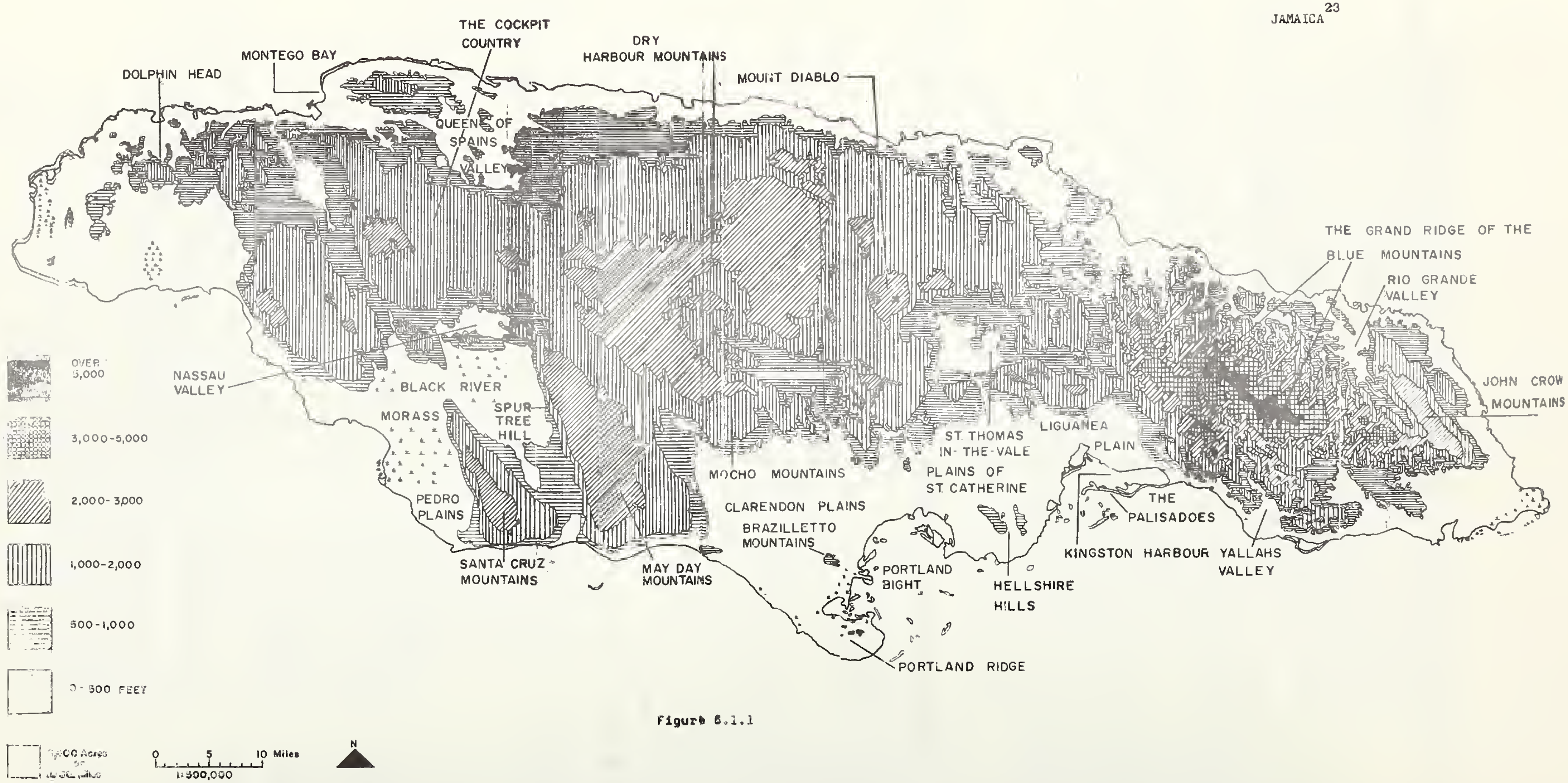

Figure 6.1.1

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

6.1.2 Climate contd.

In Jamaica, these prevailing winds are modified in three major respects: because of the high Blue Mountains in the east of the island, the trade-winds swing around St. Thomas to strike the Kingston Area from an east and east-south-east direction; alternating sea breezes and land breezes occur daily and occasional cold fronts, reach Jamaica from the American Mainland. The lower elevations are generally warm with a range of 70^{o} - 90^{o} approximately. Temperatures are 10^{o} - 20^{o} cooler in the highlands.

Hurricanes are a perennial threat to Jamaica. An analysis of Caribbean hurricanes and tropical storms between 1886 and 1967 shows that 19 had tracks which directly hit Jamaica and 98 (of which 48 were of hurricane force) had centres within 150 miles of the island. About one-third of these storms caused flooding and damage[23]. Figure 6.1.2 shows the tracks of major hurricanes affecting Jamaica from 1880 - 1970 and Table 6.1.3 shows the actual dates of occurrence of storms from 1886 - 1967.

6.2 Wind Speed Records

Prior to 1950, wind speed recordings were by "Robinson" anemometer (Wind-run Integrator). The capacity of these were limited (approximately 105 knots) and published Meteorological Office records for this period do not provide actual wind speeds but classify storms as either hurricanes (i.e. winds exceeding 73 miles per hour[17]) or tropical storms (See Table 6.1.3).

6.0 <u>CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS</u> CONTD.

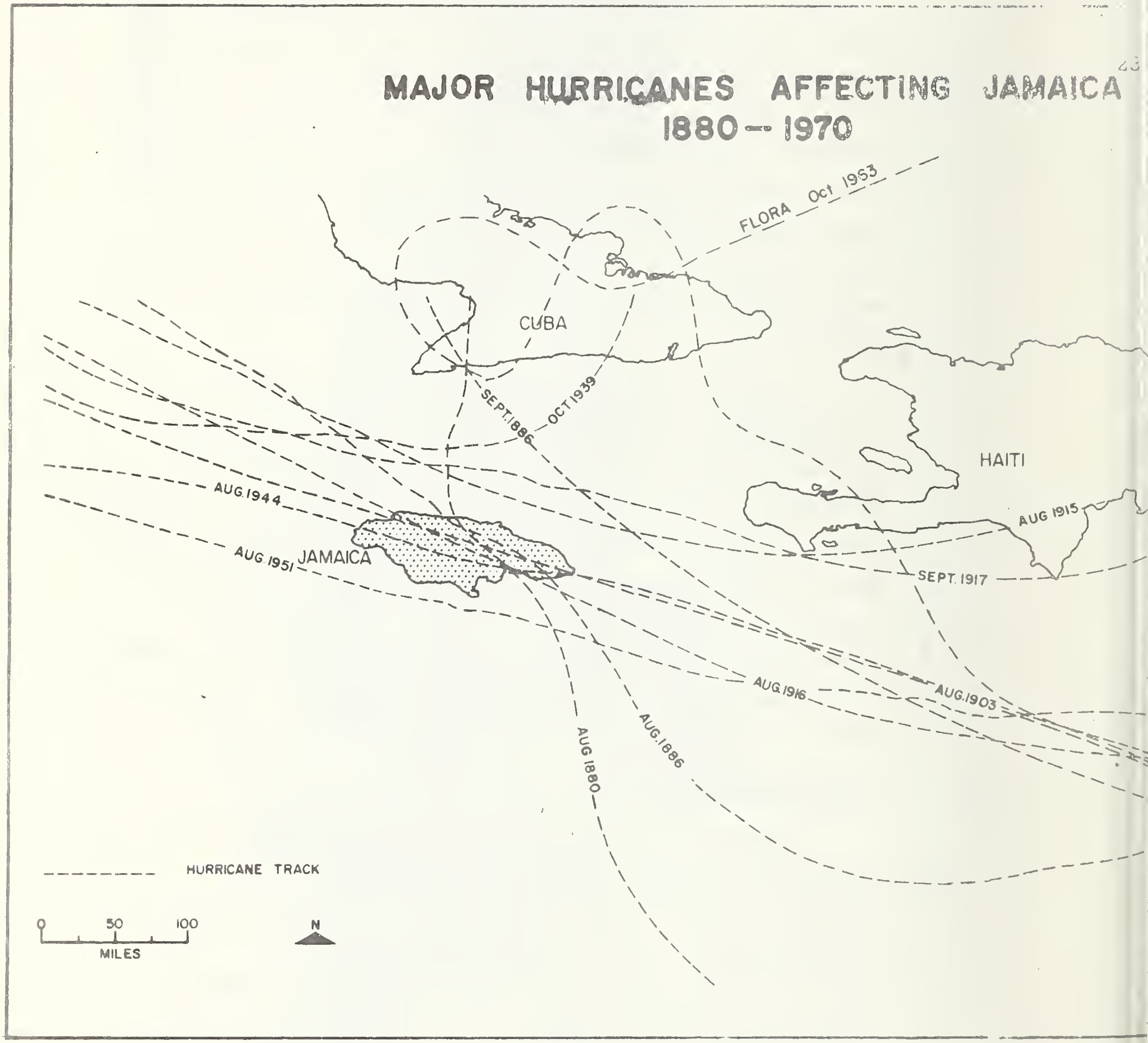

Figure 6.1.2

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

TABLE 6.1.3 - HURRICANES AND TROPICAL STORMS WITH CENTRE PASSING WITHIN 150 MILES OF JAMAICA[24]

* H = Hurricane

* T = Tropical Storm

Date	* H or T	Minimum Distance of Centre from Jamaica	Direct Hit Track across Island	Effects on Jamaica
June 1886	H	90 miles S.W.		
August 1886	H	40 miles N.E.		
August 1886	H	15 miles W.		Noteworthy damage - Flooding
Sept. 1886	H		E - N.E.	Damage
May 1887	T	15 miles W.		
July 1887	H	150 miles S.S.W.		
August 1887	T	60 miles N.E.		
Sept. 1887	H	100 miles S.S.W.		
Oct. 1887	T	120 miles W.N.W.		
Oct. 1887	H	120 miles N.N.E		
Sept. 1889	H	70 miles S.W.		Flooding
Oct. 1891	T	90 miles N.N.E. (or most nothe-ern part)		Flooding
Nov. 1893	T	80 miles W.		
Sept. 1894	H	120 miles N.N.E.		
August 1895	H	30 miles S. by W.		

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

TABLE 6.1.3 contd.

Date	* H or T	Minimum Distance of Centre from Jamaica	Direct Hit Track across Island	Effects on Jamaica
Oct. 1895	H		W - SW	Damage
Sept. 1896	H		S - SSW	Damage
July 1896	H	150 miles NW of Wrn. tip		
Oct. 1898	T		S - SSW	
Oct.,Nov.1898	T	20 miles S		
Sept. 1900	T	90 miles N by E		
1901	T	125 miles SW		
1901	T	80 miles N by W		
August 1903	H		E - NW	Major Hurricane
June 1904	T		Western tip	Severe Flooding in NW
Oct. 1904	T	50 miles W		
Oct. 1905	H	30 miles E		Damage
Sept. 1906	T	140 miles SW		
Oct. 1906	H	100 miles S by W		
Nov. 1906	T	60 miles W by S		
June 1907	T	100 miles W by S		
Sept. 1908	T	150 miles NE of East tip		
July 1909	T	20 miles SW		
August 1909	T	60 miles S by W		
August 1909	H	40 miles NE		
Sept. 1909	H	110 miles SW		

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

TABLE 6.1.3 contd.

Date	* H or T	Minimum Distance of Centre from Jamaica	Direct Hit Track across Island	Effects on Jamaica
Oct. 1909	H	120 miles SW		
Nov. 1909	T	125 miles SE		Severe Flooding
August 1910	T		E-Central-W	
Sept. 1910	H	10 miles N		Damage
Oct. 1911	T	35 miles N		
Oct. 1912	T	80 miles SW		
Oct. 1912	H		W - NW	Major Hurricane. Extensive flooding
August 1915	H	15 miles N		Noteworthy damage. Flooding
Sept. 1915	H	80 miles W by S		
Sept. 1915	H	90 miles S by W		Severe hurricane. Flooding
August 1916	H		SE-Central-NW	Major hurricane
August 1916	H	15 miles S by W		Damage. Flooding
Oct. 1916	H	60 miles S		Damage. Flooding
Sept. 1917	H	35 miles N of NW coast		Damage
August 1918	T	55 miles SW		
August 1918	H	120 miles S by W		
Oct. 1923	T	140 miles W		
Nov. 1924	T		S by N-N by E	
Oct. 1926	T	140 miles SW		
Oct. 1927	T	80 miles WNW		
Sept. 1928	T		Southern-most tip	

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

TABLE 6.1.3 contd.

Date	* H or T	Minimum Distance of Centre from Jamaica	Direct Hit Track across Island	Effects on Jamaica
Sept. 1930	T	140 miles N by E		
August 1931	T	140 miles S by W		
Sept. 1931	T	60 miles SSW		
Sept. 1931	T		E-Central-W	
Sept. 1932	T		E - SE	
Nov. 1932	H	125 miles WNW		Damage (?)
July 1933	H	55 miles SW		Flooding
July 1933	T		W Coast (Grazing)	Flooding
August 1933	T	20 miles SW		Severe Flooding
Sept. 1933	H	80 miles SW		
Oct. 1933	H	120 miles W		Flooding
Oct. 1933	T		SW by S-NW by N	Flooding
Oct. 1934	T		SE-Central-NW by N	
Sept. 1935	H	35 miles W		Damage
Oct. 1935	H	40 miles E)		Damage. Flooding
Oct. 1935	T	45 miles NW)		
August 1938	H	40 miles SW		Damage
August 1938	H	105 miles SSW		
Nov. 1939	T	40 miles N		
August 1942	H	120 miles SW		
Sept. 1942	T	20 miles S		
Oct. 1942	T	60 miles NE		
August 1944			E-Central-W	Extensive damage mostly on north

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

TABLE 6.1.3 contd.

Date	* H or T	Minimum Distance of Centre from Jamaica	Direct Hit Track across Island	Effects on Jamaica
August 1944	T	95 miles S		
Oct. 1944	T	110 miles W by N		
Sept. 1947	T	40 miles NW		
May 1948	T	150 miles E by S		Heavy Rain
Sept. 1948	T	30 miles W		
Oct. 1949	T		SW top-NW	
Oct. 1950	H	49 miles WNW		Damage
August 1951	H	5 miles SSW		"Charlie" very extensive damage in south
Sept. 1953	T	50 miles S		
Oct. 1953	T	140 miles NW		
Oct. 1954	H	100 miles E by S		
August 1955	T	100 miles W by S		
Sept. 1955	H	90 miles NW		
Sept. 1955	H	150 miles SW		
Sept. 1958	H	100 miles NE		
Sept. 1958	T	80 miles NE		
Oct. 1963	H	115 miles NE and 100 miles NNW		"Flora" severe flooding in east
August 1964	H	70 miles NE		"Cleo" No damage
Sept. 1967	H	75 miles ESE		"Beulah" No damage

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

6.2 Wind Speed Records contd.

The Caribbean Meteorological Institute are due to issue soon, a publication, "The Climate of Jamaica" by the Jamaica Meteorological Institute. This will give 30-year means for this period, based on the "Robinson" instrument.

From 1950 to 1962 recordings were made by "Dines" pressure-tube anemographs. Since 1962, the recording instrument used has been a 3-cup-anemometer with an in-line transmitter[25]. Records are taken for meteorological purposes and observations conform with guidelines set by the World Meteorological Organization.

There are at present, eight wind-speed recording stations in operation in Jamaica, maintained by the Jamaica Meteorological Office. Of these, only two, Palisadoes (20 years) and Montego Bay (12 years) are of relatively long-period. The others at Bodlee, Crawford, Mason River, Smithfield, Luana Point and Morant Point, have been in existence for 2 years or less[25]. In San Juan, Puerto Rico, such recordings extend back to 1940[21].

Figure 6.2.1 shows the location of the existing recording stations in Jamaica.

H. C. S. Thom has established that, using the highest average monthly mean wind speed V_m, and the mean number of tropical storms per year, f, it is possible to make reasonable estimates of extreme wind distribution[21].

The following Table 6.2.2 shows data required, obtained from two stations in the Northern Caribbean for the calculation of extreme wind distribution.

WIND RECORDING STATIONS IN JAMAICA

Figure 5.2.1

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

6.2 Wind Speed Records contd.

This data was compiled and analysed by the Caribbean Meteorological Institute, St. James, Barbados, W. I.

TABLE 6.2.2 - DATA REQUIRED FOR ESTIMATION OF EXTREME WIND DISTRIBUTION

STATION	V_m	PERIOD	β	f	P_t
	mile/hour				
Palisadoes, Jamaica	13.4	1950-62	51.7	1.1	0.22
San Juan, Puerto Rico	12.9	1940-55	50.5	1.2	0.27

β is a scale parameter

P_t is the probability of an annual extreme wind being produced by a tropical storm.

Thom's work refers to 'fastest mile' wind speeds as used in the U. S. A.

The following are Fastest Mile speeds for various return periods for two stations in the Northern Caribbean derived by H. C. Shellard of the Caribbean Meteorological Institute[21].

TABLE 6.1.3 - FASTEST MILE SPEEDS (MPH) FOR RETURN PERIODS OF 10, 20, 25, 50, 100

STATION	10	20	25	50	100	200 yrs.
Palisadoes, Jamaica	71	79	83	93	105	117
San Juan, Puerto Rico	72	80	83	94	105	118

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

6.2 Wind Speed Records contd.

Wind speed recordings in Jamaica and the Commonwealth Caribbean are not generally based on the fastest mile of wind but rather on the British practice of extracting the highest hourly mean speed and the highest gust speed for each day[21].

Three-second gust speeds are used in the Commonwealth Caribbean and the following relationship has been established[21] for converting fastest mile speed, v, to gust speed, g.

$$g = 1.09v + 8 \text{ m.p.h.}$$

Table 6.2.3 shows maximum gust speeds corresponding with the fastest mile speeds shown in Table 6.1.3.

TABLE 6.2.3 - MAXIMUM GUST SPEEDS (MPH) FOR RETURN PERIODS OF 10, 20, 50 AND 100 YEARS[21]

	RETURN PERIOD			
STATION	10	20	50	100
Palisadoes	85	94	110	123
San Juan	87	95	111	123

6.3 Wind Speed for Structural Design

H. C. Shellard[21] and the draft Barbados Association of Professional Engineers' Code "Wind Loads for Structural Design" have recommended a basic wind speed of 120 mph for design purposes. This is a (3-second) gust speed at 10 metres height above ground, recommended for a return period of 50 years.

6.0 CLIMATOLOGICAL DATA AND WIND DAMAGE RECORDS CONTD.

6.3 Wind Speed for Structural Design contd.

A similar speed is proposed for the Birtish Virgin Islands in the North Caribbean.

Factors are also proposed in the Barbados Association of Professional Engineers' Code for topography, ground roughness, building size, height above ground and estimated building life. These factors are identical to those used in the British Code of Practice No. 3; Chapter V; Part 2: Wind Loads and are derived from work done by Dr. K. Eaton of the Building Research Station, U. K.

7.0 WIND DAMAGE

Although hurricanes are frequently generated in the Caribbean Area, most of the islands are comparatively small in size and an examination of records for any individual island, will show much less frequent instances of direct hits. For instance, Jamaica is only 150 miles by 50 miles in size and Table 6.1.3 shows the infrequency of direct hits when compared with the number of tropical storms which pass within 150 miles of the island.

The most recent wind damage information available for Jamaica, dates back to 1951, the year of the last direct hit. Newspaper reports indicate that damage was estimated at US$56 million at 1951 prices. Twenty thousand buildings were destroyed and 150 people died. Gust speeds were 125 m.p.h. (Life Magazine 1951). Twenty-five thousand people were left homeless, and in one parish (St. Thomas) 90-100% of homes were destroyed in 15 communities (Daily Gleaner August 19-31, 1951).

7.0 WIND DAMAGE CONTD.

It should be noted that up to the time of the hurricane, the large majority of low-income houses were wooden, with roofs of corrugated iron on wooden rafters and of generally poor construction. Such buildings suffered badly and most of the recorded wind damage occurred to such structures. Light roofs on all types of buildings suffered similarly but wooden shingles performed quite well[22].

A report on Hurricane Betsy which hit Nassau, Bahamas in 1965[16], records that maximum wind speeds of 85 knots did relatively little damage. Neither wooden buildings nor buildings with concrete block walls suffered much. Asphalt shingles sustained widespread damage but wooden shingles survived quite well.

One devastating side effect of high winds in the Caribbean is flood rains. Flood rains often accompany near-misses as well as direct hits of hurricanes on the island and therefore, occur with far greater frequency.

8.0 SOLUTIONS FOR MITIGATING LOSSES DUE TO HIGH WINDS

8.1 Warning System and Precautionary Measures

Adequate hurricane warning system and speedy dissemination of instructions for the public has proven of great value in the past.

In Jamaica, the Meteorological Office and radio stations have co-operated to issue frequent new-bulletins as any hurricane shows signs of being a threat to the island. Precautions are published in newspapers throughout the usual hurricane season (June - September) and repeated on all other news media when a specific threat arises.

8.0 SOLUTIONS FOR MITIGATING LOSSES DUE TO HIGH WINDS CONTD.

8.1 Warning System and Precautionary Measures contd.

Precautions include storing water and fuel, battening windows and doors, securing loose or moveable outdoor items or fixtures and strengthening defective windows, doors or roofs.

8.2 Structural Provisions

8.2.1 General

Where good practice as defined by either local regulations or accepted standards is observed, damage is usually greatly minimized. All attempts to mitigate losses should, therefore, commence with procedures to ensure strict adherence to accepted standards and adequate inspection during construction.

In Jamaica, the registration of engineers and architects is being considered for implementation. This and/or strong, well-staffed local building authorities would help to ensure good standards.

8.2.2 Roofs

Wind damage to roofs is usually due to high local uplift forces. Damage is mainly to lightweight roofing and is greatest for metal sheeted roofs.

Inadequate fastening to sheeting, especially roof corners, edges and ridge, is the main cause of failures. With thin sheeting, the size of washers also play an important part.

The solution to this problem is for engineers to design the fastening of roof coverings for actual local suctions obtained by reference to appropriate wind codes or research data.

8.0 SOLUTIONS FOR MITIGATING LOSSES DUE TO HIGH WINDS CONT.

8.2.2 Roofe contd.

Complete removal of the roofing etructure occasionally occurs and is ueually due to a lack of straps or holding down bolte tying roof to walls. Thie too can only be avoided by proper design and detailing.

8.2.3 Walls

Lightweight e.g. wooden walle, occasionally suffer uplift and this ie usually due also to lack of etraps tying walle to foundations.

8.2.4 Glazing

Failure of windowe and glazing during extreme winds often create adverse conditions for uplift on roof structures and increase wind forces above those allowed for in design. Such apparently minor details as glazing and window anchorages should be properly designed.

9.0 LOW-COST BUILDING DESIGN PROBLEMS UNIQUE TO JAMAICA

The following is in certain respects a summary of the problems mentioned in this report and in Appendix I.

9.1 Building Codes and Standarde

As agreed in the Workshop Conference on "Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds", held in Manila, there is a great need for simple instructions set out in a "Manual of Accepted Practice" for the guidance of engineers, architects, developers, etc. This would be eupplementary to Building Codes and would provide guidance on eimple low-cost housee, that could be understood by even the untrained builder.

9.0 LOW-COST BUILDING DESIGN PROBLEMS UNIQUE TO JAMAICA CONTD.

9.1 Building Codes and Standards contd.

Where there is not yet a Registration Law, this need is even more urgent, as buildings are often designed and constructed by persons without professional training.

9.2 Structural Problem Areas

For the currently popular structural systems in low-cost housing, i.e. hollow concrete block walls and metal sheet roofing on timber rafters, the major problem area is roof fastenings and holding down provisions. General practice for holding down provisions at present, is nominal and not covered by codes. Accurate data on design forces, or recommended standard details as mentioned above, would ensure both economy and a consistent and adequate standard of safety.

10.0 CONCLUSION

The foregoing is an attempt to give a description of low-cost housing and extreme-wind-related problems in Jamaica and some parts of the Northern Caribbean.

The objective of this report and its Appendix I is to provide information on other developing regions within the Northern Caribbean Area. Information from this report will enable the final analysis and recommendations from the project to be of more universal applicability.

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A P P E N D I X I

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LOW-COST HOUSING AND EXTREME WIND-RELATED PROBLEMS IN JAMAICA

REPORT NO. 1

For

NATIONAL BUREAU OF STANDARDS

and

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

'INVESTIGATION OF WIND RESISTANCE OF LOW-COST HOUSES'

By A. D. Adams
Consulting Engineer
Jamaica

November, 1973

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LIST OF ILLUSTRATIONS

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LOW-COST HOUSING AND EXTREME-WIND-RELATED PROBLEMS IN JAMAICA

by A. D. Adams
Consulting Engineer, Jamaica

1. SCOPE

This report presents an outline of low-cost housing and low-rise building-related problems of Jamaica and data gaps both in the design (e.g. structural systems, connection details, design loads, etc.) and construction phases. It identifies the related socio-economic considerations as they affect the design of structures. It presents also, a discussion of extreme-wind-related problems as found in Jamaica.

Due to the shortage of time mentioned, the practice and problems mentioned in this paper are based on Jamaica only and does not include other Northern Caribbean Islands.

2. LIMITATIONS AND ASSUMPTIONS

General

This is the first of two reports. It is intended to present information of a more general nature here and to present more detailed information and substantiating data in the second report. This is partly necessary because of the short time that was available for developing this report.

In addition, there is a lack of technical reports on the effects of past occurrences of extreme wind in Jamaica. For aspects connected with the observed effects of extreme wind, some reliance has had to be placed on newspaper reports and photographs and other records and papers. Not all of these sources are engineering-oriented, hence they have been interpreted with some caution.

LIMITATIONS AND ASSUMPTIONS CONTD.

Data Gaps in Design and Construction

For identifying data gaps in design and construction, the author has mainly drawn on his own experience as a consulting engineer and his association with other engineers in Jamaica. This means that data gaps are indicated where information may conceivably exist, but is not known by or readily available to, the majority of Jamaican engineers. The second report will, of course, re-examine any statements made in the first.

Socio-Economic Considerations

For socio-economic considerations, statistics and economic analysis are based on government reports unless stated otherwise.

Observations on social and sociological aspects are often subjective but where supported by other reports or studies, this is noted by reference to the sources.

3. COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA

A Look at the Past

An examination of common housing systems in Jamaica should perhaps be preceded by a historical look at 'low-cost' housing as it existed before the advent of modern industrialised buildings and building materials. This seems even more relevant when it is considered that at the time of the last severe hurricane in 1951, most houses were of 'early' construction as described below:

> In the rural areas, most 'early low-cost' houses (say up to the 1930's) were constructed by peasant owners, using techniques described as "wattle and daub" (See Fig. 1). This consisted of a wooden skeleton frame of posts planted in the ground, tied at eaves level with wooden beams and with sticks interwoven horizontally between the posts, to form the "wattle". This "wattle" was "daubed" both inside and out with mud formed from readily available clay, to create solid walls. Roofs were of pitched wooden framing and battens. The roof covering was generally formed of 'thatch', made from bundles of dried leaves of certain plants, tied in place.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

A Look at the Past contd.

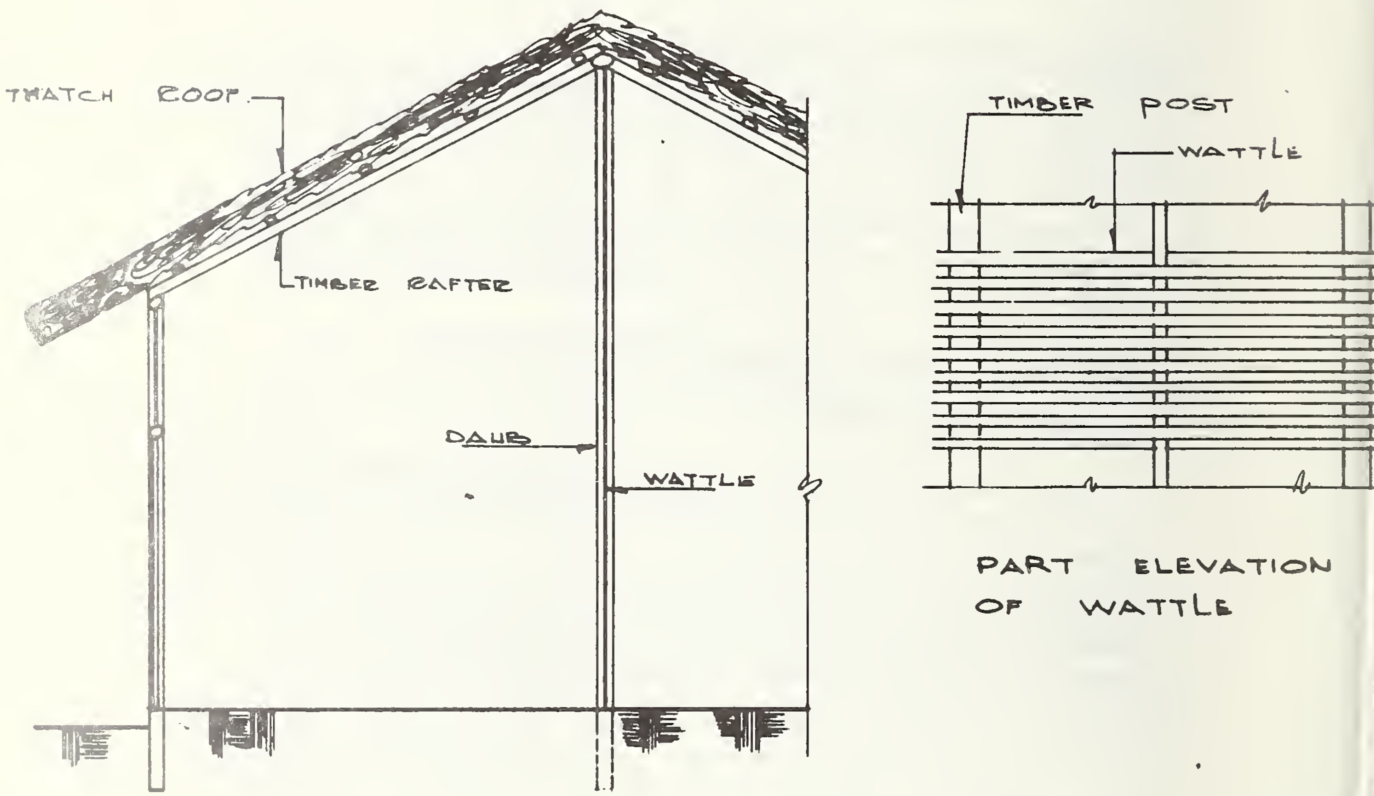

FIG. 1

WATTLE AND DAUB
EARLY LOW COST HOUSING CONSTRUCTION IN JAMAICA.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

A Look at the Past contd.

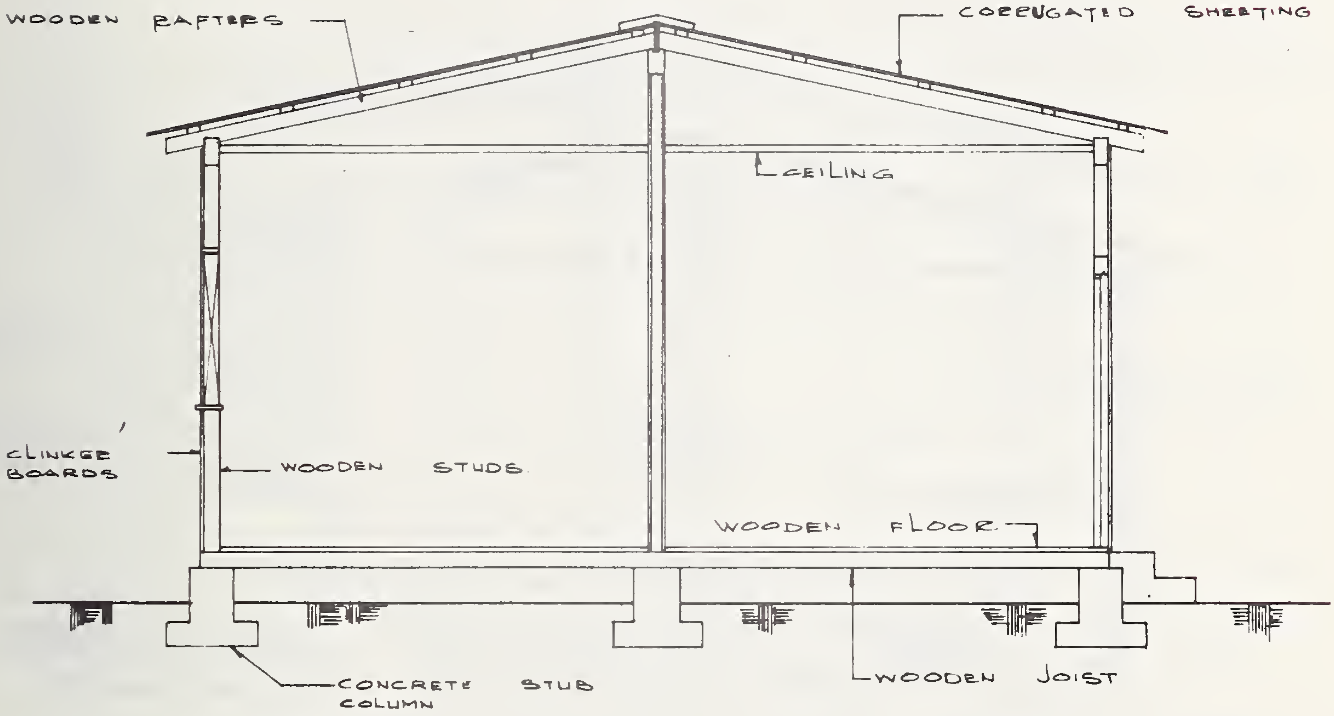

FIG. 2.

TIMBER STUD AND BOARDING.
EARLY LOW COST HOUSING CONSTRUCTION IN JAMAICA.

In urban areas, houses were mainly of timber studs with lapped horizontal boarding to walls (See Fig. 2). Roofing was of pitched timber rafters with corrugated iron sheets or wooden shingles, either on battens with a thin suspended ceiling, or on board-sheathing without a ceiling.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

A Look at the Past contd.

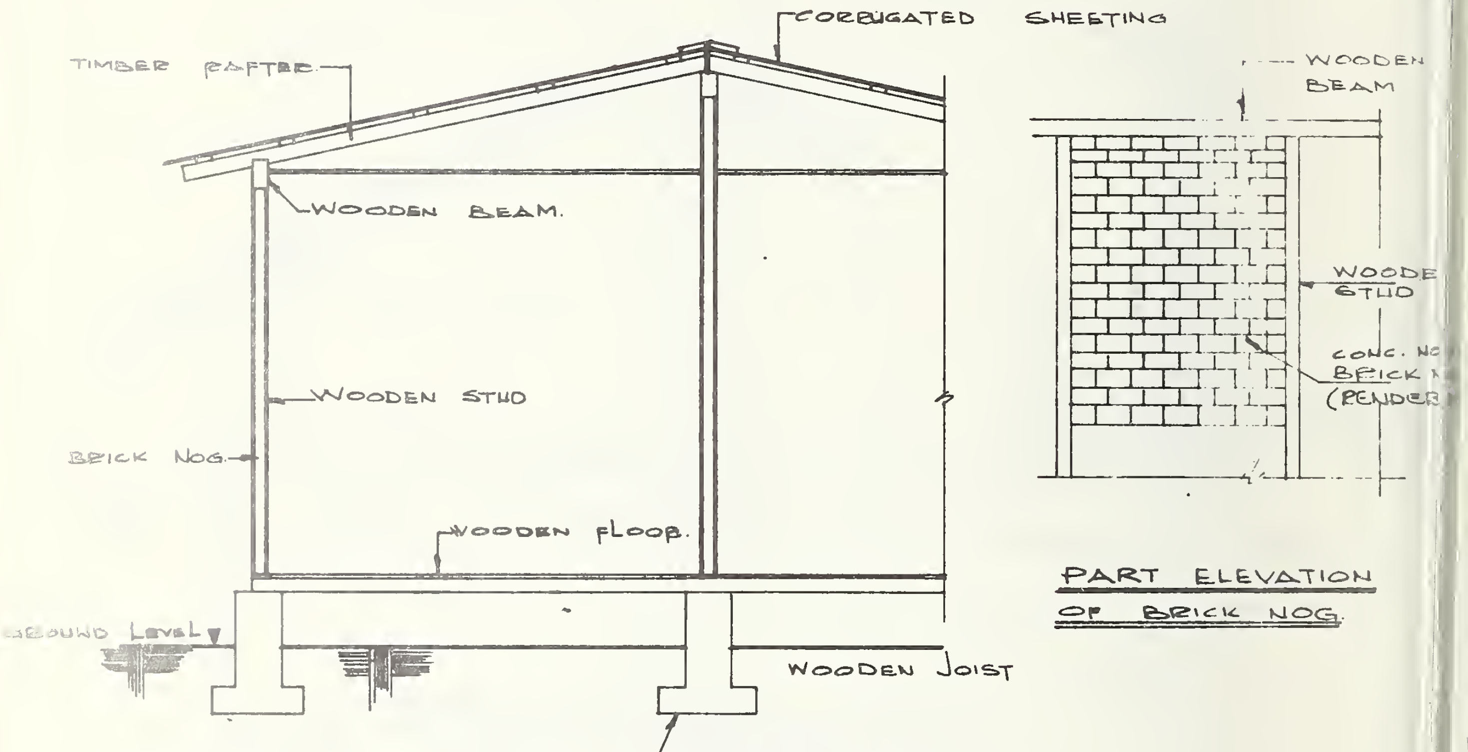

FIG. 3

BRICK NOG AND CONCRETE NOG.
EARLY LOW COST HOUSING
CONSTRUCTION IN JAMAICA

As a variation in some cases and also as a further development as time passed, many houses in the urban areas came to be built of brick-nog or concrete-nog construction (See Fig. 3). This consisted of masonry or concrete in-fill between the studs and a rendering of lime or cement plaster. A feature of both types was that in most cases houses were elevated at least 2 or 3 ft. above ground on concrete or masonry piers or 'sleeper' walls.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

Hollow-Concrete Masonry Construction

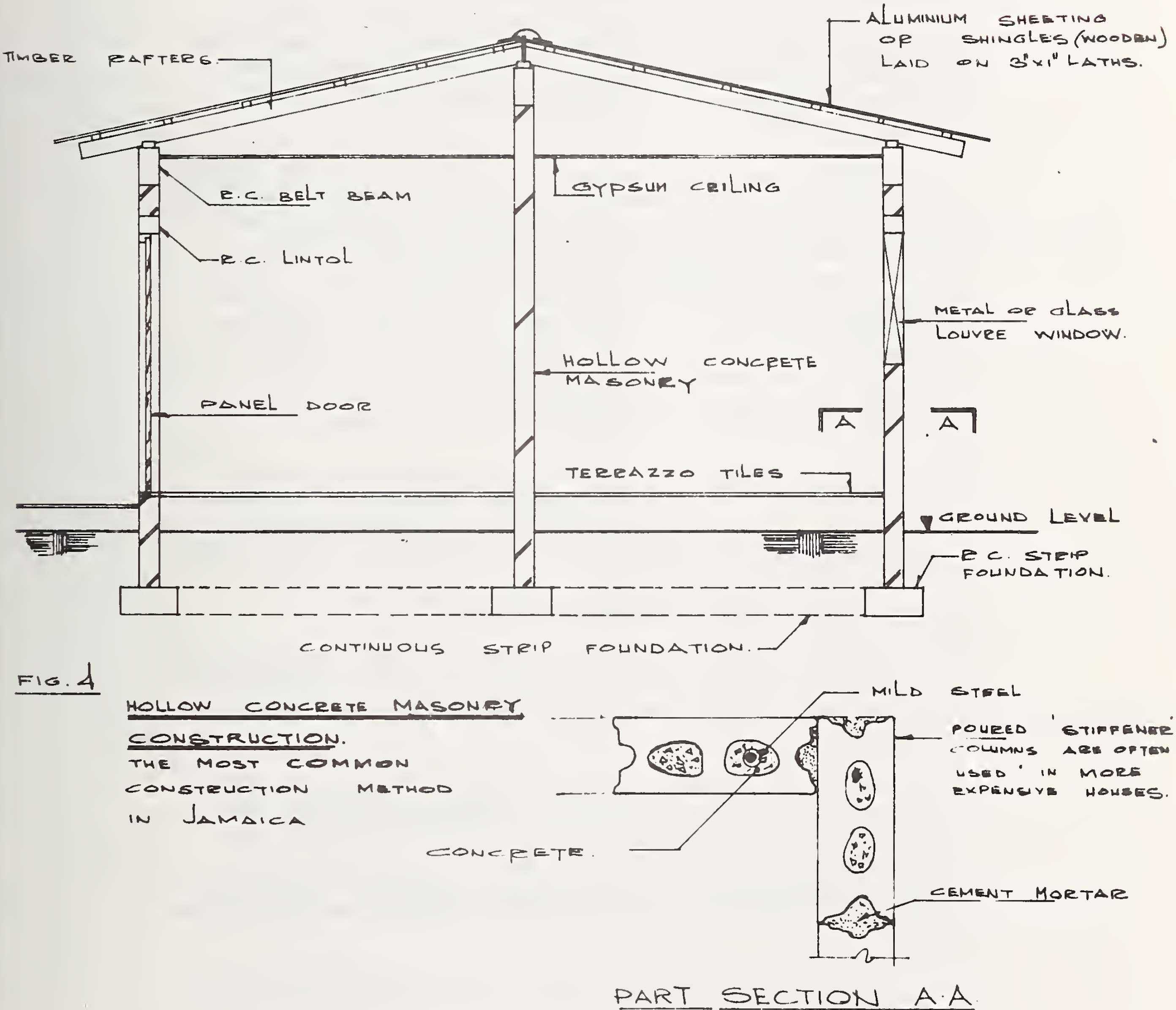

FIG. 4

HOLLOW CONCRETE MASONRY CONSTRUCTION. THE MOST COMMON CONSTRUCTION METHOD IN JAMAICA

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

Hollow-Concrete Masonry Construction (See Fig. 4)

The introduction of the hollow-concrete block as a cheap masonry unit for walls, marked the development of the first major construction method using locally manufactured components as a basic building material for low-cost houses.

Selected vertical cavities in concrete blocks are usually filled with concrete during construction and vertical and horizontal steel bars are introduced as reinforcement to resist earthquake and wind effects. Poured-in-place reinforced concrete stiffener-columns are generally introduced in unrestrained panels of wall exceeding about 16 ft. However, for low-cost housing, these stiffeners are often omitted and both cavity infill and reinforcement are generally restricted to corners and edges of openings. Reinforced concrete belt beams are used to cap walls at roof level.

Roofing Systems are of various types and include poured-in-place reinforced concrete slabs, and battens on timber joists covered with aluminium sheeting or wooden shingles. Foundations are of strip-footing type.

Large Panel Precast Concrete Systems (See Fig. 5)

These consist of full size concrete wall panels, with the largest panels being as large as the full length of the housing unit in one direction and the full storey height in the other.

In the most common local system of this type, wall and roof-panels are lifted and assembled by crane and connected by welding at matching steel inserts. Overall thicknesses of wall units vary from 3" to 6" but ribbed panels are often used for the thicker units with rectangular panel thicknesses of as little as 1½" between ribs.

Roof waterproofing is usually of a bituminous compound or waterproofing felt.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

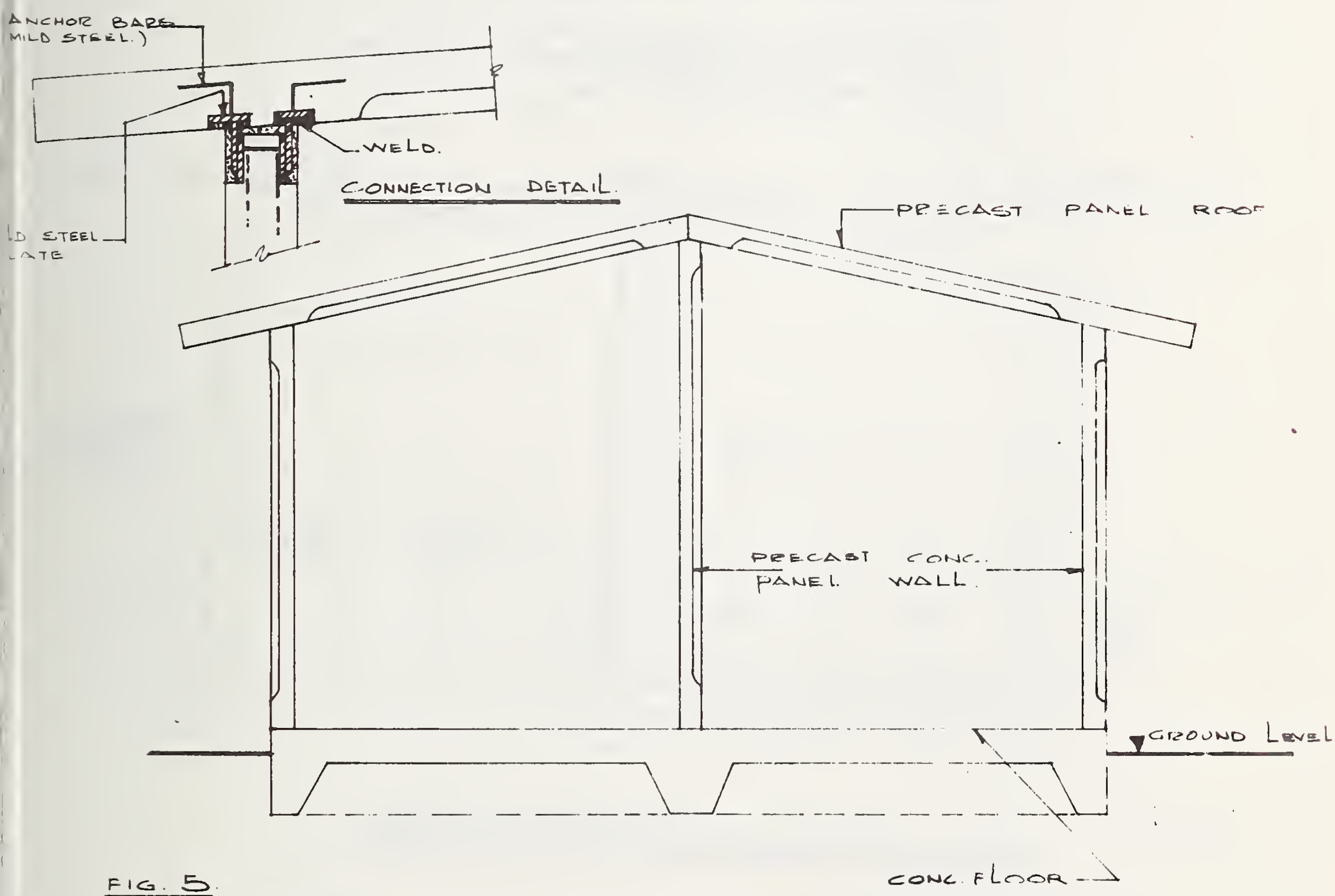

FIG. 5.

LARGE PANEL PRECAST CONCRETE SYSTEM

THE MOST ESTABLISHED, FULLY PREFABRICATED HOUSING SYSTEM IN JAMAICA.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

Small Unit Precast Concrete Systems (See Fig. 6)

These consist mainly of precast concrete posts and precast concrete or timber beams with concrete in-fill "boards" between posts.

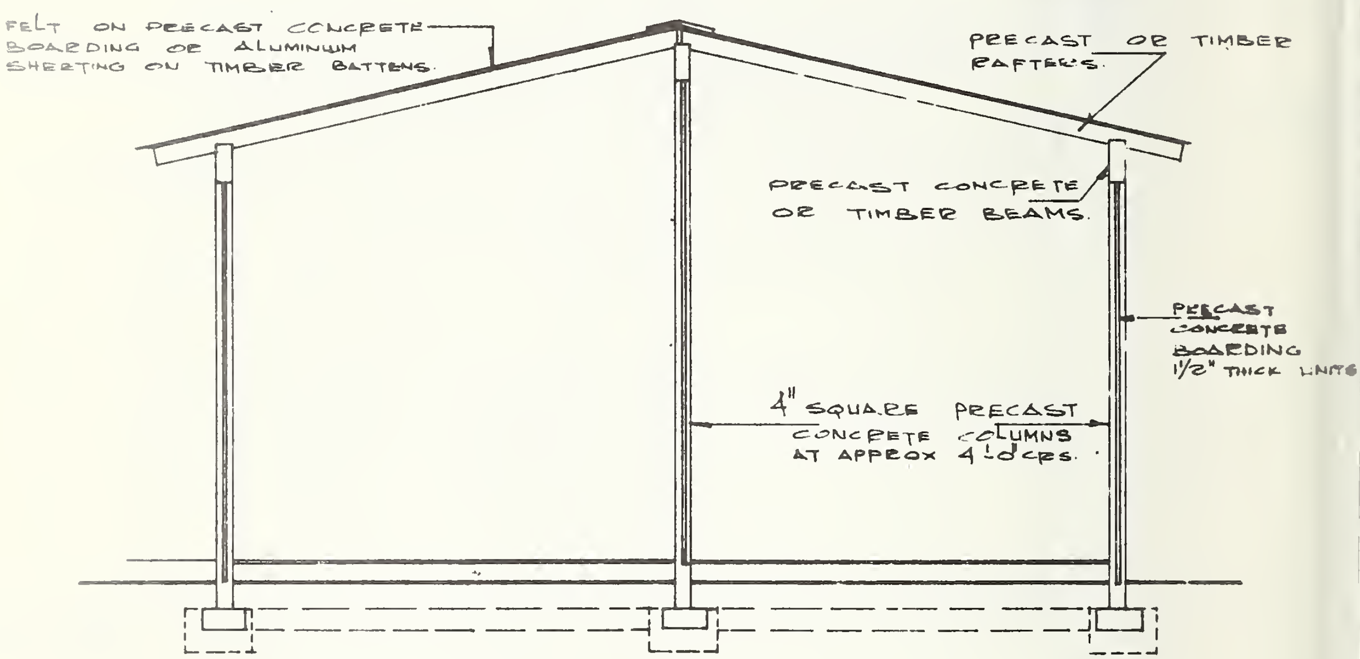

FIG 6

SMALL UNIT PRECAST CONCRETE SYSTEM.

NOTE

GOVERNMENT OWNER-OCCUPIER SCHEME USES TIMBER BEAMS AND RAFTERS.

Roofs are generally of timber framing with aluminium sheeting. In some cases, precast concrete joists and "boarding" are utilised with felt waterproofing.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

Timber Systems (See Fig. 7)

These are mainly of timber studs and 1" thick horizontal boarding on both internal and external wall surfaces. Roofs are generally of timber framing and aluminium sheeting.

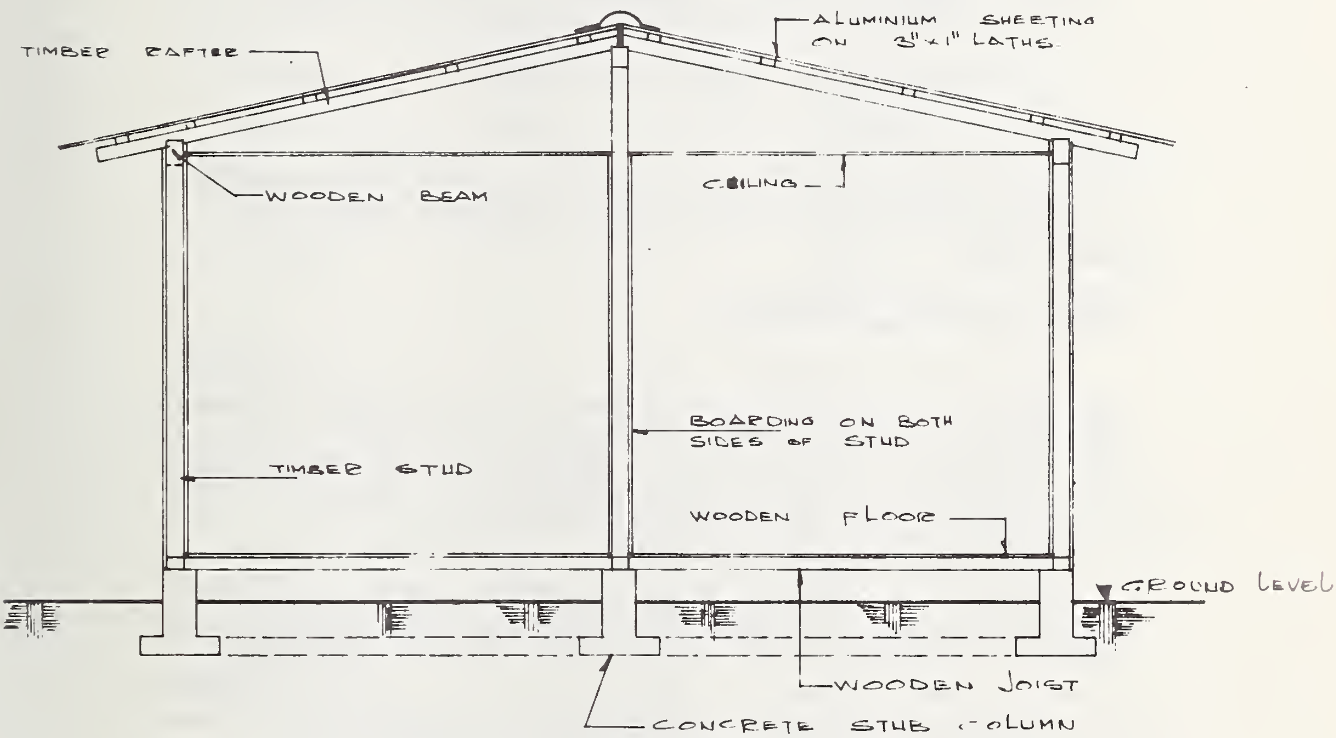

FIG. 7

TIMBER SYSTEM

STUD AND LAPPED BOARDED WALLS.

These houses are usually elevated on piers or sleeper walls at least 2 ft. to 3 ft. above ground and provided with a flooring of timber joists and boarding.

COMMON LOW-COST HOUSING SYSTEMS IN JAMAICA CONTD.

Other Lightweight Systems

Apart from timber boarded systems, other lightweight systems have been proposed and promoted, particularly by commercial or manufacturing interests. These types generally utilise a stud system either of timber or aluminium. Some of the boarding materials proposed so far are:-

(a) Particle board consisting of cane fibre (bagasse) bonded by a resin.

(b) Thermo-wall panels consisting of bagasse and gypsum bonded by a resin.

However, to date, very little if any houses and certainly no large scale developments have been done using such lightweight systems.

Other Low-Rise Buildings

For buildings under 3 storeys and requiring substantial external walls or partitions, filled hollow-concrete masonry is the most popular construction method in Jamaica. This is usually in conjunction with poured-in-place reinforced concrete floor slabs. Roofs are either R.C. slab or timber framing with aluminium sheeting.

For office and commercial buildings and for low-rise buildings above 3 storeys, the most popular construction system is cast-in-place reinforced concrete slabs and frames. Less popular variations are for slabs, composite pretensioned/reinforced concrete or post-tensioned slabs, and for frames, steel skeleton or R.C. shear wall construction.

PROBLEMS AND DATA GAPS IN DESIGN AND CONSTRUCTION OF LOW-COST HOUSING

Local Building Regulations

Most of the building regulations now legally in force in Jamaica, were first passed in the early 1900's. Despite a number of amendments of individual sections, the official building laws are out of date and far behind modern building design and construction technology.

PROBLEMS AND DATA GAPS IN DESIGN AND CONSTRUCTION OF LOW-COST HOUSING CONTD.

Local Building Regulations contd.

There has been a tacit acknowledgment of this by most local authorities and today a lot more observance is made of a Proposed Draft Building Regulations - 1971 than of the original regulations. These Draft Regulations issued by the Kingston and St. Andrew Corporation (which administers the affairs of the Capital City) is not yet available to the general public, but is well known to the initiated such as Engineers, Architects and Builders.

These regulations have been mainly based on the series of British Standards and British Standard Codes of Practice dealing with the design and construction of buildings. This is due to the fact that, so far, Jamaica has not had the financial or man-power resources, which would be needed to undertake the intensive study and research necessary to produce a comprehensive set of truly indigenous codes of practice.

One consequence of this has been a lack of detailed guidance in regulations on special local phenomena, such as earthquakes and extreme winds. There is, therefore, a lack of uniformity in the treatment of these design problems by Jamaican Engineers. The most popular recourse has been to turn to areas such as the United States with its areas of similar naturally occurring phenomena e.g. to the Structural Engineers Association of California for earthquake design.

An encouraging development in this area, has been the efforts of the Engineering Institutions in the Commonwealth Caribbean Area (CEO) to co-operate in developing individually, separate sections of a comprehensive building code, which would eventually be compiled to serve the entire Commonwealth Caribbean region.

One such effort by the Barbados Association of Professional Engineers, has produced "Wind Loads for Structural Design" Draft Code of Practice - August 1970. This too, was largely modelled on a British Code of Practice BSCP3 Chapter V: Part 2: 1970: Wind Loads, with respect to design life of buildings, topography, ground roughness, building size and height above ground. However, most importantly, it proposed basic wind speeds for various islands in the region, based on analysis of local wind data.

PROBLEMS AND DATA GAPS IN DESIGN AND CONSTRUCTION OF LOW-COST HOUSING CONTD.

Local Building Regulations contd.

Local examination of this code has raised one or two unresolved points; namely, the size of hurricane gusts for the proposed averaging times and modifications to wind speed factors which allow for variations in return period. Nevertheless, although the document is not yet widely used by practising engineers in Jamaica, it should represent the most reliable guidance on basic wind speeds in the region for design purposes.

Structural Systems

Difficulties common to all construction methods will be dealt with further in this report but problems and data gaps associated with various structural systems are best discussed under their individual headings.

Hollow-Concrete Block Masonry

For the more usual single-storey buildings involved in low-cost housing construction, load stresses are usually quite low, so that the tendency has been to design in accordance with certain nominal rules set down in regulations to ensure minimum standards. The provision of reinforcement, belt beams, poured stiffener columns and the filling of selected block cavities to improve earthquake performance, goes even further towards increasing factors of safety under wind and vertical loads.

For low-rise buildings with more highly stressed wall elements, local regulations provide little guidance for a rational working stress design except to state in the draft regulations[1] that "allowable working compressive stresses in masonry walls shall not exceed ----- 100 lb. per sq. in. gross area in the case of hollow concrete blocks" and to specify a minimum crushing strength on gross area at 28 days, of 750 lb. per sq. in. For such buildings, therefore, the practice has been to design in accordance with foreign standards such as the American Concrete Institute Report of Committee No. 531 or British Standard Code of Practice No. III. These standards are, of course, not applicable in every respect to entrenched local practice. As a result, the local Institution of Engineers is at present engaged in preparing recommendations for the design and construction of this type of building.

PROBLEMS AND DATA GAPS IN DESIGN AND CONSTRUCTION OF LOW-COST HOUSING CONTD.

Hollow-Concrete Block Masonry contd.

One area of uncertainty, unresolved to date, is the necessity for a maximum spacing of poured-in-place R. C. stiffener columns and their effects in enhancing the strength of the masonry walls under vertical loads or wind and earthquake loads.

Large Panel Precast Concrete Systems

Although there are foreign standards and design codes[3,4] which give general guidance on precast concrete work, there are no comprehensive codes which cover the various types and combinations of precast assembly systems and connections. However, these systems are generally mass produced and are usually manufactured by large, highly organised building concerns. For this reason, they are also usually designed and supervised by qualified engineers and architects. Nevertheless, there is a great need to develop standards for the use of local authorities and design engineers.

Among the specific items which can be solved only by individual engineering judgment at present are:- .

(a) The design of welded metal connections with bar anchorages to achieve ductility;

(b) Joint waterproofing and the avoidance of rain penetration in 'flat' thin section, precast concrete roofs;

(c) The design of welded metal connections with bar anchorages, subjected to combined shear and tension forces.

Small Unit Precast Systems

These fall in a somewhat different category from the large panel systems. Although mass production is usually necessary for economic reasons, in this case erection does not demand large lifting equipment.

This lends itself well to the erection of small numbers of houses in scattered locations. The Jamaican Ministry of Housing in its "Owner Occupier Scheme" has been erecting a few hundred of these annually for the last ten years.

PROBLEMS AND DATA GAPS IN DESIGN AND CONSTRUCTION OF LOW-COST HOUSING CONTD.

Small Unit Precast Systems contd.

The main problem with such units is the design of robust joints for members of such small dimensions. Where all members are precast, connections between posts and beams are generally made by half-lapped and dowelled joints. Boarding is usually slotted into place along vertical grooves in posts. This would generally provide doubtful overall lateral stability under wind or earthquake shears, so that great reliance has to be placed on the embedment of the posts in deep concrete footings.

Where timber beams are provided with concrete posts, connection is provided by bolted U-shaped mild steel straps.

Timber Systems

Local draft regulations provide for the design of timber buildings using some cross-referencing to British Standard Code of Practice No. 112.

Formerly, the problem with timber was poor durability due to rot and decay in our sub-tropical conditions. This problem has been largely solved by the use of modern pressure-applied preservatives[6].

Recognised local practice is to provide straps at roof and floor levels to resist the uplifting effects of extreme wind, but this is not explicitly mentioned in the local draft regulations.

Other Lightweight Systems

As mentioned before, there have been too few examples of the use of resin bonded cane (or wood) fibre for external work to provide an assessment. The patent-holders and manufacturers claim the following attributes:-

(1) Dense surfaces

(2) Termite and rot resistance

(3) High Water repellence

(4) High screw and nail holding properties.

PROBLEMS AND DATA GAPS IN DESIGN AND CONSTRUCTION OF LOW COST HOUSING CONTD.

Other Lightweight Systems contd.

In the constant search for very cheap housing systems, these materials represent attractive possibilities because of their lightness and consequent cheaper construction cost. However, the local government authorities and engineers in general, are still uncertain of the durability, strength, stiffness, weather-resistance and fire-resistance of these materials. Data on the performance and capabilities of these materials is limited and very restricted in circulation. They consist mainly of laboratory tests commissioned by the manufacturers themselves. As would be expected, there is no mention of these materials in the available codes of practice or regulations for the design of buildings. In the present situation, there is a natural reluctance on the part of our understandably conservative government authorities, to approve such designs, even where submissions are made by qualified engineers.

General Comments on Lightweight Roofing

The greatest single problem in the wind resistance of buildings in Jamaica is in connection with lightweight roofs. This was very evident from newspaper reports[10] of damage resulting from the last severe hurricane in August, 1951. The damage usually falls into two categories:-

(a) Stripping of roofs due to inadequate fixings to roof coverings (particularly of metal sheeted type)

(b) The lifting and removal or destruction of complete roof assemblies due to inadequate holding-down force at tops of walls.

Since the 1951 event, general building practice has been improved e.g. to provide fasteners with large heads and/or washers and to provide mild steel "hurricane straps" tying rafters to walls.

Design codes and local regulations give no explicit instructions for these provisions so that design is not done on a rational basis except where an engineer is engaged. At present the majority of houses (excepting large housing schemes) are done without the use of engineers so that such provisions are detailed nominally.

5. SOCIO-ECONOMIC CONSIDERATIONS IN DESIGN

Definition of Low-Cost Housing

The classification "low-cost housing" refers to different cost categories in different countries. Furthermore, in each particular country, the cost category can vary drastically with time as inflation pushes up the cost of construction.

The current definition of "low-income" housing in Jamaica, including land, on a developed site, is a house, the cost of which must be under J$5,000 (US$5,500)[11]. This implies a construction cost by the author's estimate of J$2,300 (US$2,530). Virtually all housing being built by the private sector today can be said to fall outside of this category. Up to the present time, therefore, low-cost housing can be described as government-built or government-financed housing.

Corresponding space requirements of 350 - 450 square feet have been quoted for "proper minimum standard, small housing units" as an international standard for minimum social housing in developing countries. However, this is not envisaged as an attainable standard for people with no fixed income and here in Jamaica, such houses reach a minimum of 200 square feet.

It should be noted that for the smaller houses, space and provision are almost invariably made for future extension by the owner.

Corresponding Income Group for Low-Cost Housing

This is, of course, determined by the ability to make down-payments and mortgage repayments for privately-financed houses (usually 20 year mortgage). Even amongst the least costly estates built by private enterprise, the down-payments effectively eliminate those earning much less than J$30 (US$33) per week or J$1,560 (US$1,723) yearly. Government-housing, however, is within the financial capabilities of persons with two-thirds that income in the urban areas and in some types of schemes even less in rural areas[13].

Annual Figures for Construction of Low-Cost Units

The following are some figures for low-cost housing units completed by the Ministry of Housing[5] or under Government Mortgage Insurance Scheme:

SOCIO-ECONOMIC CONSIDERATIONS IN DESIGN CONTD.

Annual Figures for Construction of Low-Cost Units

Table 1

SCHEME	STRUCTURAL CATEGORY	NO. OF UNITS COMPLETED			UNDER CONSTRUCTION AT 31ST DEC., 1972
		1970	1971	1972	
Government Housing Scheme	Hollow-Concrete Block Masonry	463	453	422	836
Slum Clearance and Rehousing	- do -	-	63	22	570
Owner/Occupier	Small Section Precast Conc Units	454	380	253	37
Farm Housing	- do -	287	91	-	-
Indigent Housing	Timber	26	187	354	94
*Mortgage Insurance Scheme (Inspection only)	Large Panel Precast Concrete	Figs. not available	427	378	Figures not available

* Approximately 700 houses annually in this category have been built by the private sector during the last 10 years. However, few of these could be defined as 'low-cost' [5,15].

SOCIO-ECONOMIC CONSIDERATIONS IN DESIGN CONTD.

House-Purchaser Preferences in Construction Materials

There is a well established preference in Jamaica for concrete houses[13]. There is a considerable consumer resistance, for instance, against the purchase of houses made of lightweight material unless financial restrictions make this unavoidable.

A similar prejudice exist against precast concrete houses (especially those of thin section) but to a far lesser extent and this prejudice is rapidly disappearing. Hollow concrete block masonry remains the most popular material for all income groups.

6. DISCUSSION OF EXTREME-WIND-RELATED PROBLEMS

General

Jamaica enjoys the unwelcome distinction of being in an area of frequent hurricanes and also being in an active earthquake belt. A more rational approach to design against both phenomena has developed over the past 20 years; the general conclusion has developed that where construction is in concrete, provisions to create good earthquake resistance will tend to produce adequate wind-resistant buildings.

This is mainly for single storey residential construction, where it is assumed that stability against overturning will hardly be a problem, but that instead, the main concern is local suctions and pressures. This is mainly true where both walls and roofs are in concrete, but is certainly not true of the very popular lightweight roofing used in such construction.

In the case of total lightweight construction, such as timber, wind is, of course, critical and Jamaica has experienced wide-spread damage in the past when this was not fully recognised. Where adequate fastenings and holding-down devices have been provided, buildings have performed well both here and in other adjoining islands[16, 17].

Another minimising factor in the effect of hurricanes on Jamaica, is an effective hurricane tracking and warning service, administered by the Meteorological Office, Jamaica. In the hurricane season, the public is constantly reminded of the necessary precautions and this minimises greatly the effect of any hurricanes.

DISCUSSION OF EXTREME WIND-RELATED PROBLEMS CONTD.

Summary

The following is a summary of extreme-wind-related problems which require attention or further examination:

(a) Wind Loads: Determination of gust sizes in hurricanes

(b) Hollow-Concrete Block Masonry: Necessity for and effects of poured stiffener columns

(c) Large Panel Precast Concrete Systems:

(i) The design of welded metal connections with bar anchorages to achieve ductility.

(ii) Joint waterproofing and the avoidance of rain penetration in flat thin-section, precast concrete roofs.

(iii) The design of welded metal connections with bar anchorages, subjected to combined shear and tension forces.

(d) Timber Systems: Simple minimum requirements for providing resistance against uplift.

(e) Other Lightweight Systems:

(i) Durability

(ii) Strength and stiffness

(iii) Weather Resistance

(iv) Fire Resistance

(f) Light Roofing Systems

(i) Effectiveness of fasteners in resisting uplift forces on metal sheets.

(ii) Simple rules for minimum provision in preventing uplift of overall roof system.

A. D. Adams
November, 1973

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LOW-RISE LOW-COST HOUSING AND EXTREME WIND RELATED PROBLEMS IN BANGLADESH

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LOW-RISE LOW-COST HOUSING AND EXTREME WIND RELATED PROBLEMS IN BANGLADESH

Dr. Jamilur R. Choudhury

ABSTRACT

The report deals with the present housing conditions and extreme wind related problems in Bangladesh. Bangladesh, with a population of about 75 million in an area of 55,130 square miles, has one of the largest densities of population in the world. The housing conditions are one of the poorest in the world. The problems are made all the more acute due to natural calamities - a third of the country is subject to annual floods and the coastal areas are ravaged by periodic cyclones.

Most of the houses in rural areas are 'kutcha' ('non-permanent') structures, whose plinth is made of mud and whose walls and roofs are built of bamboo, grass, straw and reeds. These houses often do not provide a safe shelter against rain and storms. The stronger type of houses in rural areas use corrugated galvanized iron sheets supported on bamboo or timber framing. No special care is taken to anchor the roof to the walls or foundations. According to the last housing census (1960), the average number of rooms per household was 1.77 and a majority of households (53%) were single room dwellings. It is estimated that the figures remain virtually the same today.

The conditions of urban houses are no better. The well-to-do class live in buildings with reinforced concrete flat roofs supported on brick masonry walls. With increasing urbanization, squatter settlements are increasing and most of these slum dwellers live in almost sub-human conditions.

Extreme winds occur in Bangladesh in three different forms : (i) the Norwesters,(ii) Cyclonic storms and (iii) tornadoes. Norwesters are violent thunderstorms occurring between March and May. They originate over land and marshy areas and occur mostly in the central and eastern districts. The distribution of Norwester squalls in the months of March, April, May and June are shown in maps. The maximum wind velocities in Norwesters are around 80 mph.

Cyclonic storms originating in the Bay of Bengal very often hit the coastal areas of Bangladesh. They are most frequent in the month of October. Usually

accompanied with storm surges, often upto 40 ft. in depth, they cause serious damage to human lives, cattles, houses and other properties. One of the severest cyclones devastated the coastal areas of Bangladesh in November, 1970. Wind speeds upto 150 mph have been recorded in recent cyclones. The C. I. sheet roofs of houses are usually blown away, but the damage to brick masonry walls and R. C. roofs is not severe.

Tornadoes, the most destructive of all storms, occur in the central and eastern regions. The outskirts of Dacca city were devastated by a tornado in April, 1969. The wind speed causing damage was estimated to be in excess of 150 mph.

Most of the 'permanent' houses with sloping roofs used to be designed according to a wind pressure derived from the formula $p = 0.003 V^2$ where p is the pressure in lbs/sft and V is the design wind speed in mph. A common value of V used in designs is 100 mph. Suction and lift forces were completely ignored. In recent years, either the B.S.Code no. 3 (Chapter V), 1952 or the A.S.CE recommendations (1936) is being used. These recognise the effect of slope of roof on the pressure distribution. Depending on the angle of inclination, either suction or pressure may be created on the windward side, whereas the leeward side is always under suction. There is no Code of Building Practice specifying the different design loads but after recent experiences of cyclonic disasters, some designers use an uplift pressure of 25 lbs/sq.ft. in designing the anchor elements for roof structures in low-rise buildings.

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CONTENTS

1. INTRODUCTION

1.1 General

Bangladesh is one of the youngest nations in the world. Formerly known as East Pakistan, it emerged as an independent nation after a short but violent war of liberation lasting about nine months from March 1971 to December 1971.

Geographically, it is located on the north-east of the South Asian Sub-continent between 20°30' and 26°45' North latitude and 88° and 92°56' East longitude. The total area is 55,130 square miles. Almost the whole of the country is a network of rivers, constituting the delta of three of the world's biggest rivers - the Brahmaputra, the Ganges and the Meghna.

The country is surrounded on the west, north and north-east by India, on the south-east by Burma and on the south by the Bay of Bengal.

1.2 Population

The present population is about 75 million. With an average of about 1360 persons per square mile, Bangladesh has one of the largest densities of population in the world. The annual net rate of population increase in Bangladesh was estimated to be 2.6 per cent in 1961. By the end of the present decade the population is expected to be about 95 million.

1.3 Economy

Bangladesh is one of the poorest countries in the world. The Gross Domestic Product (constant factor cost at 1959/60 prices) was about 4.57 billion dollars* in FY 1970.

The economy of Bangladesh is traditionally and predominantly agricultural. About 90% of the population is rural and about 80% of these are engaged in agriculture. Agricultural output accounts for about 55% of the GDP. The per-capita real income is about $ 64 (at the official exchange rate), a figure which has remained almost constant since mid-sixties. Total industrial output accounts for only 9% of the GDP out of which jute processing and manufacture is the major component.

2. THE HOUSING PROBLEM

2.1 Introduction

The last housing census was conducted in 1960. Arrangements for a population and housing census in Bangladesh have been completed and the census data collection should be completed by the beginning of 1974. In the absence of up-to-date reliable data, most of the following discussion is based on the results of 1960 census. The basic characteristics of house types, structural conditions, occupancy, etc. have not changed significantly during the last decade.

* The figures quoted are unofficial estimates.

In 1960, there were about 9.60 million residential houses in Bangladesh, The average number of rooms per household was 1.77. A majority of householdgx (53%) lived in single-room dwellings and the average density of occupancy was 3.2 persons/room. Table I gives the number of households classified according to number of rooms:

Table I

Number of Houses of Different Sizes*

(Figures in thousands)

Number of households of all sizes	Number of rooms									
	1	2	3	4	5	6	7	8	9	10
9603	5166	2652	1063	443	161	65	28	13	6	7

Five or more persons share a room in case of 31% of the population, 4 persons in case of 13% of the population and 3 persons in case of 21% of the population.

The poor housing conditions of the general populace is evident from the above figures.

2.2 Rural Housing

The bulk of the rural population of about 67.5 million belong to the poorest income group. Since the majority of this population depend on agriculture as their means

* Source: Census of Pakistan, Vol.9, 1960

of livelihood, the distribution of agricultural land holding has a marked effect on the pattern of rural ~~economy~~ housing.

The rural population may be broadly classified into two groups: (a) land-owners, and (b) landless labourers. It is estimated that about one-fifth of the villagers are landless, who work mainly as field hands or labourers in various projects. Out of the gross area of 55,130 square miles, about 25 million acres (70.8% of the gross area) is cultivable. The average land owning villager possesses only 1.5 acres. He usually rents another acre from well-to-do villagers and therefore cultivates 2.5 acres. This area is usually fragmented into ten or more plots, some of which may be a mile or more away from the homestead. The houses, in general tend to be scattered throughout the village.

Most of the rural population in Bangladesh live on the patriarchal family pattern. Peasants usually establish their households on their own fields. When the sons get married, their wives move in with them, and a new house (or room) is erected for them, on the same field, next to the parents' house. As a consequence, houses occupied by families paternally related are grouped together. The clusters of houses normally provide shelter to families of relatives numbering 20 - 40 members, but higher figures are not infrequent. The groups of houses are usually surrounded by dense tropical vegetation and trees. Fig.1 shows the layout of a typical rural house. The central courtyard is the centre of almost all family activities.

2.2.1 Dwelling Units

Most of the houses in rural areas are 'kutcha' (which literally means raw) structure, whose plinth is made of mud and whose walls and roofs are built of bamboo, grass, straw and reeds. These houses require constant maintenance and often do not provide a safe shelter against rain and storm.

According to the last census report (1960), there were 9.13 million residential dwelling houses in rural areas of Bangladesh. The increase in number of rural houses between 1950 and 1960 was about 10%. Assuming the same rate of growth the number of houses in 1970 should have been about 10 million.

2.2.2 Structural conditions of Rural Houses

According to 1960 census data, about 90% of the total rural houses are made of bamboo, thatch and mud, and 64.5% of the houses use the same material for roofs. Walls of concrete, baked bricks or stone are used in only 1% of the total number of houses. These are mostly the staff quarters built by the government. An average of 34% of the houses have C.I. (Galvanized corrugated iron) sheets or corrugated asbestos cement sheets as roofing materials.

2.3 Urban Housing

The conditions of dwelling units in urban areas are no better than those in the rural areas. A vast majority (72%) of the urban population cannot afford to pay the rent for even the cheapest form of acceptable housing. They have, therefore, to live in makeshift shacks and huts. These distressing conditions under which the low income families live present a problem which is seemingly beyond solution. The total number of urban dwelling units, according to 1960 census, was about 471,000 and it is estimated that there were about 520,000 units in 1970. Approximately 27% of the houses are permanent and semi-permanent in character, the rest being temporary and unclassified. Quite a large fraction of the urban population live in the 'bustees' and squatter settlements in the larger towns and cities. They live in bamboo shacks, often consisting of a piece of plaited split-bamboo fencing bent in the shape of a semi-circle. The headroom in such houses being low, their occupants spend most of their time under the open sky, taking shelter under the shacks only in case of rain and during night. The houses are blown away even by moderate winds, despite efforts to hold them down by putting counter-weights like bricks on top of the roofs. The government is making efforts to rehabilitate these squatters and has already built 4500 semi-permanent one-room houses on the outskirts of Dacca city.

2.4 Common Types of Houses

A very common type of construction used for rural houses is shown in Fig. 2. The roof consists of C.I.sheets screwed to timber purlins, usually about 2" x 2" section. The load bearing skeleton consists of bamboo posts. The walls are of bamboo fencing consisting of split bamboo woven diagonally. Galvanized steel wire is used in joining the different pieces. These houses are never designed from the structural point of view, and are usually built by local craftsmen, the owner sometimes providing unskilled labour.

A stronger type of construction used for low-cost housing projects on the outskirts of Dacca by the Housing Directorate of the Government uses brick walls with C.I. sheet roofing (Fig. 3). The C.I.sheet roof is anchored down to the wall through 1/8" x 1" x 5" twisted steel clamps and 1/2" diameter 'holding down' bolts. These bolts are about 2 ft. long with a 4" square 1/8" thick mild steel plate welded at the bottom end embedded in the brick masonry.*

The stronger houses in urban areas are mostly made of burnt clay brick masonry walls with sand cement mortar (usually 10" thick for buildings upto 2 stories high) with reinforced concrete roofs. The roofs are almost invariably horizontal,

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* Source: Housing Directorate, Government of Bangladesh

In the design of such buildings, no account is taken of the wind forces. The walls being much thicker than necessary from gravity load considerations, even extreme winds do not produce stresses large enough to produce failure. Most of the buildings of this type which have suffered damage due to cyclones were either made of sub-standard quality mortar or the workmanship was poor. No damage to R.C. roofs have been reported. In the island of Manpura, one of the worst-affected areas of the November 1970 cyclone, the only R.C. elements which suffered damages were 'sunshades' which were about 2½" thick, 1'-9" projections above window level. These failures might have been caused by uplift wind pressure or the pressure generated by storm surges.

2.5 Some new types of houses

In recent years, efforts have been made by different relief agencies as well as Government departments to evolve new type of houses to better resist the natural calamities. Some of these use trадiditional materials like C.I. sheet roofing whereas others are completely new in concept.

A very popular type of structure called CARE type houses (after the U.S. relief organization Co-operative for American Relief Everywhere) uses soil cement blocks for walls and C.I. sheets for roofs. The primary emphasis is on promoting housing on 'self-help' basis, a minimum of skilled labour being necessary for its construction. However, the problem of properly anchoring the C.I.sheet roofs to the wall still remains.

Hyperbolic paraboloid reinforced concrete shells roofs have been used in both industrial housing and suburban housing. One system uses 1" thick precast R.c. elements with in-situ concrete interconnection. The roof is anchored to the supporting brick walls through 1/2" M.S. bars at the corners. Cast-in-place hyperbolic paraboloid shell roofs have also been used in a recently constructed industrial housing project in Jessore.

CARE is experimenting with a revolutionary type of house design. Both the shape and the materials used are completely new in Bangladesh. The integrated roof and wall element is semi-elliptic in shape and is made of pre-formed elements of polyester resin, jute and polyurethane. These elements are anchored to the underlying soil and their performance in severe winds has so far been satisfactory.

2.6 Current Housing Programmes

Bangladesh had the misfortune of suffering two disastrous natural calamities in 1970. In August 1970, flood waters destroyed about 80,000 rural houses completely; moreover about 224,000 houses were partially damaged. In the severe cyclonic storm of November 12, 1970 about 100,000 houses were completely destroyed. The liberation struggle of 1971 left about 2 million families homeless. Attention of international relief agencies and humanitarian organizations were naturally focussed on Bangladesh after their series of destructions. Sizeable housing rehabilitation and reconstruction efforts are now underway in rural areas. The Government of Bangladesh through its Rural Housing Rehabilitation Project envisaged the construction of 1 55,000 semi-pucca rural houses and 21,000 pucca houses in the coastal areas in 1972-73. The Government has also undertaken construction of 2-storied cyclone shelters in coastal areas which will also serve as community centres, schools, dispensaries and post-offices.

Table 2 shows the summary of housing programmes undertaken by the different relief agencies during the last two years:

Table 2

Housing Programme of Different Relief Organizations in Bangladesh*

Name of Organization	Number of Houses	
	Target upto 1972-73	Construction upto August 1972
1. CARE	12,500	5,600
2. CONCERN	2,000	50
3. R.K.Mission	1,500	1,000
4. BERRS	45,220	24,003
5. CORR	3 00,000	1 85,260
6. Uncle Erik's Children Help	31	31
7. Service Civil International	925	135
8. SAWS	2,730	200

9. AUSTEAMS	2,668	2,668
10. Baptist Mission	1,494	1,264
11. Danish Association for International Co-operation	125	15
12. EFICOR	581	95
13. ICRC	991	991
14. RDRS	15,060	2,960
15. Salvation Army	2,331	1,081
16. IPS	1,000	-
17. BVSC	5,000	-
18. BRAC	1,000	-
Total	3 95,156	2 25,153

3. EXTREME WIND RELATED PROBLEMS

3.1 Types

Extreme winds affecting houses in Bangladesh may be classified into three categories:

(a) The Norwesters* ('Kalbaishakis')

(b) Cyclonic Storms, and

(c) Tornadoes.

3.2 The Norwesters

Norwesters are violent thunder-storms and occur during premonsoon months, i.e. March to May. They are most frequent in the month of April (which corresponds to Baishak, the first month of the Bengali calendar - hence the name 'Kalbaishaki'). They originate over land and

* Source: Report on the National Workshop on Low-cost and Co-operative Housing in Bangladesh, Nov.29 - Dec 5, 1972, Prepared by International Co-operative Housing Development Association.

marshy areas and occur mostly in the central and eastern districts.

In a study of Norwester squalls over Dacca, it was observed that before the onset of a Norwester, the prevailing surface wind was southerly or south-westerly but with the onset of the squall, a sudden shift to the west, south-west and even south-east was observed.

Some of the Norwesters originate from West Bengal and Chotanagpur in India and move in a north-west to south-east direction. Another category of Norwesters originate from Assam in India to the north of Dacca and move more or less in a southerly direction.

The ~~areal~~ distribution of Norwester squalls over different areas in the months of March-June are shown in Figs. 4, 5, 6 and 7.* It is observed that in the month of March, an area around Dacca and north-east of Dacca has the highest concentration of squalls. In the month of April, the March cell expands in area and another cell near Sylhet near the north-eastern boundary starts developing. In the month of May, three cells are observed:

(a) the Dacca Cell well expanded,

(b) a cell near Pabna and around, possibly extending to Calcutta in India; and

(c) Sylhet cell in the north-east becoming prominent.

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* Source: The Climatology of East Pakistan by M.A.Quadir, Govt. of East Pakistan Publication, 1962.

In the month of June, only two cells are observed, both with considerably reduced frequency distribution. These are the decaying Dacca and Pabna cells.

The Maximum wind velocities encountered in case of Norwesters is in the region of 40 - 80 miles per hour.

3.3 Cyclonic Storms

3.3.1 Storm tracks and frequency

The south-west mansoons, over which the entire agricultural production of Bangladesh is dependent, is ushered in pulsations, through the agencies of 'depressions' and cyclonic storms. High winds with frequent squalls, heavy rain and storm surges are the destructive agencies of a cyclonic storm.

A study of the storm tracks in the Bay of Bengal between 1891-1923 reveals that the cyclones may originate anywhere in the Bay of Bengal and then travel either North-west towards the Madras coast in India or North and North-easterly towards the head of the Bay. The Bay of Bengal is practically free of cyclonic storms in the months of January, February and March. In the months of April and May, Bangladesh has occassionally been struck by cyclones affecting the Cox's Bazar coast and the area East of Barisal. During the monsoon months of June, July and August, cyclonic storms are frequent but of moderate intensity and they do not affect Bangladesh; they form at the head of the Bay of Bengal and travel in West and

North-westerly direction to the Orissa and West Bengal coast in India. Cyclonic hazard is greatest in Bangladesh in the period starting from September and ending in December. Cyclones are then most frequent and severe and may attack any of the coastal areas at Madras and West Bengal in India, Bangladesh and Burma.

Table 3 shows the frequencies of cyclonic storms and depressions in the Bay of Bengal at different periods of a year. Although more depressions were formed in the months of July, August and September, the number of cyclonic storms was much higher in the month of October.

Table 3*

Frequencies of Cyclonic Storms and Depressions in the Bay of Bengal (1948-1960)

Month	Depressions Total nos:	Storms Total nos:
January	1	0
February	1	0
March	0	0
April	3	0
May	6	5
June	11	0
July	19	2
August	19	2
September	21	5
October	12	10
November	2	5
December	3	2

* Source: Op. Cit.

The total number of cyclonic storms by decades is given in Table 4.

Table 4*

Total number of cyclonic storms in Bangladesh (1890 - 1959)

1890-1899 :	68	of	which	2	were	reported	devastating
1900-1909 :	65	"	"	0	"	"	"
1910-1919 :	48	"	"	1	"	"	"
1920-1929 :	77	"	"	3	"	"	"
1930-1939 :	81	"	"	8	"	"	"
1940-1949 :	89	"	"	4	"	"	"
1950-1959 :	76	"	"	0	"	"	"

3.3.2 Disastrous Cyclones of the Past

Coastal regions of Barisal and Noakhali districts have been subject to severe cyclones and destructive storm surges in the past. In such severe cyclones, thousands of human lives and cattle were lost, houses and crops worth millions of Takas were destroyed. Some of the more severe cyclones of the past 400 years are mentioned below:

(a) Cyclone of 1584: The cyclone hit the districts of Barisal and Patuakhali. There was a huge storm surge and nearly 200,000 people perished in the calamity.

* Source: Op. Cit.

(b) Cyclone of 1797: The cyclone affected the islands south of Noakhali and has been described as the "most destructive".

(c) Cyclone of 1822: Unlike other cyclones, which generally occur in October, a great cyclonic storm ravaged the southern areas of Barisal, Patuakhali and the islands of Hatiya on June 6-8, 1822. In the district of Barisal alone about 72,000 people were killed.

(d) Cyclone of 1876: The coastal districts of Barisal, Patuakhali, Noakhali and Chittagong were hit by a cyclone on October 31 - Nov 1, 1876. Storm surgeg upto 40 feet deep have been reported from the coastal areas. A total of 215,000 people were probably drowned. This represented 20% of the population of the affected areas.

(e) Cyclones of 1960: After a comparatively quiet period in the first half of the century, two severe cyclones hit the coastal regions of Barisal, Noakhali and Chittagong in October 1960. The cyclones occurred in quick succession - the first one on October 9-10 and the second on October 30-31. The areas affected by both the cyclones were almost the same in both the cyclones.

A maximum wind speed of about 140 mph was reported from Chittagong port.

(f) Cyclone of 1970: The cyclone of 12th November 1970 is the most disastrous in recent times. It affected the southern regions of Barisal, Patuakhali, Noakhali and the islands of Hatiya and Manpura. The accompanying storm surges were upto about 25 feet in height. Almost 100% of the kutcha and semi-permanent houses were destroyed in the affected areas. The extent of damage indicates that the maximum wind speed was more than 120 mph.

3.3.3 Probable Areas of Attack by Cyclonic Storms in Bangladesh

The coastal areas of Bangladesh are the most vulnerable to cyclonic storms originating in the Bay of Bengal. The southern parts of Barisal, Patuakhali, Noakhali and Khulna districts and the western coast of Chittagong have suffered extensive damages in recent cyclones. The severest damage is caused in the off-shore islands of Hatiya, Sandwip and Manpura, which are often completely inundated by storm surges accompanying the cyclones. Areas of Dacca and Comilla districts are also affected but the intensity is less severe than in the southern regions.

Fig. 8 shows the probable storm tracks in different parts of the year and Fig. 9 shows the track of a typical cyclonic storm with maximum wind velocities in different regions.

3.4 Tornadoes

Tornadoes are the most destructive of all storms. They generally occur on land during the warm season of the year in flat areas, where there are few topographical barriers to impede their movement. The approaching storm may be recognized by a dark funnel-shaped cloud whose small portion extends downwards to the earth's surface. Usually such storms cover a narrow path of upto about half a mile in width and their force is spent in 20 to 100 miles of travel. The major flow of the air in motion at ground level during a tornado is basically circular and translational at the same time. The average translation speed is about 50 mph but the peripheral wind velocities are much higher. In 1961, the Task Committee on Wind Forces of the American Society of Civil Engineers concluded that the peripheral velocities would be in excess of 300 mph. However, maximum wind speeds upto about 500 mph have been estimated by some authors.

One of the severest tornadoes in recent momery hit the outskirts of Dacca city in April 1969. A textile mill at Demra, about 10 miles from Dacca, built of brick masonry walls with C.I.sheet roofing on steel trusses was completely destroyed. It is estimated that the maximum wind speed in the tornado was in excess of 150 mph.

4. PRESENT DESIGN CRITERIA

Most of the existing houses in Bangladesh have never been designed from a structural point of view, but their form and use of various materials have evolved over decades of experience and tradition.

For permanent and semi-permanent structures, a very popular form of construction uses steel trusses or timber trusses as the load carrying element of the roof. Corrugated galvanized iron sheets are commonly used as covering although in some cases corrugated asbestos cement sheets are used.

The trusses are designed to withstand wind forces which were usually calculated in the following way:

If V is the speed of wind in mph for which the structure is to be designed, the pressure p in lbs/ft^2 is taken to be

$$p = 0.003\, V^2$$

Duchemin's formula for sloping roofs was then used to calculate the component of wind force normal to roof surface

$$p_n = p \cdot \frac{2 \sin \phi}{1 - \sin^2 \phi}$$

, where ϕ is the angle of inclination of the roof with the horizontal.

Use of the above formula implies that wind forces act only on the windward slope of a roof and ignores the effect of suction in the leeward slope.

However, most of the structures designed to withstand wind forces calculated from the above formula with a wind speed of 100 - 120 mph have withstood the forces generated by severe cyclones. It is worth noting that no account is taken of vertical uplift forces which may be generated by the cyclone.

Current design practice, however, uses a more realistic pressure distribution. In the absence ofaunified code of building practice in Bangladesh, most of the 'permanent' buildings are designed either according to the British Standards Code of Practice No.3 (Chapter V) 1952 or according to American Society of Civil Engineers report on Wind Loading (1936).

The B.S. Code recognises the influence of roof slope as well as the height to width ratio of the building and the recommendations are based on results of wind tunnel tests on scale models carried out at the National Physical Laboratory.

The A.S.C.E. recommendations give wind pressures for a given wind velocity with the angle of inclination of the roof as the only variable.

The velocity pressure is taken as $q = 0.002558\ V^2$ where q is in lbs./sq.ft. and V is in mph.

The leeward slope is assumed to be subject to a suction of 0.6 q for all slopes whereas the windward slope pressure (or suction forces) are given by the following expressions:

$$\phi \leqslant 20^0 \quad : \quad p = -0.7q$$

$$20^0 \leqslant \phi \leqslant 30^0 \quad : \quad p = (0.07\,\phi - 2.10)q$$

$$30^0 \leqslant \phi \leqslant 60^0 \quad : \quad p = (0.03\,\phi - 0.90)q$$

$$\phi \geqslant 60^0 \quad : \quad p = 0.90q$$

(Positive values of p mean pressure and negative values mean suction)

The above pressures and suction forces are assumed to act in a direction perpendicular to the surfaces on which they act.

The internal pressures developed in buildings with openings are not usually considered in the design of such structures.

The most commonly used slope for pitched roof ~~in~~ is 4 span to 1 height or 2:1 slope. This gives an inclination of 26.5^0. Both the windward and leeward slopes, will, therefore, be subject to suction forces. This calls for secured fixing of the rafters to the walls and the covering sheets to the rafters. A wall plate runs on the top of the walls parallel to the ridge and rafters are generally nailed to it. The roofs usually have projections at the eaves to ensure that the rainwater from the roof does not drip down the walls. The presence of these projections may alter the distribution of wind pressure on the roof and there is a possibility of increase in the suction force due to these projections.

It has been observed in recent cyclones that most of the failures of roofs were due to the wind having gone inside, pressed from underneath and lifted up the roofs.

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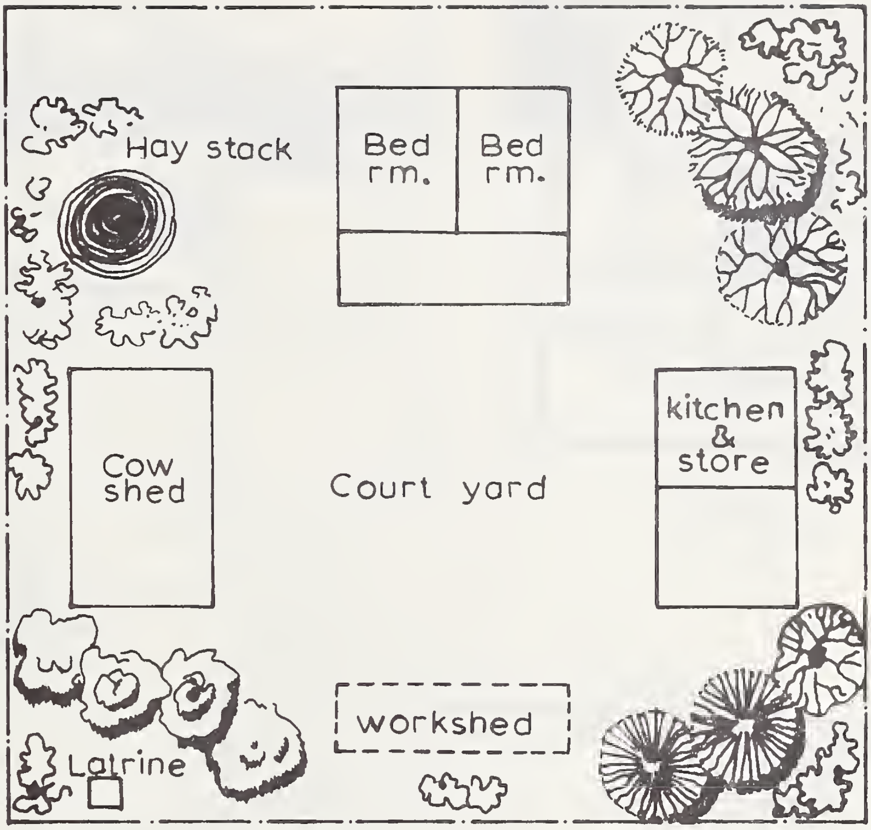


Fig. 1 Lay-out of a typical Rural house

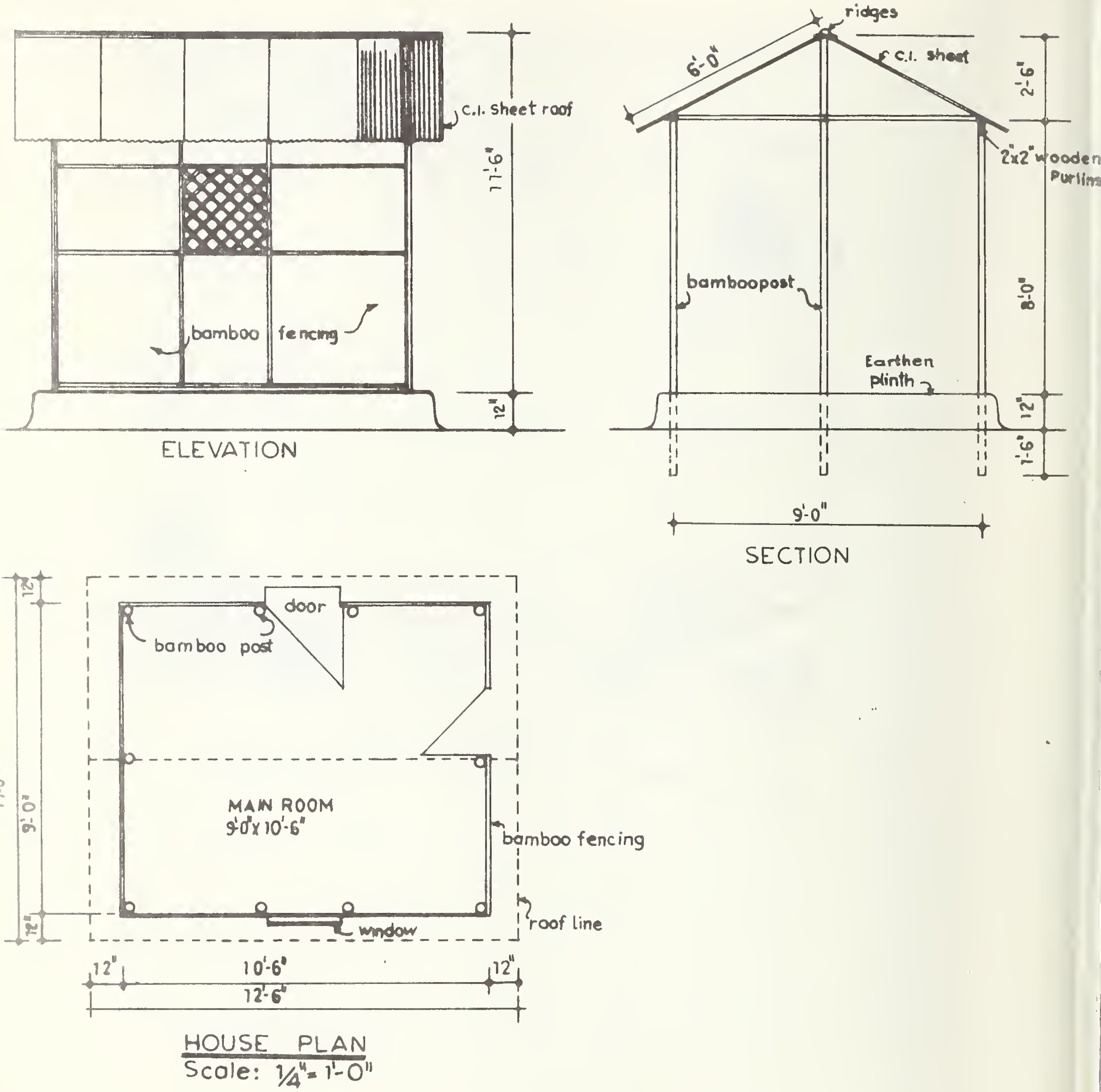


Fig. 2 Details of a typical Rural house with bamboo

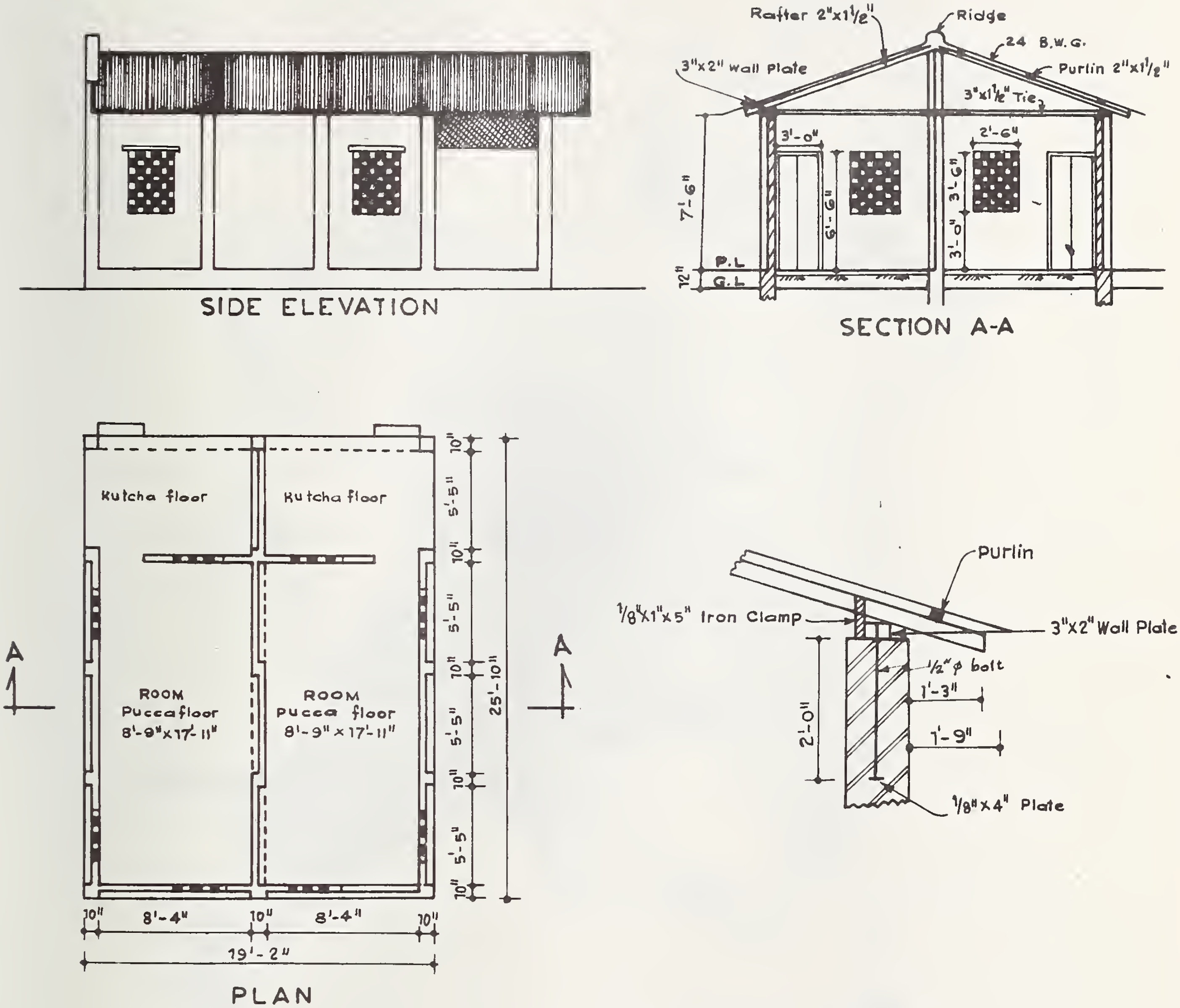


Fig. 3 Details of a typical low cost house with brick walls

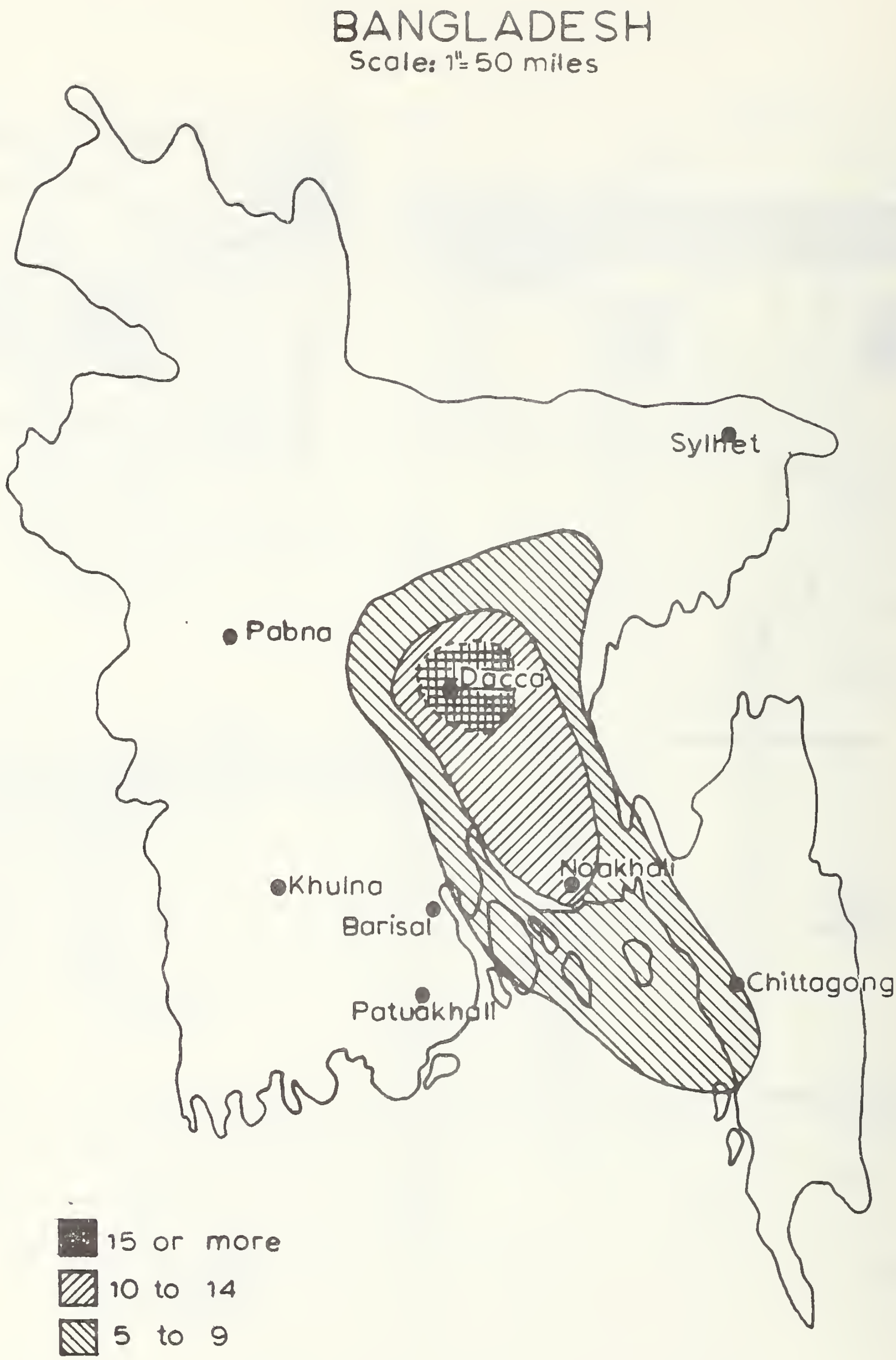


FIG. 4 Area distribution of nor'wester squalls (March)
(Figures indicate total no. during the period 1955-61)

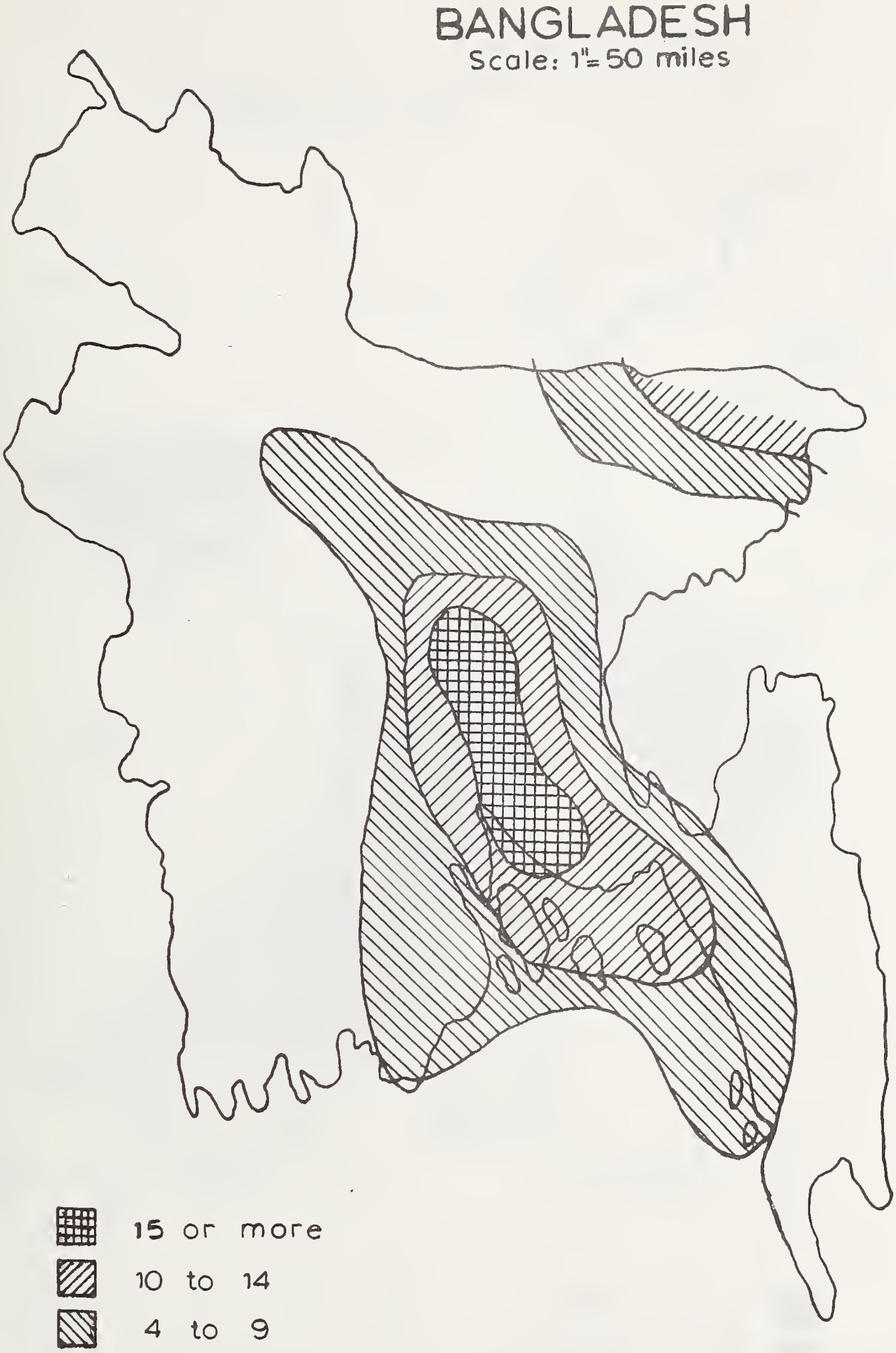


Fig. 5 Area distribution of nor'wester squalls (April)
(Figures indicate total no. during the period 1955-61)

Fig. 6 Area distribution of nor'wester squalls (May)
(Figures indicate total no. during the period 1955-61)

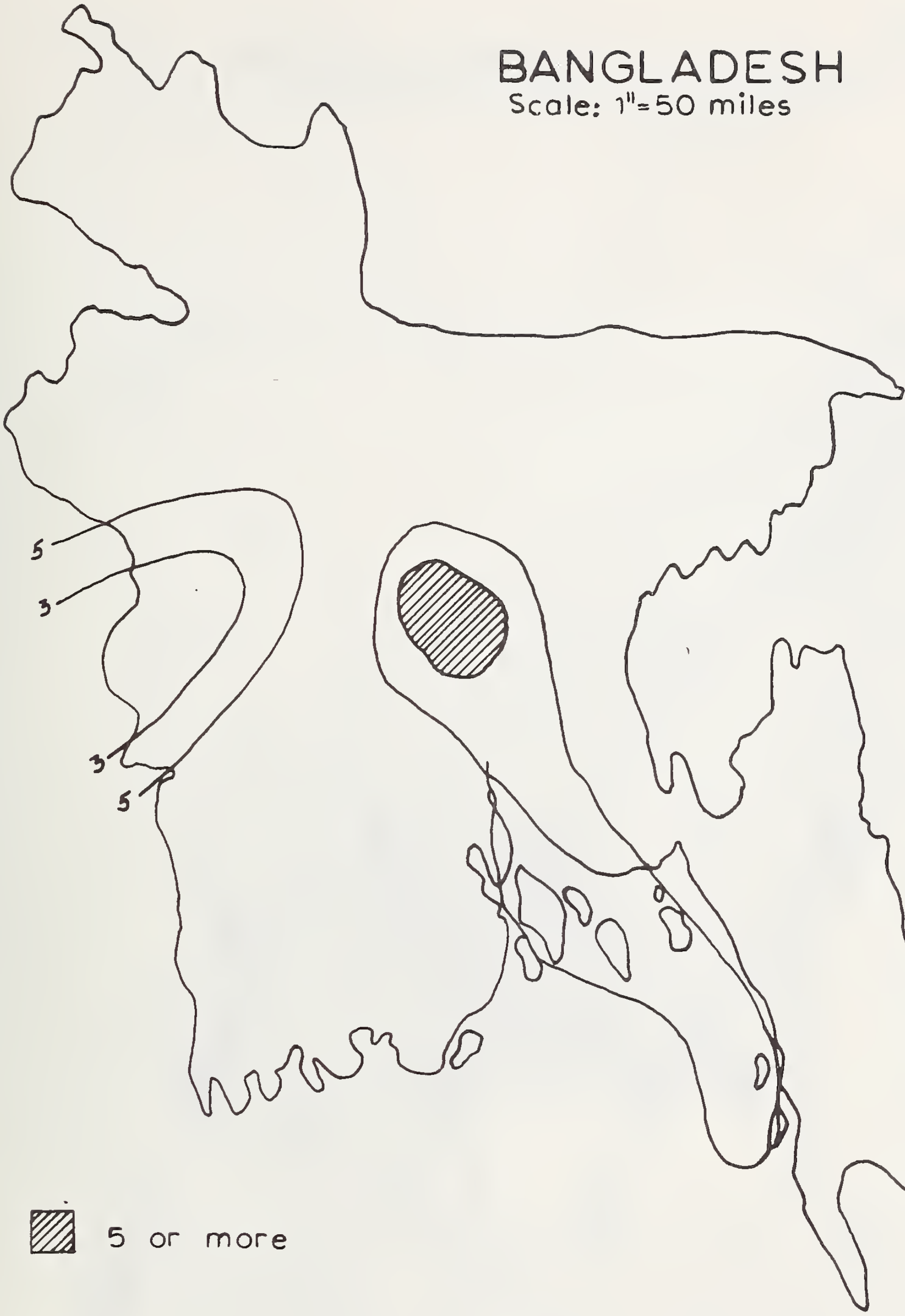


Fig. 7 Area distribution of nor'wester squalls (June)
(Figures indicate total no. during the period 1955-61)

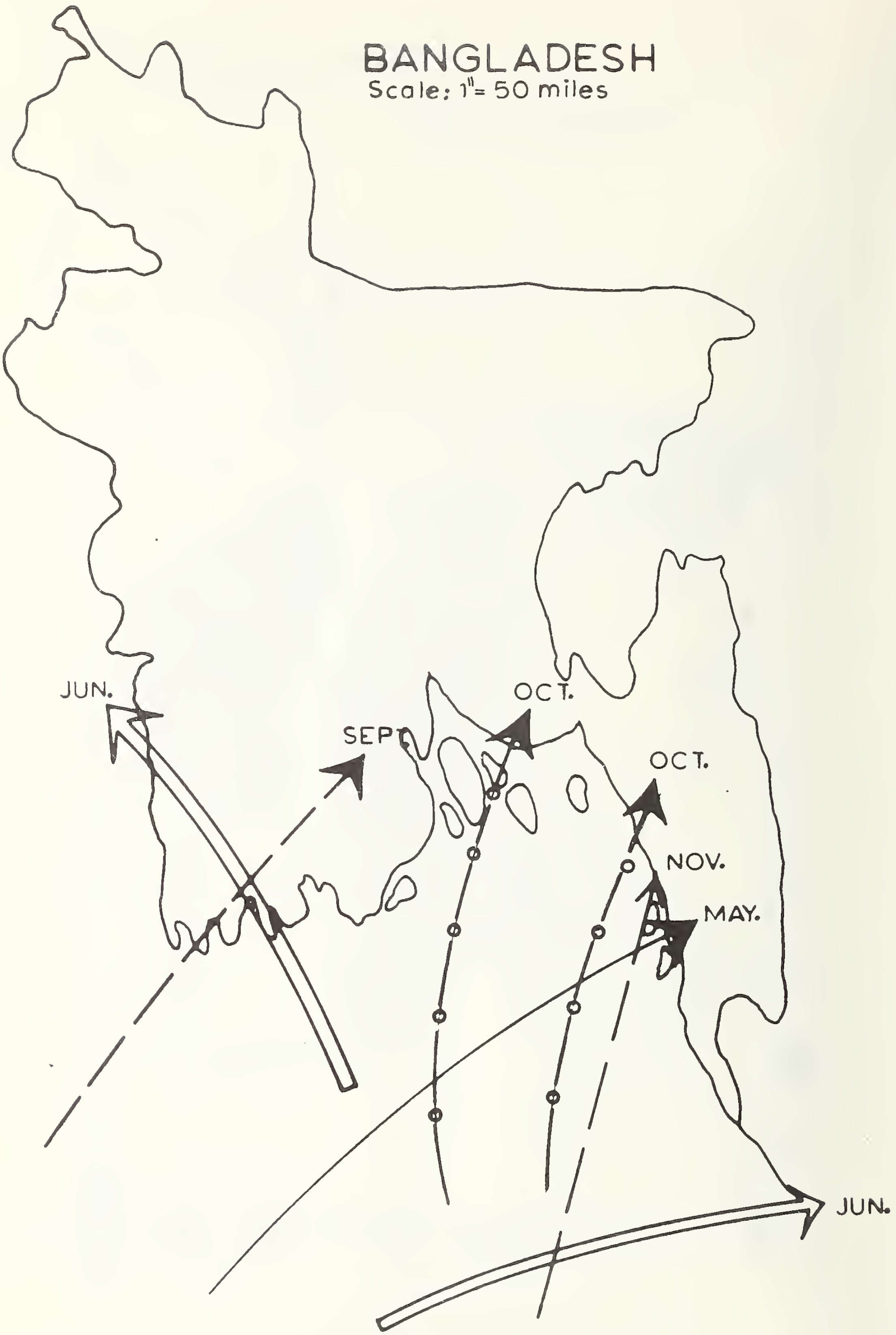


Fig. 8 Storm tracks in the Bay of Bengal Affecting Bangladesh

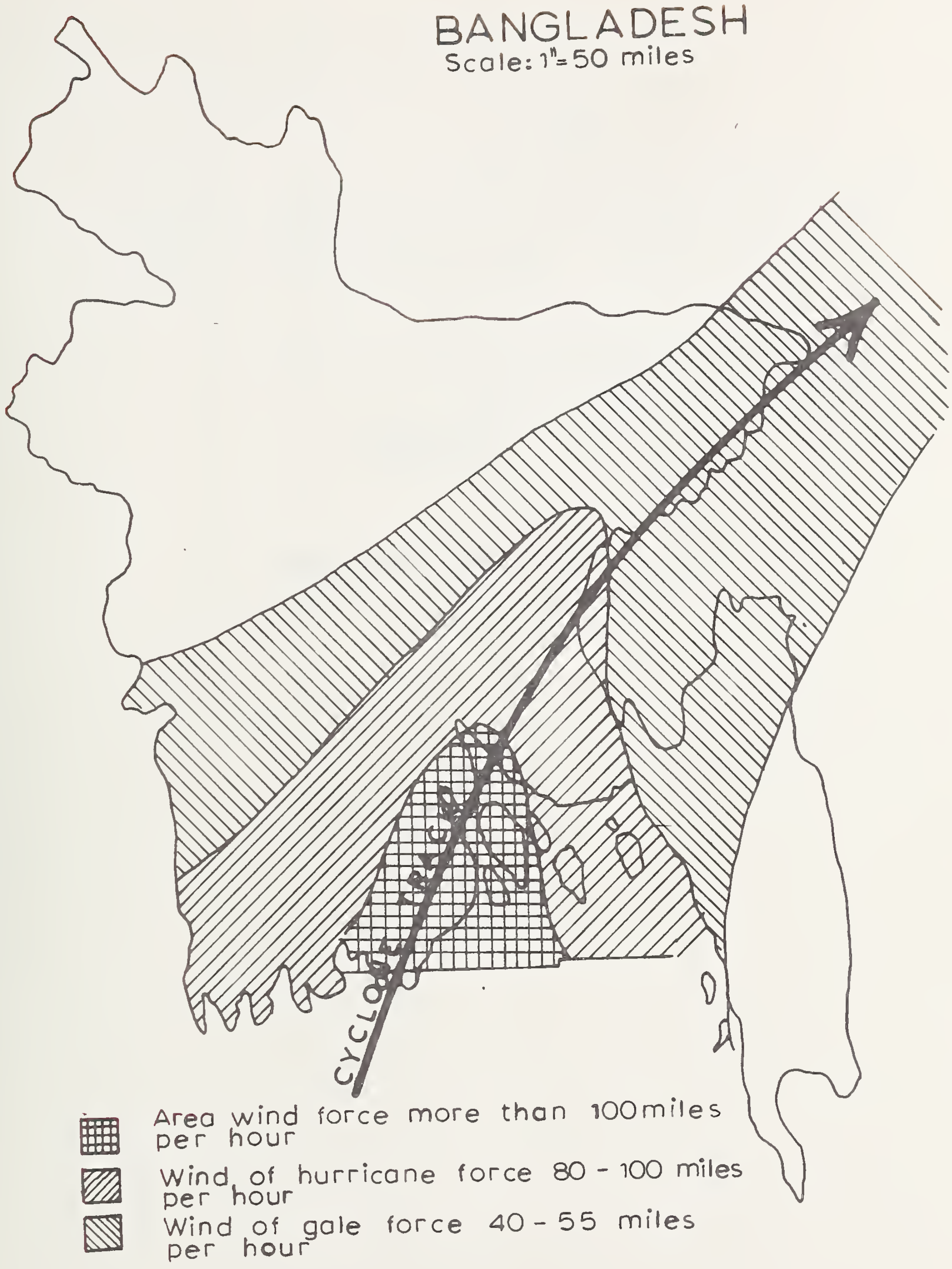


Fig. 9 Typical cyclone in Bangladesh
(9th May, 1961)

APPENDIX E

HOUSING IN EXTREME WINDS

Housing in extreme winds

A study of the Socio-Economic and Architectural Aspects of Low-Rise, Low-Cost Housing in three High-Wind Geographic Areas.

Submitted to the Office of Federal Building Technology, Center for Building Technology, National Bureau of Standards, Washington, D. C. 20234

Report

Preamble

Windstorms are considered by most sources to be the most destructive of natural forces. A survey of damage inflicted in the Philippines, for example, by cyclones alone between 1948 and 1971 shows an average of fatalities close to one thousand persons per year, and annual property losses of some $10 million. In Bangladesh, the infamous typhoon of 1970 killed a far greater number of people through the floods it generated.

This draft report reviews the socio-economic and the architectural aspects of low-cost, low-rise housing in three developing countries subject to extreme winds: the Philippines, Jamaica and Bangladesh. It is based on a review of 5 key and 9 supporting publications listed in the References section of the report.

A final report will include a review and study of many additional documents, and from discussions and correspondence with appropriate officials in the above developing countries; the text will be adjusted in the light of that review.

The group of basic documents that are the basis for this draft report none the less provide a good solid profile of housing in those three developing nations.

For the reader's convenience, the information is arranged under two headings:

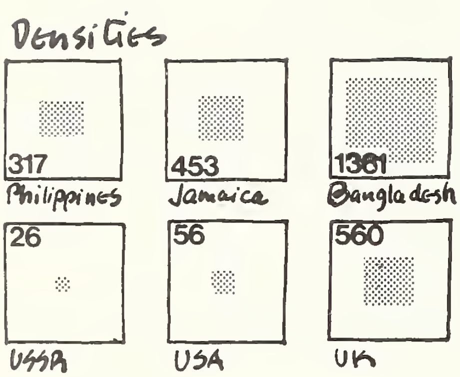
1. Socio-economic factors in the three countries.

2. Housing characteristics.

Contents

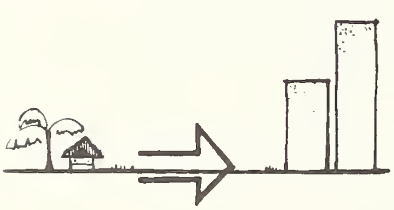
General data

Socio-economic factors



The safety aspects of low-cost, low-rise housing have always been at the mercy of tradition. Cultural patterns, socio-economic restraints and technical expertise (or lack of it) can both enhance and be a severe barrier to innovation. Thus, understanding a nation's socio-economic profile, the characteristics of its housing and its administration, is a vital matter.

The comparative socio-economic profile as outlined in Table 1 tells us a good deal. For one thing, all three countries have a very high density of population. It ranges from 317 persons per sq. mile in the Philippines to 1,361 per sq. mile in Bangladesh, one of the highest in the world. Compare this with the U.S. density of 56 and the USSR, which has only 26 persons per sq. mile.



These figures do not tell us the whole story. In all three of these developing countries there is a strong migration from the country to the cities. The major cities in all three have teeming squatter towns.

In the Philippines, one person in 16 lives in squatter towns, which as of 1970 were increasing at the rate of 12 percent a year. In Jamaica, squatter towns are illegal but growing.

Table 1: COMPARATIVE CHART OF SOCIO-ECONOMIC CHARACTERISTICS

	Philippines	Jamaica	Bangladesh
Population (million)	36.7(1970)	2.0(1972)	75.0(1972)
Population increase (% per year)	3.01	1.46▲▲	2.6
Density (persons per sq. mile)	317*	453	1361
Squatter towns common	YES	YES	YES
Squatter population increase (% per year)	12.0	N.A.	N.A.
Percent of population in slums/squatter towns (%)	5-6**	N.A.	N.A.
Annual housing need (units)	100,000(urban) 370,000(rural)	14,400 N.A.	N.A.
Urban population (%)	32	34.5	10
Rural population (%)	68	65.5	90
Average household size (persons)	6.0	4.0	N.A.
Typical number of rooms in household	2.0(Manila:3)	1.0▲	1.77△
Number of persons per room	2.7(median)		3.2(average)
Population under 15 years (%)	N.A.	47***	N.A.
Population that can afford adequate housing			
.open market (%)	12	N.A.	N.A.
. government subsidized (%)	23	N.A.	N.A.
. cannot afford (%)	65	60-70	72

*USA=56. United Kingdom = 560. USSR=26
**Major cities: 10-45%
***Based on limited sampling. See ref. 8
△Rural: but 53% of rural households have one room only

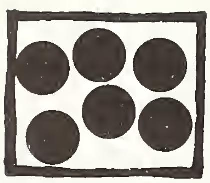
N.A. Not available
▲ 42% of all urban dwellings have one room only, compared to 24.9 for rural (Ref.4) ▲▲Ref. 4 puts it at 2.7, but this appears to ignore emigration.

Note:
This table is designed to give general comparisons only, based on preliminary analysis of available information from references listed at the end of this report. Readers should keep in mind that survey methods and frequency vary from one country to another.

Over and above all this, the populations have been rising at a steady rate, from a low of 1.46% per year in Jamaica (which has suffered emigration of its most skilled workers) to 2.6 percent per year in Bangladesh and slightly over 3 percent in the Philippines. Furthermore, even though infant mortality has been dropping and lifespan rising through improved health care, citizens in these countries tend to live less long and this has led to a very high proportion of youngsters under 15 years. (For example, in a not untypical part of Kingston, Jamaica, known as Delacree Pen, nearly half the population is under 15).

By tradition and necessity this has forced onto housing such normally distinct functions as day care, education and play to accommodate this many youngsters.

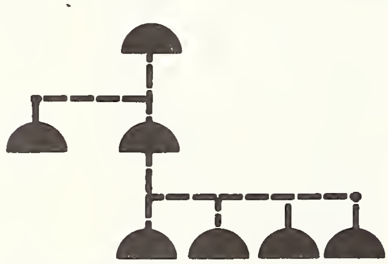
- There are other ramifications to these population patterns. The economics in all three countries are highly labor intensive, so that children are in the Philippines, for example, seen as an economic asset. Family planning efforts designed to bring population more in line with food and other resources run up against this barrier. This is especially true in rural areas where agriculture is the main source of income.



The Philippines average 6 persons per household

Despite city migration, most of the populations are still classified as rural (68% in Philippines, 90% in Bangladesh, over 60% in Jamaica).

- Several other socio-economic factors stand out strongly. Foremost is the tremendous over-crowding of available housing. In the Philippines, average household size is 6 persons. The typical household has only two rooms (in Manila three). The median number of persons in a room in the Philippines is 2.7. In Bangladesh, the average number is 3.2. It is common for several generations (so called "extended families") to make up a single household.



A household often consists of several generations

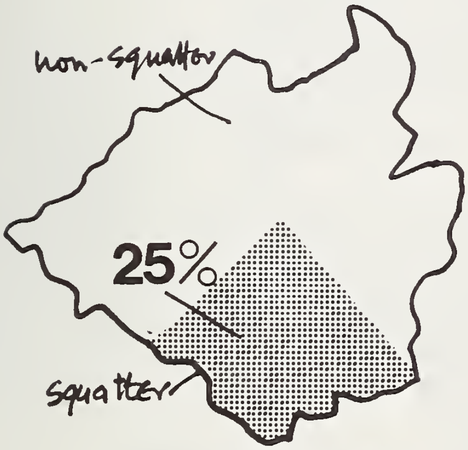
- There are these other factors: shortage of funds, markets not large enough to stimulate economics of scale in prefabricated construction, undeveloped transportation and distribution systems, a shortage of skilled labor and, by and large, low standards of workmanship.

Round shapes ignored needs and traditions of occupants

Another factor is the resistance by the population to certain construction materials and systems. Adobe blocks are not considered "noble" when compared with brick or stone in many countries.

An experiment carried out in Peru some years ago using igloo-shaped houses made of polyurethane were rejected because families were unhappy with the lack of corner areas where one could put "things out of the way", predictably bad interior acoustics, and a lack of normally defined property lines in which to fence in animals. They were eventually abandoned.

Most families cannot afford housing on the open market and in many cases not even housing subsidized by the government. With some exceptions, private housing is better so far as wind resistance is concerned, but those who cannot afford housing <u>of any kind</u> range from 65% in the Philippines, 67% in Jamaica up to a high of 72% in Bangladesh. Consequently, the very poor must fall back on government public housing programs (which are modest in all three countries) or build their own housing according to demonstrably unsound wind-resistant principles.



- Squatter settlements

Squatter settlements tend to be the fastest growing areas in cities and often cover a quarter of the city area. They can be put up fast to meet demand. In essence, it is the squatters who are providing a housing solution, and the sense of community and morale are known to be high.

"SITES & SERVICES" help improve squatter settlements

A policy that is becoming more and more accepted is to focus on improving squatter settlements. This is done by providing so called "<u>site and services</u>". Land, water supply, electric power and waste disposal are provided. Better structures come along with appropriate help as the settlement becomes more established. This way, self-help is stimulated.

● User requirements

Research into user requirements on low cost housing can help evolve designs that are not only adequate technically but also meet socio-economic needs. Clearly, as most current designs do not meet proper wind-resistant criteria, new designs, quite possibly using unfamiliar building materials and methods, will have to be used. As there is no hard data on user acceptance of such designs, this information must be sought out.

Mrs. Tarja Cronberg (Ref. 1) uses these sources of information: statistics of the country's population (death rate, size of families, average income, etc.); interviews with local builders, architects, and construction workers; and observation.

She divides the information into two classes: user characteristics, and user activities.

Under user characteristics, she determines the users' typical physiological and psychological characteristics, plus such socio-economic characteristics as family size and structure, mobility, identification with a particular ethnic, religious or geographic group, and educational background.

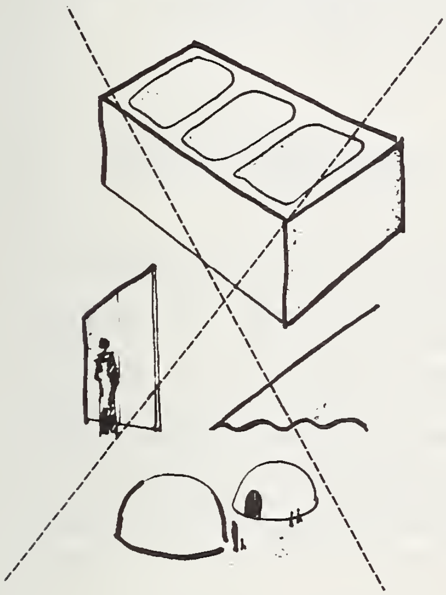
Under user activities, Mrs. Cronberg identifies 9 headings:

- Sleeping
- Food preparation
- Storage
- Personal sanitation
- Work
- Recreation/play
- Social (receiving of guests, etc.)
- Identification/participation
- Learning and orientation

She now feels that more information is needed in four areas:

- Health standards in existing environments.
- Need for personal space and privacy in overcrowded housing.
- Social activities in the neighborhood and community.
- Activities of specific groups such as children.

New construction materials are rejected, at least at the start



This determination, done with aid of local experts, is clearly important in arriving at a clear, objective set of criteria of how families in a given milieu are likely to respond to innovative, wind-resistant design that is new or unfamiliar.

● Acceptance and rejection

The Cronberg study also indicates that innovative housing designs and new materials are widely accepted in the Philippines, even by low income owners. This is true especially where the owner is able to make small individual changes on his house after he moves in. Most practicing architects and engineers in the country are said to accept new materials which have the needed properties and do not cost too much.

The opposite has been the experience in Peru. Peru is not a part of this report, but is a useful object of study nevertheless. New construction materials always run into a strong initial period of rejection, and only a few have survived this reaction and kept a place in the market (Ref. 1). Examples of th is rejection include:

- ○ A hollow block based on a Swiss patent and made up of mineralized vegetable fibers encased in cement.
- ○ A panel-sized product made of expanded gypsum.
- ○ Corrugated sheets of glass fiber and polyvinyl chloride (PVC). Plastic bathtubs and basins.
- ○ Sprayed polyurethane igloos developed in Germany for use after an earthquake (as discussed earlier).

The few construction materials (other than indigenous materials) that are broadly accepted are corrugated sheets of galvanized steel or asbestos cement. The former, despite poor thermal and acoustical properties, are popular because they are strong, do not weigh much, and can be easily and cheaply transported on the backs of mules. The latter, though superior in thermal and acoustic terms, are quite fragile, and the resulting higher breakage also drives up costs.

●Attitudes to prefabrication

Another Peruvian study with clear lessons for other developing countries is a 1962 survey of public attitudes towards prefabricated housing. It was carried out by students at the Architecture Department of the National University of Engineering.

Prefabricated look-alikes slow down acceptance

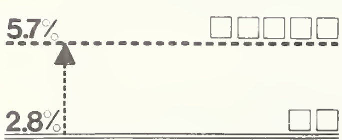
Consumer interest was found to be low because prefabricated houses cost only a little less than brick and concrete houses and a good deal more than adobe houses; they looked too uniform; and the public did not really appreciate the savings inherent in the shorter construction time.

As for builders, they found that a restricted market led to high sales costs; financing was difficult; and complex transportation sharply raised construction costs outside the immediate area of Lima.

●Housing economics

Housing approaches in developing countries have been critized on two grounds.

First, because housing deficits are computed without taking into account the values or preferences of those to be housed. Secondly, because the traditional solutions to housing deficits have turned out to be well beyond current capital investment rates. Even in countries that anticipate a high rate of growth, the competing demands of agriculture, industry, and other programs reduce the funds available for housing to a level far below needs (according to a report by William F. Reps, Ref. 1).



In the Philippines, doubling capital investment would fill housing demand

In the Philippines, for example, demand for new dwellings would require a capital investment about 5.7 percent of the gross national product; in fact, in 1967 only 2.8 percent was so invested. As a result, slums and squatter towns grew - 10% of the population of Manila and 30% of the population of key other cities lived in squatter areas.

Yet the "sites and services" solution referred to earlier has been found desirable, especially in the Philippines, where self help (known as "bayanikan") is widely accepted in the building of dwellings. It is discussed in greater detail later in this report.

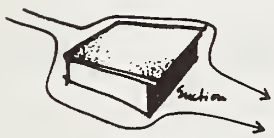
Housing characteristics

Four ingredients of housing are discussed. These are: siting, design, construction methods, and materials.

Siting

With the relatively primitive wind risk maps, little regard has been given to the placement of houses in relation to danger. Good site location or orientation linked to local terrain and natural cover can be, but usually has not been, determined from historical wind data. This data provides the frequency, velocity and direction of the prevailing winds, especially in their extreme form. Hence, windstorm damage can be cut back a great deal by placing buildings so they are protected by hills, stands of trees and other natural elements.

Design

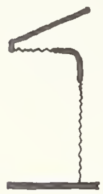


Windstorm resistance can be notably improved by various simple measures. These include horizontal bracing of certain types of roofs over houses made of adobe masonry and other small unit construction; a more rational disposition of openings in bearing walls; reinforcement of critical areas of a building subject to being overstressed; and the strengthening of connections at joints.

All this may not be enough. Special studies on how turbulence in a storm is distributed are required.

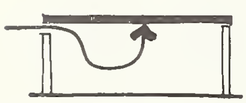
Large overhangs invite problems

It is possible to make buildings more wind resistant by improving connection details, by learning more about the effects of wind loading on buildings, and by avoiding shapes or arrangements of buildings in groups so as not to cause undesirable aerodynamic effects. For this, theoretical as well as experimental/wind model study research is currently being conducted as part of this project's research activities.



Rough surfaces, smooth transitions aid behavior in wind

Certain design elements can be very unfavorable. Sharp edges, low-pitched roofs, large overhangs and improper grouping of buildings will cause problems. Textures, too, are important. According to R. M. Aynsley (Ref. 1), the aerodynamic behavior of buildings can be improved by providing rough surfaces or ribs on the exteriors of walls. Grass roofs have allegedly served to relieve pressures, as have smooth transitions between planes of a house.



Openings can cause dangerous internal pressures

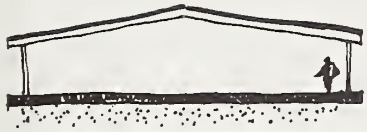
Unfortunately, the internal pressures developed in buildings with openings are usually not considered in design. Roof failures have been caused by wind which penetrated the structure and pressed up on the roof from beneath.

Certain configurations (such as cylinders), or igloo-type structures, are far more stable than box-like structures, but in the few places where they have been tried the cultural attitudes of the population caused them to be abandoned.

In Bangladesh, a revolutionary type of design has been tried, using materials and shapes new to the country. These are integrated roof and wall elements, made up of units consisting of polyester resin, and jute. They have performed well in winds but their final social acceptance is still unknown.

Construction technique

In developing countries, it is often hard to separate design from construction. By and large, typical characteristics can be summarized as follows:



Mat footings spread loads over a greater area

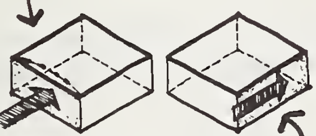
- Foundations: Load transmission to soil becomes less critical since low-rise dwellings of one or two stories do not generate a high dead load. Where flooding is not common, rectangular footings of plain or reinforced concrete or gravel are used.

In flood-prone areas houses may be built on stilts (e.g. bamboo) driven into the ground to the appropriate depth. Mat footings are sometimes used on unfavorable soil.

In flood-prone areas, stilts may be driven to solid ground

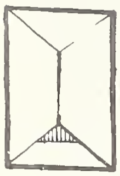
- Walls: Walls are either structural or non-structural. When non-structural, they merely serve as an in-fill for a frame and their constribution to the overall structural resistance of a building to wind pressure should be minimal.

Structural walls of wood, concrete, burnt clay or soil-cement composition are the most common in low-cost housing construction. Walls are either monolithic or small unit masonry type, where units are layed in staggered courses, usually in beds of mortar. Clay brick and title, adobe brick and concrete block are the most common masonry units. Quality control in making these units, as well as the mixing of the masonry mortar bed, can make or break the structural strength of the total wall.

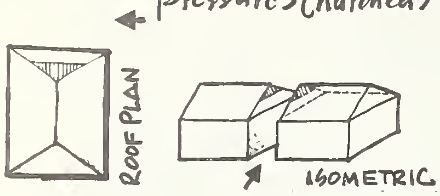


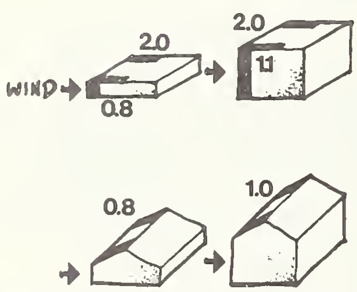
Wind stresses on walls are either plain bending or in-plane stresses. Out-of-plane pressures (when wind acts directly at right angles to a wall) cause deflection and eventually failure. Tornadoes common in Bangladesh have pressure drops so strong and sudden as to cause an actual explosive action of the wall.

Builders sometimes use an ingenious network of cocoanut matting and cables to anchor roof down.



Presence of an adjacent building creates zones of increased pressures (hatched)





"Shaded" areas are zones of maximum wind pressure. Numbers are a measure of relative intensity. Note effects of height and roof pitch.

In-plane stresses are developed in walls which act as shear-resisting elements within the building, the plane being parallel to the wind direction.

Moreover, incorrectly planned wall openings may be critical, especially at corners. In any case, conditions where two walls intersect or between walls and foundation or walls and roof, require special design due to the high stresses at those joints.

- Roofs: Roof pitch is an important design element for good wind resistance. The magnitude of positive or negative wind pressures on roof surfaces is directly related to roof pitch. Wind affects roofs in two ways, direct and indirect.

Direct local effects are made up of high positive pressures (or suction) over local areas of the roofs. This may lead to damage to roofing -- whether shingles, tiles, corrugated sheets, etc. Overhangs, common for sun protection, are especially liable to wind damage, as they undergo positive pressure from below and suction from above.

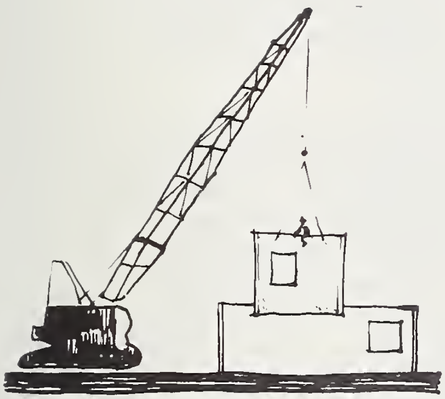
Indirect effects occur when wind loads are transferred to lateral walls, causing stresses. If this mix of pressures on the roof is strong enough, the capacity of the connections will be exceeded and the roof will be lifted off. This brings additional danger since every roof has a structural role as a horizontal diaphragm. This transmits wind-loads from the front to the side walls. If a roof is off, both frontal and lateral walls may collapse.

Flat roofs (especially with overhangs) are more subject to wind damage than roofs with a steeper pitch.

- Prefabrication

Any method that will produce housing more effectively must, at least in its first phase, make the best use of available local labor. And the choice and control of the dwelling environment resulting from any industrialized housing must not conflict with individual uses, traditional preferences and outlook.

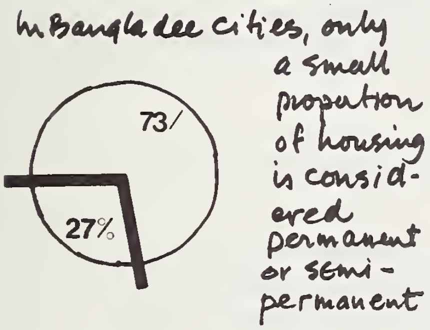
In the Philippines, few companies make prefabricated components, including a private firm which produces wall panels and roof trusses, and a government firm which makes lightweight concrete panels. Filipino builders are said to recognize the savings which prefabrication offers, and feel they can make it work. Their problems at present are lack of adequate financing and too small a volume.



In Bangladesh, reinforced concrete shell roofs in a shape of a hyperbolic paraboloid have been used, using one inch pre-cast reinforced concrete elements, with concrete connections made on site.

In Jamaica, the most common form of industralized construction consists of large precast concrete panel systems. Wall and roof panels are lifted and assembled by crane. Other forms of prefabrication in Jamaica use precast posts combined with precast concrete or timber beams, with concrete infill "boards" between posts.

Materials

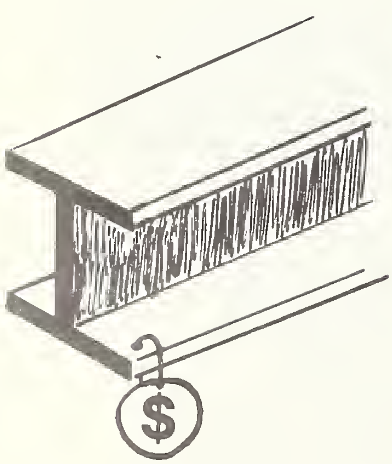


The most commonly used materials of construction are those that are found plentiful locally and require little or no sophisticated equipment to convert into building materials. In Bangladesh 90% of rural houses (and 90% of Bangalis live in the country) are made of bamboo, thatch and mud. Two out of three houses use the same materials for roofs. Only 1 percent of these houses have walls of concrete, baked brick or stone, and these are mostly staff quarters built by the government. The remaining roofs are of galvanized corrugated iron or corrugated asbestos cement sheets. In its cities, only some 27% of housing is considered "permanent and semi-permanent."

Following are other common materials used in the three nations:

- a. Soil: Natural earth is about the most common material used. Sun-dried adobe bricks have been the basic masonry units for low-cost housing. These bricks are often untreated against penetration by water. More recently adobe brick has been stabilized by the addition of asphalt. This boosts the durability and water-repellent properties and is a major breakthrough. The social acceptance, however, of adobe, stabilized or not, is still not high.

- b. Wood: Wood, while popular, easy to handle, versatile and strong in tension, is not everywhere available. It is useful as a framing material. When not available in milled, dimensioned form, it is replaced by non-dimensioned lumber -- as cane, bamboo, palms and thatch for structural enclosure and roofing purposes. Cane, bamboo or split wood are often used to reinforce adobe masonry. Major drawbacks are moisture, fire and insect infestation. Chemical preservatives which can be produced in developing countries can prevent this kind of danger and deterioration. Also, chipboard products are used for walls and ceilings.



- c. Concrete: Where sand, cement, water and various additives are plentiful, concrete is a logical and widespread local building material. Weak in tension, it can be reinforced by a local material such as bamboo as well as by costlier imported steels and fiber glass. Concrete reinforced with a wire mesh and known as ferro-cement has been used with very little supervision in some countries, and the materials needed are cheap and usually readily available.

- d. Brick and concrete block masonry are common.

- e. Steel: As a capital-intensive material, steel is rarer. Its most common use is as a roofing material (in the form of corrugated sheets of galvanized steel or aluminum), and to a small extent as connectors for bolting and anchoring the various structural elements.

- f. Plastics: Plastics are a highly adaptable material. Depending on the choice of components, they can be tailor-made to adapt to most structural and enclosure needs of housing. Not enough is known about the weathering properties of plastics in outdoor use (as compared to traditional materials), especially in tropical areas such as those in this study. Use is most advanced in the Philippines, which also is one of the chief plastics producing countries in the Far East. They use native as well as imported raw materials and processing machinery. Several important tests underway in Bangladesh are described later in this report.

  Still, plastics are resisted as a new and unfamiliar material. Solid-seeming and demonstrably durable materials are preferred. Plastics are likely to be more widely accepted in the future as they penetrate the private, for-profit housing market and non-housing uses such as clinics and schools. They can then be observed and their performance seen by those who presently must rely on housing provided by their governments or through their own labors.

- g. Indigenous fibers, such as palm leaves, coconut husks and peanut shells have served as filler materials in spaces between structural supports or between roof rafters; and grasses such as jute and hemp can be used as reinforcement for concrete or adobe masonry.

Review by country

The preceding chapter described the overall picture of housing in the three countries of the Philippines, Jamaica and Bangladesh in terms of socio-economic profile and physical housing characteristics. The three sections that follow are based in greater detail on documents developed specifically to describe conditions in each of these three countries. In this sense, this chapter should be seen as an extension of the preceding one.

The Philippines

The Philippines is said to have the highest frequency of tropical storms in the world. Average annual frequency is 20.

Filipinos have always depended on water (whether river or salt) for food, transportation and for watering their fields. This is still the pattern in rural areas. This attachment to low land and water logged areas led to a unique type of dwelling, with a raised floor on stilts. Communal activities centered around the houses of the village elders, who also were religious and judicial officials. This organization has today been formalized into the barrio, which is the lowest political unit of government.

- The Filipino family and its housing needs

The family is the strongest unit of society. Typical of the family system is bilateral kinship. This is extended often as far as the third or fourth cousins. Families with at least three generations are common. In times of crises, family members are expected to share board and shelter with less fortunate members, especially parents in old age and widowed relatives with children. The family acts as the economic unit in rural and urban areas. Children are seen as economic assets. A large family is regarded as a means to social security.

● The community

The term "barrangay" exists to define this conscious sense of belonging. It is a pattern into which the activities of the family units are woven. Extended families exist not only in the country but also in cities. Their percentage in low income areas around Manila is said to reach 55 percent. Family size ranges from 7 to 11 in these cases, with at least 18 percent made up of 9 members or more.

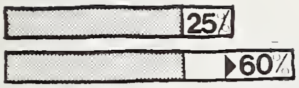
Only 12 percent of urban families can afford housing in the open market; 23 percent can afford home ownership provided they receive long-term financing at low interest rates. The remainder cannot afford adequate shelter even at reduced rates.

Ranking cities in the Philippines have between 10 and 45 percent of their populations in slums or in squatter areas; the national average is 5 to 6 percent. Filipino squatters are not said to be shiftless people, but well motivated and resourceful.

A study made by Jaime Laya, Remedios Balbin and Romulo Neri of the Agno-Leveriza squatters area of Manila (Ref. 10, part H) paints a grim physical picture. Eight hundred dwellings are crammed into two city blocks behind a prosperous seeming facade of solid apartments and houses. Most structures are of one or two rooms, without running water or toilet. 11.5% of surveyed heads of household were unemployed, compared to a 1969 national average of 7.3%.

Yet the study team noted little active discontent; rather, they found an attitude of initiative, of moving on by one's own effort and enterprise. Education level was relatively high (7.1 years of schooling on average for heads of household, more than needed for the jobs they hold), and income level varied widely, from destitute all the way to families with a refrigerator, television set and telephone service.

Another study, by Mary R. Hollnsteiner (Ref. 10, part I) confirmed a sense of excitement among squatter families after they left a dull rural existence and moved towards economic opportunity in the city. One recommendation of this study, which looked into options for relocating Manila squatters, was to weigh with care any plan for moving families off to a site too remote from urban job opportunities.



Prices of construction materials have risen twice as much as all other commodities

The estimated annual need for urban housing alone averages 100,000 units -- to accommodate population increase, new family formations and replacement of squatter dwellings. The cost of land is high and this has a direct effect on the high cost of adequate housing. In addition, wholesale and consumer product prices grew sharply between 1970 and 1973. The average increase for all commodities was 25 percent; for most construction materials the figure was 40 to 60 percent.

This does not jibe with other, more optimistic reports which indicate that materials and skilled labor for conventional construction methods are said to be fairly available. The cost of delivering materials is reported low because production is spread throughout the country.

● Economic aspects

Only 12 percent of the population (with annual family income over $1490 -- U.S. dollar equivalent based on exchange rate of the Philippine peso as of August 9, 1974) can afford housing on the open market. (Ref. 10, part A).

23 percent can afford to own a house if offered long term cheap financing with modest land, development and construction cost ($596 to $1489 annual income range).

The rest cannot afford shelter at any cost.

Investment in housing rose from 2.8 percent of GNP in 1967 to 4.0 percent in the early 1970's. But to meet the country's housing need of some 470,000 units per year, an allocation of 5.7% be required.

Yet the Filipino economy as measured by its GNP has risen at an average annual rate of 6.6 percent from 1968 to 1973. Average per capita income ($130 in 1970) also rose, and is expected to double in the next 10 to 15 years.

The amount a family can afford for housing varies chiefly with its income and location along with other lesser factors. For example, according to a study by Sixto L. Rojas III (Ref. 10, part F), a family with an annual income of $300 can afford a house 1.3 times its income, or $390. At an annual income of $450, it can afford a house of 1.8 times its income, or $805. This sets certain numerical limits on the cost of low income housing.

In addition, income varies in different regions of the country, with families in urban areas outside of Manila having a higher pattern of income than Manila and rural areas (Ref. 10, part F). All these economic aspects are important in determining realistic parameters for the design and construction of low-cost, wind-resistant housing.

- Housing characteristics

Some key housing characteristics are shown in Table 2. Note sharp differences between statistics for metropolitan Manila and for the Philippines as a whole. They are based on surveys by the Bureau of the Census and Statistics and by the Population Institute National Demographic Survey. They give little idea of the actual condition of the dwellings themselves.

Table 2: KEY HOUSING CHARACTERISTICS IN THE PHILIPPINES (Ref. 2)

Part 1. TYPE OF DWELLING UNITS BY STRUCTURE (PERCENT)

Type	Metro Manila	Philippines
Single Family Dwelling	57.6	78.9
Duplex	5.5	4.1
Accessoria	15.1	2.3
Apartment	8.1	1.1
Barong-Barong (shack)	4.4	5.4
Commercial Building	1.0	1.3
Other or No Response	8.3	6.9

Part 2. NUMBER OF ROOMS IN HOUSEHOLD EXCLUDING BATHROOM AND TOILET (PERCENT)

Type	Metro Manila	Philippines
One Room	11.3	14.1
Two Rooms	22.5	28.4
Three Rooms	23.1	25.7
Four Rooms	19.8	14.3
Five Rooms	8.0	6.5
Six Rooms	3.8	2.6
Seven Rooms	1.3	0.8
Eight or More Rooms	1.6	0.6
No Response	8.7	7.0

Part 3. DENSITY (PERSONS PER ROOM) WITHIN HOUSEHOLD (PERCENT)

Type	Metro Manila	Philippines
Less than one person per room	5.1	6.1
1.00 to 1.99 persons per room	27.8	27.4
2.00 to 2.99 persons per room	26.5	25.4
3.00 to 3.99 persons per room	14.1	13.7
4.00 to 4.99 persons per room	7.7	7.7
5.00 to 5.99 persons per room	4.2	3.7
6.00 to 6.99 persons per room	1.5	2.8
7.00 to 7.99 persons per room	1.8	1.7
8 or more persons per room	2.7	4.5
No Response	8.7	7.0

Jamaica

● Socio-economic aspects

Virtually all Jamaican housing built by the private sector today falls outside the definition of low-income housing, that is, the cost of house plus a developed site must be under $5,500 (U.S.). Whereas 350 to 450 sq. feet is said to be a minimum standard for social housing in developing countries, a more attainable standard for people with no fixed income brings this closer to 200 sq. feet. In such cases, provision is usually made for the owner to extend the house at some future date.

Traditionally, urban low-income housing has been in the form of high-density apartments -- terrace houses or small groups of houses closely clustered around a communal yard.

Detached houses have been more typical of middle income groups, and have become the goal of upwardly-mobile low-income groups. Over the past 10 to 15 years, this has caused developers of low-cost housing, in order to keep prices down, to erect groupings of closely spaced, single-story detached units on tiny lots.

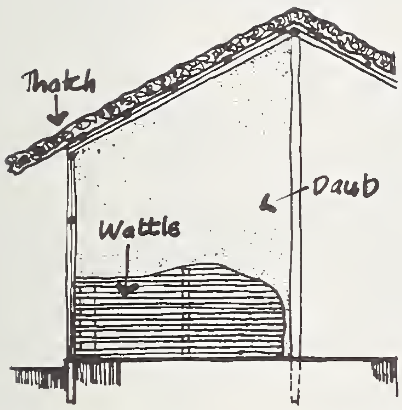
Oddly enough, a middle income trend back to apartment living is seen as encouraging a similar trend among low income groups; these may now be more likely to accept multi-story and terraced housing, with its more efficient use of limited land and resources.

A useful if not totally representative picture emerges from a survey of housing conditions in the Delacree Pen district of Kingston (Ref. 8). Delacree Pen is the site of an urban renewal project. The survey disclosed among other things that:

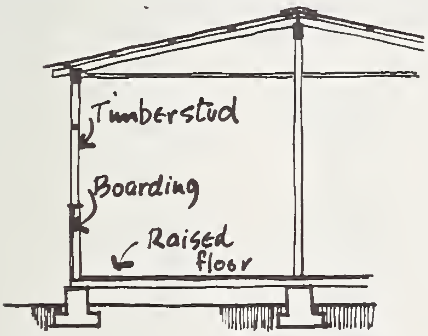
- Of the 4,935 households, 68 percent lived in one room; 18 percent in 2 rooms and 8 percent in three rooms. The most common household size was from 5 to 7 (24 percent); 37 percent were of one or two persons, and 11 percent had eight or more members.

Construction costs have gone up due to a 1973 money devaluation and higher labor costs, with 70 percent of Jamaican out-migration consisting of skilled labor.

- **Housing characteristics**
(See also Table 3)



Traditional low-cost houses



Jamaicans by and large prefer concrete houses and do not like houses made of light-weight materials, unless forced to do so for financial reasons (Ref. 4). Until recently there has been a bias against precast concrete houses (especially those of thin cross-section) but this is disappearing.

The most popular material among all income groups is hollow concrete block masonry.

Physically, low cost housing in Jamaica falls into six types (Ref. 4).

1. Wattle and daub (4%): Until the 1930's rural owners built most low-cost houses in this fashion. The framework of wooden posts and beams, with sticks interwoven horizontally between the posts, was the wattle. This was daubed inside and out with mud from available clay, to create solid walls. The roofs were pitched and made of a thatch made from bundles of dried leaves and tied in place.

2. Timber stud and horizontal boarding (36.9%): Roofs were pitched, made of timber rafters covered with corrugated iron sheets or wooden shingles.

Table 3: KEY HOUSING CHARACTERISTICS IN JAMAICA (Ref. 4)

Part 1: DISTRIBUTION OF DWELLINGS BY TYPE OF TENURE (PERCENT)

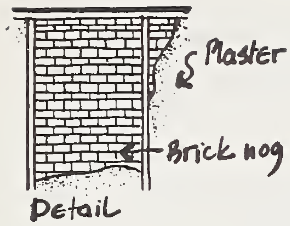
Type of Tenure	Total	Urban	Rural
Owned	52.4	29.7	70.8
Leased	2.5	3.9	1.4
Rented	36.5	59.9	17.6
Rent-free	7.9	5.8	9.6
Squatter	0.4	0.5	0.3
Other	0.3	0.3	0.3
Total	100.0	100.0	100.0

Part 2: DWELLINGS CLASSIFIED BY TYPE

Type of Dwelling	Number	Percent
Separate house	327,656	78.0
Flat/Apartment	67,083	16.0
Barracks	3,223	0.8
Out-Room	4,069	1.0
Part of Commercial Building	11,765	2.8
Other Private	3,886	0.9
Other	2,477	0.5
Total Dwellings	420,159	100.0

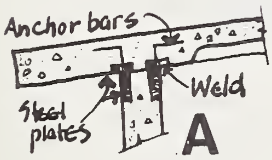
Part 3: PERCENTAGE DISTRIBUTION OF DWELLINGS BY NUMBER OF ROOMS

No. of Rooms	Total	Urban	Rural
1	32.7	42.3	24.9
2	26.3	19.6	31.7
3	16.1	11.7	19.7
4	8.5	7.5	9.3
5	5.3	5.9	4.9
6	2.8	3.3	2.4
7	2.6	3.4	1.9
8 or more	5.8	6.3	5.3
Total	100.0	100.0	100.0

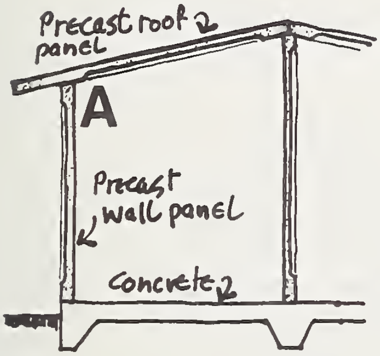


○3. Brick or concrete nog (11.8%): Like the preceding, these are typical of urban areas. Wood studs receive a brick or concrete infill or "nog" and are covered with a lime or cement plaster. Houses are usually raised two or three feet above ground.

43.4% of Jamaican housing is concrete-based:



○4. Hollow concrete masonry: Blocks are manufactured locally: cavities are filled with concrete during construction, and steel bars are added to reinforce against wind and earthquake. Poured in-place reinforced concrete stiffener columns should be included in panels over 16 feet long, but are often omitted in low-cost housing. Reinforced concrete belt beams are used to cap walls at roof levels.



○5. Large-panel precast-concrete systems: Single panels can extend to the full length and height of a unit. Wall and roof panels are lifted by crane and connected by welding at matching steel inserts. (These systems are not strictly speaking "low-cost" but could be if one steps up volume of production and accepts a lower standard of finishes).

○6. Small-unit precast concrete systems: Precast concrete posts are combined with precast concrete or timber beams, with an infill of concrete "boards".

Remaining housing is of brick or stone.

● Housing programs

Except for the 20 percent of needed units supplied or aided by the government (Ref. 5), there is presently no machinery for providing housing for the very bottom of the income scale. The mechanism used is either the continuing growth of shanty towns or the creeping subdivision of existing houses to accommodate new households.

On the other hand, the government now has underway a "site and services" project which selects land; provides an "infrastructure" of utilities; a minimum core unit; certain community facilities such as a school; possibility of employment and skill training.

Families with an annual income of less than $1650 (U.S. equivalent) are eligible (Ref. 4). The goal is to provide 6,000 serviced lots in the next three years. Lots are to be available in three options:

- with connections for electricity, water-supply and sewerage, plus materials for a toilet-kitchen-shower core unit.

- the same, but with a built core unit, plus materials for shelter and enclosure for the rest of the house.

- the same as the preceding, but with the core-unit and shelter being built, and materials only provided for enclosure of the rest of the house.

Serviced lots are to be owned on a leasehold basis, and loans for materials will be provided through credit unions.

Although the main focus of the Jamaican government is on "sites and services," there are other government programs. These consist of a mix of government-built housing for sale or lease (1970-1975 goal: 3,125 units); owner-occupied, government subsidized units (3,600 units); rural housing projects (4,880 units); indigent housing built on land owned by recipient (2,250 units); urban renewal projects focused on Kingston (4,876 units); plus assistance furnished to housing cooperatives (Ref. 4).

- Wind patterns

Despite the frequency of hurricanes in the Caribbean, direct hits on Jamaica are few when compared with the number of tropical storms which pass within 150 miles of the island (Ref. 4).

On the other hand, near misses are often accompanied by flood-rains which cause much damage. Records made between 1886 and 1967 show that the paths of 19 hurricanes and tropical storms passed directly over Jamaica and those of 98 (48 of them having hurricane force winds) passed within 150 miles of the island (Ref. 4). About one-third of the latter brought about flooding and damage.

Reporting on wind damage caused by the latest "direct hit" hurricane of 1951, The Daily Gleaner, a Jamaican newspaper, noted damage at $56 million (1951 prices); 20,000 buildings were destroyed and the death toll was 150. In St. Thomas Parish, 90 - 100% of homes were demolished.

Most of the recorded wind damage occurred to poorly built wooden low-income houses with corrugated iron roofs over wood rafters.

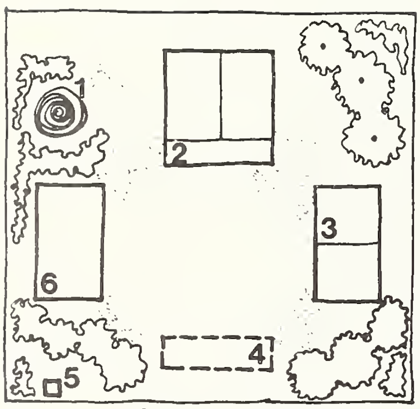
Bangladesh

● Socio-economic aspects

Bangladesh has one of the largest densities of population in the world. Measured by gross domestic product, it is also one of the world's poorest countries. 90 percent of the population is rural, and industrial output accounts for only 9 percent of the gross domestic product (mostly jute processing). (Ref. 9)

The last housing census was done in 1960; results from a new housing census are to be ready sometime in 1974. As Table 1 shows, the average number of rooms in 1960 per household was 1.77. 53 percent of householders lived in single room dwellings, and the average density of occupancy was 3.2 persons per room. In the case of 31 percent of the population, five persons or more share a room. Clearly, any damage from intense windstorms risks major casualties to a population as densely crowded as this.

The rural population lives in the patriarchal family compound. When sons marry, a new room is erected for the new household on the same field as the parents, next to the parents' house. Thus, houses occupied by families that are paternally related are grouped together. These clusters provide shelter to families numbering as many as 40 members; even higher figures are common. Houses are usually surrounded by dense trees and other tropical vegetation.

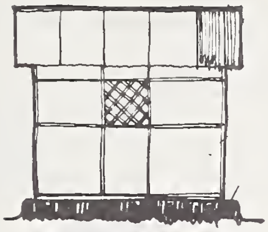


Family compound

1. Haystack
2. Sleeping
3. Storage, kitchen
4. Workshed
5. Latrine
6. Cowshed

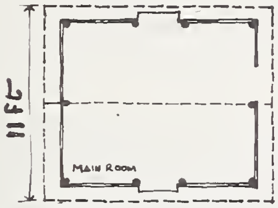
● Housing characteristics

○ Rural: The rural population is divided into land owners and landless laborers. One out of five villagers is landless. The average land owning villager has 1.5 acres and usually rents another acre from well-to-do villagers. Houses tend to be scattered throughout the village.

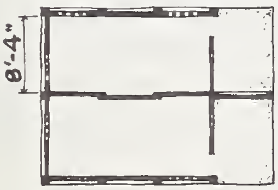


Typical rural house with bamboo. posts, fencing and corrugated iron roof.

Rural houses are known as "kutcha" or raw structure, with a plinth made of mud, and walls and roofs of bamboo, straw and leaves. These houses need to be maintained constantly and seldom provide safe shelter against rain and wind. 90% of rural houses are built this way. Only about one in a hundred has walls of concrete, baked brick or stone. About one house in three has roofing made of corrugated galvanized iron or asbestos cement.



○ Urban: As 72 percent of the urban population can't afford to pay rent for even the cheapest housing, they live largely in flimsy shacks, mostly in so-called "bustees" and squatter settlements. This housing is made of bamboo, often consisting of a piece of woven split bamboo fencing bent in the shape of a semi-circle. Headroom is low and occupants spend most of their time outdoors. Even moderate winds blow these houses away despite efforts to hold them down by putting counterweights on roofs. To rehabilitate these squatters the government has built some 4,500 semi-permanent one-room houses on the outskirts of Dacca, the capital.



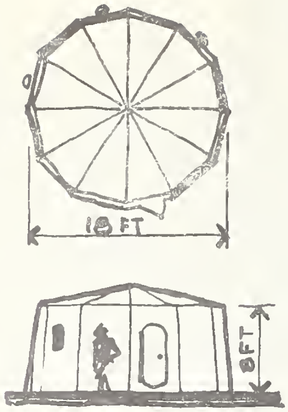
Typical low-cost house with brick walls

The stronger urban houses are mostly made of burnt clay brick walls, with flat reinforced concrete roofs. As the walls are usually 10 inches thick, gravity usually precludes failure through wind stresses. Failures occur largely due to substandard mortar or poor workmanship. No damage to the flat roofs has been reported, except in cases of projecting sunshades.

● Other types of housing

Simple machine makes blocks made from soil and cement

○ So-called CARE types (named after the U.S. relief organization) use soil cement blocks and corrugated iron sheets for roofs. Units roughly the size of an American concrete block are made in a simple-to-use machine which compresses a mixture of 90 percent non-saline soil and 10 percent cement to make about 300 blocks a day. A typical house requires some 1200 blocks. The essence is selfhelp, as a minimum of skilled labor is needed to put up this kind of house. The key to wind safety is to properly anchor the roof to the block walls. This type of structure is very popular in the country.

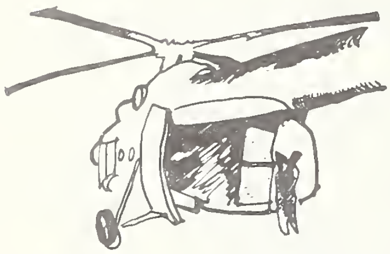


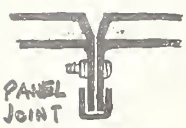
Pie-shaped CARE house (Prototype 1) was sturdy, but shape caused some problems

CARE has also developed 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. This seeks to combine a locally plentiful material (jute) with synthetic binders which can be manufacturered into panels by domestic industry.

Several variations of material and configuration have been formulated for laboratory testing, prototype construction and wind testing of full-scale units.

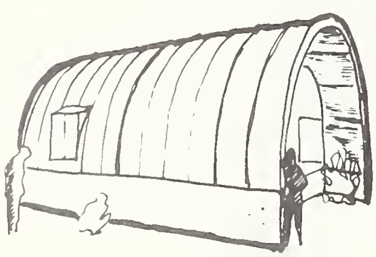
Four prototypes have been developed so far. These are:





CARE Prototype 2 has small, light components, is more traditional shape

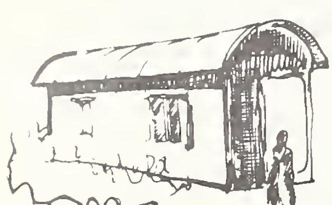
1. A pie-shaped, domed structure made of a 3/4 in. compressed jute-waste board faced with polyester resin and glass. Public reaction was good until the facing was identified as plastic, for plastic was identified in the public mind with a brand of cheap and brittle crockery. Those who acknowledged the strength of the plastic nevertheless faulted the house for its roundish dome-like shape. This made partitioning difficult and made it unsuitable for low-income families -- especially the 80 percent Muslim families with their tradition of isolating women in one part of the house.



2. A self-supporting house, rectangular in plan and with an elliptical roof profile, with curved panels made of the same combination of synthetic resin and jute. No component was to weigh more than 100 lbs., so it could be easily managed by two men. It was designed to resemble traditional house shape

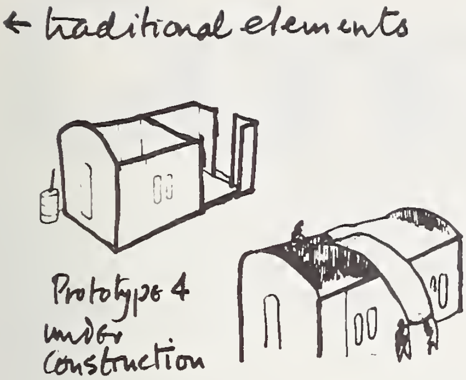
3. A structure using the above materials but geared for use in larger, non-residential buildings.

4. A structure designed to substitute the jute/plastic material for the traditional thatch or corrugated metal roof and its customary wood or bamboo support rafters. The new roof of this prototype was designed to fit over either traditional or new walls.



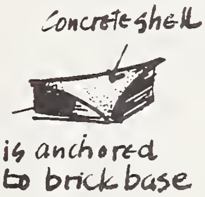
Prototype 4 is designed to be used with more of →

These four prototypes can be anchored directly to the soil or to standard perimeter footing foundations.



Many of these prototypes have been used for other than residential purposes, and as such have been very popular. These uses have included a medical operating theater, dispensary and office. From a socio-economic view, this is seen as a useful lesson, in that citizens of Bangladesh can get to know the structures in a service role without having to accept them suddenly into their personal lives as homes.

Two additional CARE prototypes of more traditional appearance were developed in the United States using a panel made of a jute reinforced polyester core and a fiber glass reinforced polyester facing. The 10 ft. x 20 ft. two room units successfully passed severe simulated wind and water tests. (Ref. 14).



○ Reinforced concrete shell roofs of hyperbolic paraboloid shape have been used for industrial and suburban housing. The roof is anchored to the supporting brick walls by means of half inch mild steel bars at the corners.

● Housing programs

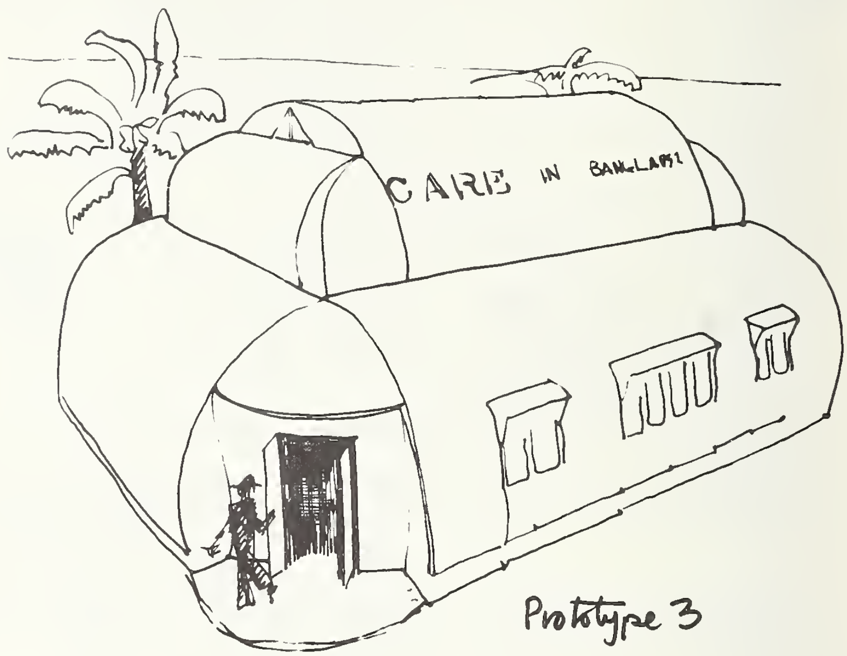
The 1971 war of independence left about 2 million families homeless. Sizeable housing rehabilitation and reconstruction efforts are now under way in rural areas. Some 175,000 houses were to be put up in coastal areas in 1972 and 1973.

A far-reaching decision was for the government to decide to put up two-story cyclone shelters in coastal areas. These would also serve as schools, health clinics, post offices and community centers. Some 18 national and international relief agencies have undertaken to put up housing, with a target figure of just under 400,000 units. 225,000 of these were completed by August 1972.

● Wind patterns

The most common sources of wind in Bangladesh are the cyclonic typhoons, tornadoes and norwesters. Damage is not only from wind pressures but from heavy rain and storm surges or high walls of water. Thus, the cyclone of November 12, 1970 caused storm surges some 25 feet high; nearly 100 percent of the kutchas and semi-permanent houses were demolished in the area of the storm. The coastal areas of the country are the most vulnerable to cyclonic storms.

Tornadoes are the most destructive storms. They usually happen on land during the warm season in flat areas, with few natural barriers to hinder them. 200 mph winds are common, but maximum wind speeds up to 500 mph have been estimated by some experts.



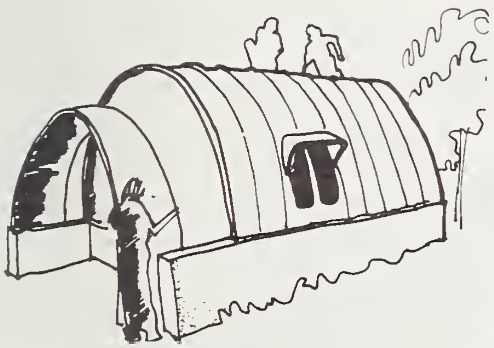
Prototype 3

Conclusions

A clearcut picture of problems, needs and solutions emerges from the diverse research reports, surveys and statistics that served as a basis for this report:

- As to the socio-economic aspects of designing wind-resistant low-rise low-cost housing, the cultural characteristics and financial capacity of low-income groups must be taken into account along with the technical criteria if sound solutions are to stand the test of widespread acceptance.

  This does not mean that new, stronger and less costly materials and construction techniques must blindly imitate traditional forms and processes. Nor, on the other hand, should these ignore the long traditions of indigenous building in the three countries of this report.



Highly visible use as non-home helps pave way for acceptance

- One emerging result of new low-cost housing tests in Bangladesh bears watching. The interim use of new prototypes for other than residential use, in a highly visible way as clinics and community offices, points up a viable way of exposing new forms and materials to prospective users before they must take the big cultural step and live in them as families.

- Similarly, the so-called "sites and services" approach, if tailored closely to the characteristics and outlooks of the communities involved, can capitalize on the proven initiative, ingenuity and hardiness of squatter and similar families. This will help overcome the chronic barriers of insufficient financial and material resources in developing countries.

- Closely allied with the thinking behind "sites and services" is the wisdom of gearing innovations in materials or method to the relatively plentiful labor supply in most developing countries.

- This does not preclude prefabrication, but places new focus on the need to identify, produce, adapt or combine cheap local substances made from natural earth, trees and plants. Bamboo, various kinds of soil, as well as jute, hemp, cane, split trees, straw, peanut shells and coconut husks are among materials that have been combined with manufactured substances such as cement, plastics and metals to produce inexpensive, sturdy building materials.

- How the building blocks are assembled is one of the major touchstones for stable, wind and water damage resistant houses. The chief caveats are adequate anchorage of roofing materials and trusses (if any) to walls. Structural design of roof members, splices and joints must accommodate high wind velocities. Anchorage of houses to the ground must be designed to prevent overturning; and wall openings must be placed to avoid weakening the structure at vital points and to prevent wind from entering and exerting interior upward pressure on the roof.

  Similarly, design features such as roof pitch and overhangs must observe latest findings on positive and negative wind pressure distribution.

- Proper placement of houses in groups as well as to accommodate prevailing wind direction and land features will always raise the wind damage resistance of houses. This should be one of the first criteria to observe when planning houses in areas subject to extreme wind.

  This information, when supplemented by the results of NBS' wind research project, will provide the realistic criteria needed to improve wind-resistance of low-cost, low-rise housing.

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Many of the following studies and reports contain additional references, varying from two or three to as many as seventy five.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report gives the major accomplishments of the second phase of a three year project to provide engineering and technical assistance to the Agency for International Development (AID), Department of State in developing improved design criteria for low-rise buildings to better resist extreme winds. During FY 74, the Center for Building Technology project staff members commenced several tasks. These tasks will serve as major inputs to the development of improved design criteria. The principal tasks include: 1) selecting a second and third field test site in the Philippines, 2) instrumenting four full scale houses, at the sites, 3) instrumenting the University of Philippines wind tunnel facility, 4) participating in an International Workshop at Manila during November 1973, and 5) developing, in conjunction with short-term consultants in Bangladesh and Jamaica, a methodology for the transfer of technology.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)* Buildings; Construction; Data acquisition equipment; Design criteria; Extreme winds; Information transfer; Instrumentation; Wind loads; Wind tunnel modeling

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