NBSIR 75-790

FY75 Progress Report on Design Criteria and Methodology for Construction of Low-Rise Buildings to Better Resist Typhoons and Hurricanes

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

November 1975

Interim (July 1, 1974 through June 30, 1975)

Prepared for

The Office of Science and Technology
Agency for International Development
Department of State
Washington, D. C. 20523

Under a
Participating Agency Service Agreement (PASA)
No. TA(CE) 04-73

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TABLE OF CONTENTS

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) units of measurement.

Length

1 meter (m) = 3.281 feet (ft)

Velocity

1 meter per second (m/s) = 3.281 feet per second (f/s)
= 2.237 miles per hour (m/h)

ABSTRACT

The annual progress report presents major NBS accomplishments and activities during the third phase (FY75) of a forty month project concerned with developing improved design criteria for low-rise buildings in developing countries to better resist extreme winds. The research study, sponsored by the Agency for International Development, commenced in March 1973. Two other progress reports: NBSIR 74-582 FY73 Progress Report (first phase of the research--4 months) and NBSIR 74-567 FY74 Progress Report (second phase of the research--12 months), document the first 16 month level of effort. During FY75, 6 major tasks were completed; instrumentation of remaining two of six test houses, continuation of technician training, analysis of extreme wind data, development of draft reports describing project results, participation in regional conferences in Manila and schedule a regional conference in Jamaica during November 1975. During FY76, data collection and analysis activities will be completed. A final report will be published by the end of the fiscal year.

Key words: Buildings; codes and standards; housing; hurricanes; low-rise buildings; natural disaster; structural connections; typhoons; wind loads.

INTRODUCTION

The FY75 progress report is the third in a series of annual reports describing the National Bureau of Standards' activities in developing improved design criteria for low-rise buildings in developing countries to better resist extreme winds. The research project is sponsored by the Office of Science and Technology, Agency for International Development (AID), under a Participating Agency Service Agreement (PASA) No. TA(CE) 04-73.

The report discusses the principal activities and accomplishments during the period July 1, 1974 through June 30, 1975. Information about FY73 and FY74 accomplishments are contained in the two National Bureau of Standards Interagency Reports, NBSIR 74-582 and NBSIR 74-567, Project Status Reports - Design Criteria and Methodology for Construction of Low-rise Buildings to Better Resist Typhoons and Hurricanes.

The FY73 Project Status Report provides the initial project background and discusses the formation of a Philippine Advisory Committee. The committee was instrumented in coordinating local project research activities, selecting field test sites, providing field test buildings and selecting appropriate personnel to work on the project.

The FY74 Project Status Report covers the instrumentation of test houses, the training of technical personnel at the field test sites and the wind tunnel facility, the preliminary analysis of wind load data, the four-day NBS international workshop on designing for high winds, and an assessment of the state-of-the-art of wind technology on low-rise buildings.

This report discusses activities performed during FY75 and includes additional technical information resulting from FY75 activities. Draft technical outputs are found in the appendices as listed below.

During FY75, six principal tasks were completed. The tasks were:

a. Instrumentation of the fifth and sixth test houses (Quezon City and Laoag City field sites),

b. Continuation of technician training for full-scale data collection and wind tunnel testing,

c. Transfer to the Philippine Advisory Committee of a computer program developed by NBS to determine extreme wind speeds for various mean recurrence intervals,

d. Scheduling of a Caribbean regional conference at Kingston, Jamaica for November 6 and 7, 1975 to disseminate project results to Caribbean wind-prone countries,

e. Development of draft reports on:

   - distribution of extreme winds
   - improved design pressure coefficients
   - guidelines for timber fasteners and masonry connectors
   - economic analysis/housing forecasting methodology
   - socio-economic and architectural considerations

f. Dissemination of draft reports at regional conferences in Manila during May 1975.

The Appendices are:

Appendix A - Minutes of the 7th - 10th Philippine Advisory Committee Meetings

Appendix B - Low-Rise Low-Cost Housing and Extreme Wind Related Problems in Bangladesh

Appendix C - Manila Regional Conference Program

Appendix D - Estimation of Extreme Wind Speeds in the Philippines

Appendix E - A Guide to the Determination of Wind Forces

Appendix F - A Guide for Improved Masonry and Timber Connectors in Buildings

Appendix G - The Economics of Building Needs: A Methodological Guide

Appendix H - Housing in Extreme Winds

A. SUMMARY OF PROGRESS FOR FISCAL YEAR 1975

Background

The project originated from the recognition by AID and NBS that additional research on wind is needed to reduce property losses, human suffering, disruptions of productive activities, and expenditures for disaster relief. Information is needed to supplement the limited amount of existing data on wind effects on low-rise buildings. Existing wind load criteria do not make adequate provisions for steady and fluctuating wind pressures along the edges of roofs and walls where separated flows occur. Extreme negative pressures (suction) acting on these building surfaces are one of the primary contributors to building damages. This research project possesses a potential for reducing building damages worldwide, as well as in the U.S.

The research centers around field studies (direct measurement of wind loads on six low-rise buildings at three separate sites in the Philippines) and wind tunnel studies (scale models of the field test buildings and models of other typical dwelling geometries).

The primary purpose of the full-scale field studies and the wind tunnel model studies is to refine the design pressure coefficients for low-rise buildings. While a great deal of work on wind loading on tall buildings has been accomplished during the past 10 years, very little parallel work has been devoted to buildings having heights less than 10 meters. Investigations of wind damage strongly suggest that coefficients contained in most current codes and standards do not adequately describe the wind characteristics near the ground and the pressure distributions on low-rise buildings. Highly localized wind pressures on buildings tend to be underestimated while overall pressures tend to be overestimated. This was confirmed from full-scale test results obtained in this program.

Equally important to the understanding of wind pressures on buildings, is the selection of design wind speeds in geographic areas having a high frequency of tropical storms. By taking proper account of these frequencies and local terrain effects, it is anticipated that design speeds can be selected which will accurately reflect the risk of wind damage to buildings. It will thus be possible for the building designer to specify more realistic design loads (from the NBS improved pressure coefficients) which should permit buildings to better perform during their expected life.

The reader is referenced to Appendix A, "Minutes of the 7th-10th Philippine Advisory Committee Meeting," for a review of the Committee's involvement with this research project.

Activities at the Field Test Sites

Three field test sites (see Fig. 1) were selected for recording wind load data on buildings. The sites are Quezon City where 3 houses were instrumented with wind pressure equipment. Laoag City about 500 kilometers north of Quezon City is the site of two test houses. Daet, about 230 kilometers south east of Quezon City is the location of one test house.

A detailed description of the three field test sites and related instrumentation was presented in the FY74 Progress Report (NBSIR 74-567). Three site visits were made by NBS personnel during FY75. These occurred in July and November of 1974 and May of 1975. Although most of the activities conducted during FY75 were of a routine nature (calibration and main-

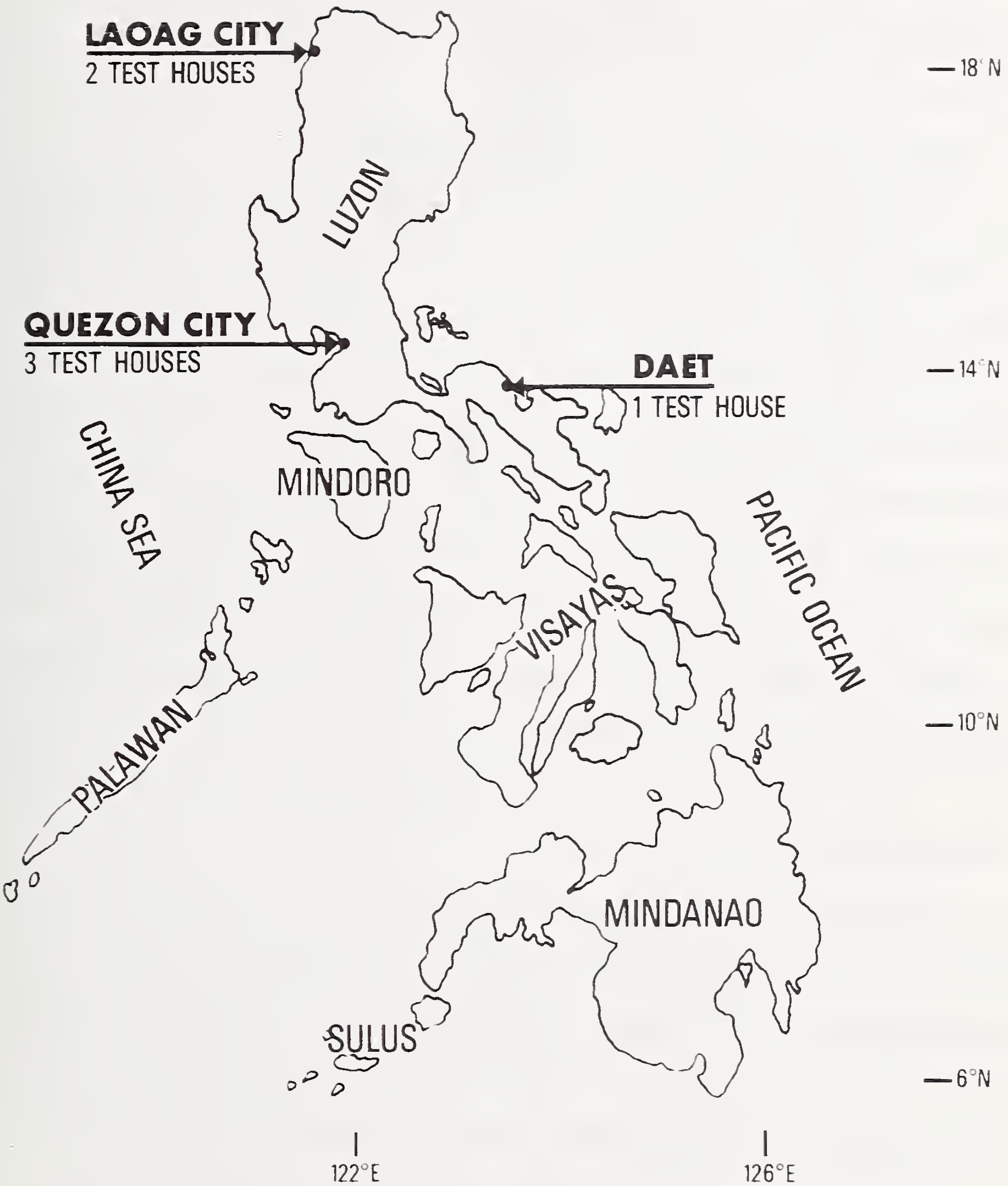

Figure 1 Building test sites

tenance of test equipment), several serious problems were encountered which required component repair or replacement and certain changes in operating procedures. Summaries of activities at the three sites and the status of each site as of June 30, 1975, are discussed below:

1) Quezon City, Science Garden Weather Station

This site currently has three test houses which are instrumented with a total of 19 pressure transducers. A delay in shipment of the third test house provided by CARE, Inc., Bangladesh, at this site made it impossible to complete the instrumentation of the house in FY74. This unit was subsequently instrumented by the NBS team during July, 1974. Minor problems were encountered with the time code generator and pressure transducer signal conditioner. These units were either replaced or repaired with no loss of test data. A more serious problem was encountered in November, 1974, when a number of pressure lines and signal cables were damaged by rodents which infested the test site following the clearing of a nearby squatter settlement. Approximately one week of repair work was required. A rodent control program was initiated.

Approximately eight hours of recordings were obtained during the year. These data were recorded during a time when significant changes in the wind exposure occurred with recent construction of tall buildings southeast and west of the test site. The construction provided an ample opportunity to collect wind pressure data under differing topographic conditions.

2) Daet Weather Station

The single test building at Daet is currently equipped with 10 pressure transducers. The Daet test site has been relatively free of problems since the installation of test equipment in March, 1974. A fence was erected in July to protect the meteorological tower and guy cables from livestock grazing on the station grounds. Corrosion due to the ocean exposure required the replacement and painting of a number of tower bolts and cable clamps in May of 1975. It was necessary to replace most of the exposed flexible pressure tubing at the same time because ultraviolet radiation deteriorated the tubing. Commercial power at the site has been extremely unreliable over the past six months which required a change in data recording operating procedure. Rather than keeping the data system in a "power on" mode, the test equipment is now turned on only when a tropical storm is known to be approaching the site. If no commercial power is available, the system is switched over to the generator which normally supplies the station radar system.

Approximately eight hours of records were obtained during the passage of Typhoon Bidang in November and Typhoon Andoy in December of 1974. Wind speeds in excess of 30 m/s (68 m/h) were recorded and wind directions ranged clockwise from north to southwest.

An additional problem at the Daet test site has been the transfer of trained personnel to other Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) Stations. This action required NBS personnel to perform additional training sessions for replacement personnel during each site visit.

3) Laoag City Weather Station

The two test houses at Laoag City are currently equipped with 10 pressure transducers. Construction of a barrack by the Philippine Air Force has changed the exposure of the test site to easterly winds.

As with the Daet test site, construction of a stock fence and replacement of exposed pressure lines were required at the Laoag City site. A short circuit in the wind direction data line resulted in the loss of some data during the passage of Typhoon Aning on November 6, 1974 during which winds with gusts up to 47 m/s (105 m/h) were recorded at Laoag City. More recently (June 1975), two data lines were accidentally cut by a construction crew. This damage was repaired by the PAGASA. In spite of these problems, the Laoag City test site has yielded several valuable records on the first test house, which is adjacent to weather station buildings, and on the second test house, which was instrumented in July of 1974. Approximately four hours of valid recordings were obtained this past fiscal year. Test tapes from Laoag City have not been fully analyzed.

Activities at the University of the Philippines Wind Tunnel Facility

Two building models were tested at the University of the Philippines Wind Tunnel Facility during FY75. They were a 1:80 scale model of Test House No. 1 located at the Quezon City site, and a 1:80 scale model of the RP-US Bayanihan School Building. The house is single story with a plan dimension of about 6 by 7 meters. The school building is single story and 8 by 18 meters in plan. Tests were conducted to evaluate the performance of the tunnel and of the characteristics of the simulated atmospheric boundary layer in producing pressure fluctuations on building models. The agreement between model and full-scale indicates that this facility is entirely suitable for modeling buildings in the lower 10 meters of the atmospheric boundary layer at scales of 1:80 or smaller.

Following validation of the wind tunnel flow simulation, a model of the AID funded RP-US Bayanihan School Building was tested at the request of the local AID Mission to determine overall load coefficients and localized pressure coefficients. The results of these tests were presented in a draft report which has been reviewed by the AID Manila Mission, the Philippine government and other interested parties. The report is currently being prepared as a final NBS document. Although the UP Wind Tunnel Facility has been shown to yield satisfactory results and is fully operational, serious local staffing problems have arisen. A key technician who had undergone continuous training since the initiation of wind tunnel operations in November of 1973, left the University in September, 1974 for an educational opportunity abroad. No satisfactory replacement has been found. The University also seems relatively disinterested in establishing a viable alternative research facility in the area of building aerodynamics. Because the University lacks trained staff in fluid dynamics or aerodynamics, they do not currently have the capability of conducting wind tunnel tests without NBS supervision. Some interest has been shown by PAGASA (who have appropriate staff members) in assuming responsibility for wind tunnel operations; this matter has to be fully resolved.

Wind Tunnel Studies

Because of the problems outlined above and to keep the project on schedule, NBS project staff initiated a series of wind tunnel tests at the Virginia Polytechnic Institute and State University (VPI and SU) using a flow simulation technique similar to that which was perfected at the UP. Since VPI and SU's test section was larger than that at the UP (2.14 x

2.14 meters square and 5.5 meters long) the scale ration was increased from 1:80 to 1:70. The tests initiated in April, 1975, have been completed. They cover 32 combinations of roof slope, height-to-width ratio, length-to-width ratio and size of roof overhang. The test results are still being analyzed. Preliminary data suggest that additional studies be conducted on roof slopes near 10 degrees. The wind tunnel test results and the full-scale test results obtained during previous studies in Montana, and studies conducted by the Building Research Establishment in England including research by NBS in the Philippines provided the basic data used in developing tentative design pressure coefficients. These data were presented at regional conferences in Manila in May, 1975. These results are discussed in more detail in a later section and fully reported in Appendix E. It is anticipated that the remaining tests and data analysis can be completed by the end of December, 1975.

Analysis of Climatological Data

Work continued during FY75 on the analysis of wind speed records in the Philippines. Several station data series were fitted with extreme value distributions using a computer program developed at the NBS. This program is currently being modified for use on the PAGASA computer facility in Quezon City and is expected to become fully operational early in FY76. Features of this program and preliminary results of the data analysis were presented at regional conferences at Manila in May. The computer program is available for use by other wind-prone countries. Additional information on the estimation of wind speeds may be found in Appendix D.

Other Project-Related Activities

On December 25, 1974, Cyclone Tracy passed over the city of Darwin, Australia, causing almost total destruction of the residential areas of the city. Because of the widespread use of corrugated galvanized iron sheet and light timber frames, the behavior of housing in Darwin has a definite bearing on the development of design criteria for housing in other tropical regions of the world, particularly those regions having a high frequency of intense storms. Due to its involvement in wind load research, the NBS was invited to participate in post-disaster studies of Darwin and a close liaison is being maintained with Australian research establishments which are conducting follow-on projects relative to Darwin. It is anticipated that some of these findings will be incorporated in the final design criteria.

Regional Conference

As previously mentioned, draft project results were disseminated and discussed at a regional conference held in Manila, Philippines, on May 16-17, 1975. The purpose of the conference was to provide draft results to the professional building community from Asian wind-prone countries. The conference provided the NBS team an opportunity to receive technical feedback as an indicator of project research relevence. This information serving as inputs will assist future data analysis and in developing final technical reports for the completion of this study. The conference program is contained in Appendix C.

The first day of the two-day regional conference was devoted to presentation and discussion of technical results. A short description of each presentation is presented in the following section. The second day was devoted to an open forum. The technical reports are contained in Appendices D - H.

Information transfer between Bangladesh and the project was performed by Dr. Jamilur R. Choudhury, Professor of Civil Engineering, Bangladesh University of Engineering and Technology, Dacca. Dr. Choudhury is under contract with NBS to provide technical inputs relative to the Bay of Bengal Countries. He presented a paper (based on his latest report to NBS) on housing, socio-economic aspects, and wind distributions in Bangladesh, India, Burma and Sri Lanka. This report in Appendix B supplements a previous report (see Appendix D, NBSIR 74-567). Additional information on socio-economic factors, anticipated housing needs through 1985, and data on wind speed records and wind damage statistics is discussed. The report will be submitted separately to the National Technical Information Service (NTIS).

The conference was scheduled just prior to international conference (also in Manila) on civil engineering in disaster prevention and control. The draft project results were presented at this meeting. This provided an opportunity to discuss the high wind project with another segment of the international and Philippine professional building community.

This conference was sponsored by the Philippine Institute of Civil Engineers (PICE). Approximately 450 professionals from seven countries attended. Countries represented were the United States, Republic of China (Taiwan), Philippines, Japan, United Kingdom, Indonesia, and New Zealand. Proceedings of the conference will be published by the PICE.

The project results were also discussed at the Seventh Joint Meeting of the U.S.-Japan Panel on Wind and Seismic Effects, May 20-23, 1975 in Tokyo. On June 17, 1975, the project draft results were presented at an

AID-sponsored international disaster preparedness seminar.

Description of Draft Project Outputs

The following is a brief description of the contents of the reports presented at the conferences. Reports were presented in draft form and were circulated to all attendees for review and comment. These reports included in Appendices D -H[1] are briefly reviewed in the following paragraphs.

1) Basic Wind Speeds

The report, Estimation of Extreme Wind Speeds in the Philippines, by Dr. Emil Simiu, is found in Appendix D. The report contains a comprehensive review of probabilistic techniques for the analysis of extreme wind speeds. Corrections of annual extreme speeds for the type of instrumentation used, averaging time, height above ground, and type of exposure are covered so that homogeneous sets of wind records can be established. Probabilistic models are then described and are applied to wind records for several Philippine stations using a computer program developed at the NBS. The results are compared with design speeds presented in the National Structural Code of the Philippines.

It is concluded that design speeds currently used in parts of Mindanao can be reduced while those in use for Northern Luzon and certain coastal exposures should be increased. Finally, problems related to the estimation of basic wind speeds for very long mean recurrence intervals in tropical storm areas are outlined.

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[1] The reports contained herein were developed for the regional conference in Kingston, Jamaica held during November 6-7, 1975; the contents contain additional data analysis subsequent to the Manila and Tokyo conferences.

2) Design Speeds and Pressure Coefficients

The report titled, A Guide to the Determination of Wind Forces, by Dr. R. D. Marshall of the NBS, is found in Appendix E. The report describes the basics of wind flow around buildings and the pressures created by these flows on building surfaces. Effects of such features as roof slope, roof overhangs and building openings are also discussed. This paper refers to material covered in the paper by Dr. Simiu and assumes that the basic wind speed is known or can be calculated by the designer. A procedure for determining the design speed is presented which takes into account the general terrain roughness, local topographical features, height of building, expected life of building and acceptable risk of failure.

Once the design speed has been obtained, the mean dynamic pressure is calculated and pressures acting on walls, roofs and internal portions of buildings are then determined by use of appropriate pressure coefficients which are tabulated in the paper. Finally, corrections are applied to the calculated pressure to account for terrain roughness and height of building. The steps required to calculate pressures and total drag and uplift forces are summarized and a worked example is presented. It is intended that this paper form the basis for wind load design standards in developing countries.

3) Masonry Connectors and Timber Fasteners

The report, A Guide for Improved Masonry and Timber Connectors in Buildings, was prepared by Dr. S. George Fattal of NBS and Messrs. Gerald Sherwood and Thomas Wilkenson of the Forest Products Laboratory and is found in Appendix F. The buildings discussed are one and two stories in height, generally with a gable timber roof covered with corrugated iron with overhangs of up to 1.5 meters. The chapters on connectors lead off with an introductory background discussion. They are followed by a section on buildings damaged by high winds. Examples of wind damages are presented through use of photographs and an analysis is presented in textual form. The report also discusses building damages caused by the December 1974 cyclone at Darwin, Australia.

A survey and evaluation of some current masonry practices as used in the tropics are presented. Local practices, investigation of building products, and standards compliance are discussed and evaluated with the aid of photographs of buildings during various stages of construction.

Current masonry practices in the United States are presented. Also, various types of connectors used in such construction are discussed. This serves as a reference for improving building practices.

The last section of the report addresses suggested improvements in masonry construction. The suggestions are based on a review of several masonry documents, appropriate reports, building codes, specifications, working drawings and photographs of Philippine houses and post-disaster surveys of typhoon-damaged buildings.

The chapter on timber fasteners is similar in format to that for masonry connectors; it presents a general introduction to timber fasteners and a review of Philippine timber fastener construction practices. Recommendations follow.

4) Economics of Building Needs

The report, The Economics of Building Needs - A Methodological Guide, by Dr. Joseph Kowalski of NBS, (see Appendix G) serves as a tool to assist the decision maker in assessing the impact of the development of buildings to better resist winds on local housing needs. This document leads off with a review of the economic background of forecasting housing needs. This is followed by an economic model to forecast housing needs. The report attempts to identify those parameters that define a low-cost house. This is determined by a simple mathematical procedure based on readily available data i.e., family income, housing expenditure, and the established regional poverty line.

5) Socio-Economic and Architectural Considerations

The report, Housing in Extreme Winds, by Steven Kliment, architectural consultant (see Appendix H) is a review of socio-economic and architectural aspects of low-rise/low-cost buildings exposed to high winds. The report is consumer-oriented in nature and is intended for residents, owners, planners and builders of low-cost/low-rise housing in developing countries.

The report addresses the Philippines, Jamaica and Bangladesh. A general review considers socio-economic conditions prevailing in developing countries. These conditions include: strong respect for traditional materials and methods of house construction with a corresponding suspicion of innovative forms and approaches; a high proportion of rural residents, remote from new building concepts as well as from post-typhoon/hurricane relief programs; a rising proportion of urban poor who live in squatter settlements; a very high ratio of citizens (in a range from 60% to 72% depending on country) whose incomes are at a level where they cannot afford housing of any kind--either on the open market or government-subsidized;

and a chronic shortage of capital funds to stimulate or support a national program of wind-resistant housing construction.

The report reviews approaches for providing assistance in "sites and services". This concept suggests that squatters and other low income individuals be provided through gift, loan or lease with a site equipped with water supply, sewerage and electricity, on the condition that the beneficiary erect and maintain a house upon it. The importance of land from the social standpoint is stressed. Advantages and limitations of squatter settlements are discussed.

Suggested solutions include the placement of buildings to exploit existing land contours and vegetation, and the design of buildings so as to conform to research recommendations concerning preferred configurations of roofs, walls, overhangs and openings. In addition, construction techniques are briefly covered.

Materials that are cheap, strong and locally available are recommended, and several innovative methods of construction are mentioned. They include soil that has been stabilized or strengthened by means of asphalt or cement and indigenous fibers and grasses for possible use as reinforcement for concrete, adobe and brick. Plastics have been produced using native and imported raw materials and could serve as an excellent low-cost house once their configurations become more familiar to the population. At first, they may be used for clinics, schools and warehouses.

Rural and urban components of population trends for each of the three countries are reviewed. The greatest projected increase in population will be in Bangladesh (a rise of 110% by the year 2000). These percentages tend to conceal actual numbers; the 86.6 million projected increase in

Bangladesh will raise even further the 1970 average population density of 1,361 persons per square mile. The density will be much higher in urban areas and on rural high ground during the flood season.

Finally, housing characteristics peculiar to each country are summarized through text and in thumbnail sketches, in both architectural terms and in terms of occupancy characteristics. The socio-economic functions of family ties and housing needs are reviewed. The community structure, the economics of housing, the housing characteristics, and the housing programs are summarized by country.

Technology Transfer

The NBS/AID high wind project results should have an impact on several key sectors of the local developing country's population--the professional community, the government policy-making sectors, and the building user both owners and tenants.

It is hoped that attendees from the Manila conferences have become more proficient in applying improved wind technology to low-rise buildings so they in turn can inform others. NBS has a responsibility to the building tenants and is very concerned about establishing effective methods for the transfer of technical information. To stimulate the homeowner and tenants interest to read the final reports; the documents must be made readily available through concise and graphic descriptions, of technological issues, the research, the findings, and the conclusions.

The use of brochures, pamphlets and other consumer-oriented material is an excellent first step in transferring a glimpse of the project. They serve as "pointers" to technical information and reports. Brochures have been and are being developed to summarize various aspects of the project.

Consumer-oriented information pamphlets for the five draft project reports were developed in August 1975. These pamphlets contain about five pages of summarized material. They may be loosely inserted in a folder for ease of removal or annotation, addition or substitution of information. The individual folders forming the file package may be circulated individually or together to users in government agencies, the professional community and individual households within the community.

A movie, another consumer-oriented package, was completed in April 1975. The movie summarizes the high wind research project to date. Through illustrating the destructive effects of winds on buildings, it informs the viewers of the NBS field testing activities and the wind tunnel testing program. The movie also uses computer graphics to illustrate the effect of wind on buildings. This 16 mm color movie is a transfer of information mechanism aimed at architects, engineers, building officials and students in both developing and developed countries. The movie is intended to be both educational and entertaining. Copies of the film are available on free loan from Association Sterling Films, 600 Grand Avenue, Ridgefield, New Jersey, 07657. Prints of the film may be purchased for $73.25 from the National Audiovisual Center (General Services Administration), Washington, D. C., 20409.

In addition to these informational tools, and equally important to the whole concept of information transfer, is establishing an effective working relationship with the users of the research early in the project. Through such working relationships, efficient training programs for both on-site and in the laboratory, provides appropriate continuity through the project. Such a relationship was established during the past two years.

Local Filipinos had responsibilities in the project under the direction of Drs. Roman Kintanar and Ernesto Tabujara, from the Philippine Weather Bureau and University of Philippines respectively. The results of these efforts are significant. These activities provided the first step toward the preparation of improved wind codes and standards for developing countries. The Philippine National Building Code is currently undergoing revision to incorporate new technology which will lead to improved building practices. Section 2.05, Wind Pressures, is scheduled to be revised by September 1975. Results from this project will be incorporated into this Section. Also, test data will be made available to the subcommittee on wind loads of the American National Standards Institute (ANSI) for possible incorporation into American National Standard A58.1--"Minimum Design Loads for Buildings and Other Structures".

B. EXPECTED PROGRESS THROUGH PROJECT COMPLETION

Field Test Sites

Operation of test equipment at the three field sites will continue through the 1975 typhoon season (December 1975). It is quite likely that data collection will continue beyond December 1975 because PAGASA has expressed a strong interest in continuing the field activities. This would be particularly advantageous in the case of the Quezon City Science Garden site since building construction is rapidly changing the wind exposure, thus providing a unique opportunity to assess the effects of urbanization on the local wind environment. There is also a possibility that instrumentation at the Laoag City field site can be transfered to a new barrack building located adjacent to one of the two test houses. The size and shape of the barrack building is quite similar to typical community service buildings. This transfer will not be made before December because considerable information remains to be collected from the two test houses.

Analysis of wind speed and pressure records will continue, using data recorded to date and data acquired during the current typhoon season. The basic procedure for calculating wind loads has already been established. New test results will be used to refine the design pressure coefficients which have been tabulated in the draft document outlining design procedures (Appendix E). It is anticipated that the forthcoming data will be important in establishing internal pressure coefficients since these coefficients cannot be obtained from wind tunnel tests.

Wind Tunnel Operations

As indicated previously, some serious problems have been encountered with the wind tunnel operation at the University of the Philippines. Discussions with the Philippine Advisory Committee on this matter will continue in an effort to obtain local funding and a commitment from the University of the Philippines to establish an active and continuing wind tunnel program. Failing this, efforts will be made to transfer this program to another agency.

The wind tunnel program at the Virginia Polytechnic Institute and State University will continue. The primary effort will be the analysis of extreme pressures on various roof geometries. The major portion of the wind tunnel work has already been completed. However, the data analysis quite likely will indicate the need for additional tests on specific roof geometries.

Preparation of Design Criteria

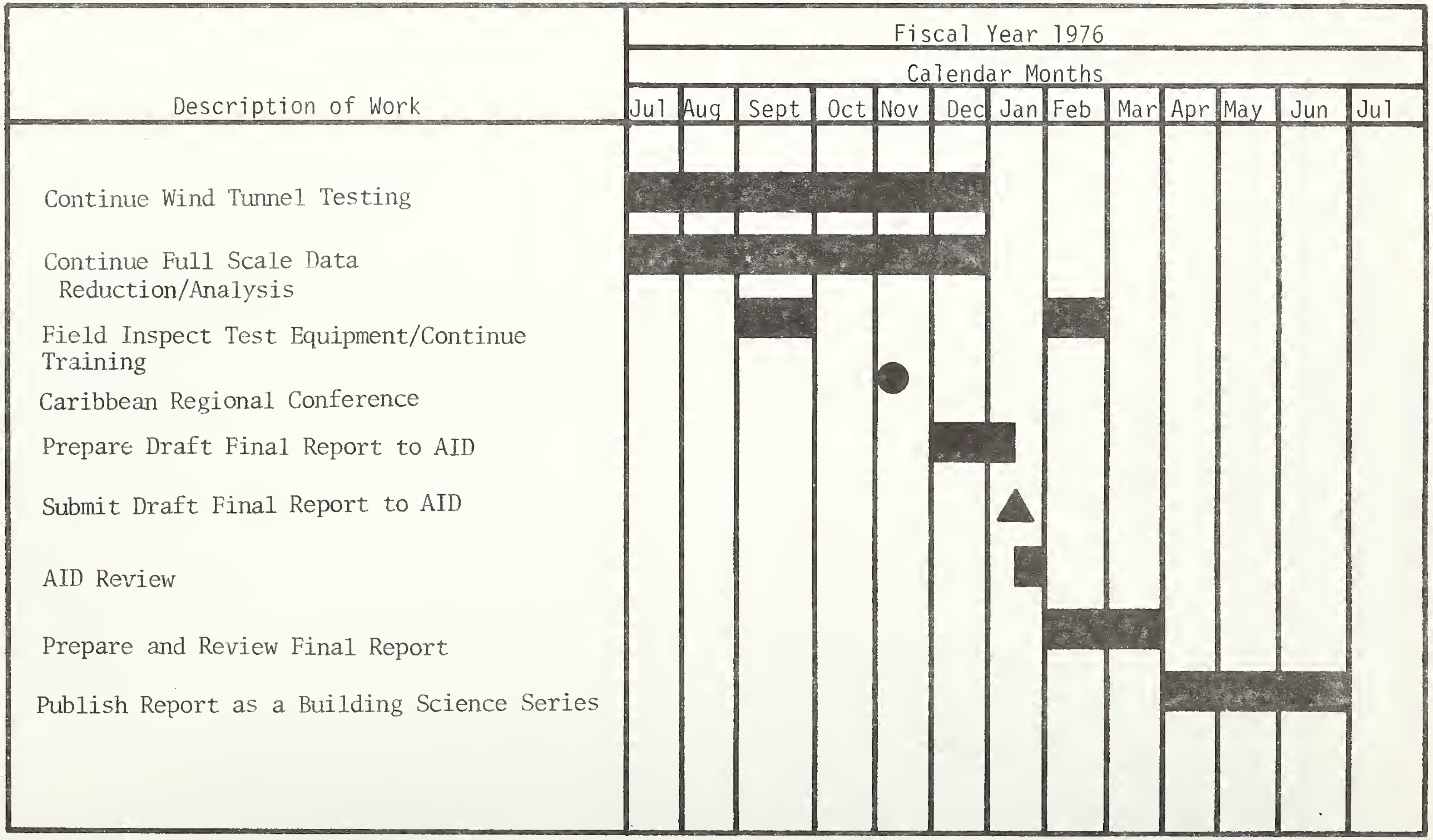
The draft documents covering the selection of design wind speeds and the calculation of corresponding loads have been prepared with the intent that they will form the basis for codes and standards in developing countries. This same approach will be followed in preparing the final versions. Additional information will be included concerning site selection, effect of clusters of buildings and of extreme wind speeds in the Caribbean. The final version will also include several illustrative examples and a commentary on the behavior of certain building materials subjected to repeated loading and missile impact.

Caribbean Regional Conference

A Caribbean regional conference is scheduled for November 6 and 7, 1975 in Kingston, Jamaica. The conference will be similar to that held during May in Manila. The local conference organizer is Mr. Alfrico Adams of Douet Brown and Adams and Partners, 7 Lismore Avenue, Kingston, Jamaica, West Indies and a member of the Jamaican Institution of Engineers.

C. FISCAL YEAR 1976 PROJECT SCHEDULE

The project schedule for FY76 is presented on the following page. The schedule may be adjusted to accommodate, to the maximum extent possible, full-scale and wind tunnel data analysis and publication of project results.



FY76 PROJECT SCHEDULE

APPENDIX A

Minutes of the 7th - 11th Philippine Advisory Committee Meeting

MINUTES of the 7th 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 6 August 1974 at the National Hydraulic Research Center, College of Engineering, University of the Philippines, Diliman, Quezon City at 2 p.m.

Present: Dr. Ernesto G. Tabujara, Presiding
Prof. Geronimo V. Manahan, Secretary
Prof. Angel A. Alejandrino
Mr. Manuel C. Bonjoc
Engr. Ambrosio R. Flores
Col. Alejandro R. Kabiling
Mr. Wellington A. Miñoza
Engr. Jose P. Orola
Dr. Josefina M. Ramos
Col. Manuel R. Rebueno
Col. Alberto R. Sanchez
Engr. Modesto D. Soriano, Jr.

Dr. Richard D. Marshall
Mr. Peter Paul M. Castro
Mr. Joaquin O. Sicpongco

7:01 The Minutes of the 6th Meeting were read and approved. Dr. Tabujara mentioned that after the November 1973, March and April 1974 Meetings, the membership's attendance in meetings has dwindled. He further mentioned that the model houses at Daet and Laoag have been erected and the CARE House at the Science Garden has been in full operation.

7:02 After a brief review of the Philippines regarding the wind studies, Dr. Marshall gave a comprehensive report of activities from March to August 1974 as follows:

a. Daet House
This model was erected last March 1974. Here, Dr. Marshall's work has been divided between wind tunnel activities and field inspections. The building at Daet has a hip roof, the only one in the whole program. As of July 21, 1974, it has been instrumented. He inquired about the possibility of erecting another building in the site close to the runway after which instrumentation of the structure can be easily undertaken.

b. Laoag House
The GSIS structure located next to the runway was erected late March. Problems were encountered on the site. Winds coming from the southwest are obstructed by the CAA and PAL Buildings. Furthermore, goats grazing in the area have eaten a portion of the electric cable necessitating the fencing of the area around the mast. Presently the building is being used as a

residence typifying normal domestic functions. The other house erected by NHC is in an isolated area and Dr. Marshall suggested that the other house be furnished with plumbing facilities so that it can be occupied, too. The house having the data system is air-conditioned to control high humidities.

c. Science Garden Site
The first model was erected last September 1973 while the second unit was completed November 1973. These units have experienced from 3 to 4 hours of tape records due to strong winds. A third unit, the CARE House, has been instrumented during the last week of July 1974. This unit has 4 transducers, 3 external, 1 internal. The work on the instrumentation will be completed by the first week of August. Dr. E.G. Tabujara has the complete technical data on the CARE House.

7:03 Major points discussed on the model houses were:

a. The possibility of having another unit in Daet. Currently PHHC is not in a position to furnish the building. However, Col. Rebueno will make a last plea with the PHHC Board.

b. For the possibility of the second house at Daet, Dr. Tabujara will visit Col. Rebueno to negotiate with PHHC.

7:04 Wind Tunnel Studies:

In Dr. Marshall's opinion, the wind tunnel tests are heading towards a critical stage and graver problems may then crop-up. The problem as he sees it is that he has a limited time in the Philippines and is leaving by Monday. Specific problems are:

a. Equipment problem:
Voltage of power supply greatly fluctuates and a number of equipment malfunctions have been attributed to the variability of the voltage. A voltage regulator has been provided for the more sensitive instruments.

b. Availability of the DC power is limited for there are other priority projects that have to be serviced with direct current. In asmuch as data are needed by January 1975 the formulation of design criteria for major building layouts have to be established early enough to meet planned schedules.

7:05 PAGASA's Miñoza mentioned that his agency has a wind tunnel under construction at the Science Garden, but its specifications are very different from U.P.'s so that PAGASA's tunnel cannot be used for the program. The alternative that was reached is that Dr. Marshall and his men will make a day-to-day visit to the tunnel to maximize available operational time.

It was further mentioned that by the end of the year design engineers can apply and make use of the information and initial results of the study. By November Dr. Marshall may be back in the Philippines, this time with Mr. Noel Raufaste, Jr.

7:06 Other matters:

a. NBS has informed the committee that the Proceedings of the recent Workshop are now being printed and each Workshop participant will be given one copy. A mini-brochure of the project is also being printed.

b. The Regional Seminar-Workshop slated for spring 1975 at Bangladesh may not push through in that country since Dr. Choudury is on sabbatical leave. The Philippines is again being considered with Cebu City as the suggested site for the activity. The objectives of the Seminar-Workshop are:

1. To dessiminate any results arising from the project.

2. To concentrate on what was learned on the progress of the project, particularly with activities in the Philippines.

3. To improve on the format of the report before the results are printed.

4. To assess the overall program and to see what other directions can be done.

5. To dessiminate the socio-economic data gathered in conjunction with the technical studies.

It was decided that in two months the Advisory Committee will meet to finally establish whether the Philippines can host the Regional Seminar-Workshop at Cebu City or any other agreed site.

c. The NBS wants to receive technical publications from the Philippines-like a list of engineering and architectural journals, monthly journals on economics, consumers' price index and construction price index.

Further to this, NBS is also interested in getting information on connections as well as practices on connectors and anchorages.

d. Mr. Miñoza reported that "Bulletin Today" is preparing an article on wind study. He is inviting the members of the Committee to the PAGASA's Penthouse on 7 August 1974 at 10:00a.m. to sit for the reporter's interview.

7:07 The Meeting was adjourned at 3:45 p.m.

(Sgd.) GERONIMO V. MANAHAN
Secretary

(Sgd.) ERNESTO G. TABUJARA
Chairman

MINUTES of the 8th MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DEVELOPMENT OF IMPROVED DESIGN CRITERIA TO BETTER RESIST THE EFFECTS OF EXTREME WINDS FOR LOW-RISE BUILDINGS IN DEVELOPING COUNTRIES".

Held on 12 November 1974 at the PAGASA Penthouse, Development Bank Bldg., Quezon Blvd. Ext., Quezon City at 2:30 P.M.

Present: Dr. Ernesto G. Tabujara, Presiding
Dir. Angel A. Alejandrino
Engr. Cesar A. Caliwara
Mr. Hugo de la Cruz
Engr. Ambrosio R. Flores
Mr. Rodolfo A. de Guzman
Engr. Andres O. Hizon
Col. Alejandro R. Kabiling
Engr. Octavio A. Kalalo
Adm. Roman L. Kintanar
Engr. Rosalio A. Mallonga
Dr. Josefina M. Ramos
Engr. Joaquin O. Siopongco
Engr. Modesto D. Soriano, Jr.

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

8:01 The Minutes of the 7th meeting held last August 6, 1974 were read. Item 7:02-A was corrected by Dr. Marshall in that the proposed Daet house was not erected, but instead, an existing building was instrumented for the study. The Minutes were then approved as corrected.

8:02 Dr. Tabujara welcomed Mr. William Littlewood of USAID, Dr. Richard Marshall and Mr. Noel Raufaste, Jr. Two new members of the Advisory Committee were introduced; namely, Mr. Hugo de la Cruz and Mr. Rodolfo de Guzman, both of the PAGASA. Likewise, Mr. Roger Balinong and Miss Minda Aguilar, BRS' new Research Aides were introduced to the body. Dr. Tabujara aknowledged the dedication to Mrs. Templa on the cover of the published Proceedings of the Seminar Workshop held at the NSDB on Nov. 14-17, 1973. He also thanked Mr. Raufaste, Jr. and Dr. Marshall for their invaluable contribution which included published materials aside from editing and printing the Proceedings.

8:03 Mr. Noel Raufaste, Jr. extended the greetings and best wishes of Dr. Richard Wright of NBS. He also mentioned that Dr. Marshall and he were very glad to be back in the Philippines. Mr. Raufaste, Jr. then presented a summary of his findings on the three test sites located at Laoag, Daet, and Quezon City. He said that the complete instrumentation of the houses have been accomplished but there are still problems with the Wind Tunnel phase of the program. On the whole, there has been improved efficiency on the job and processing of relevant data needed for analysis is going smoothly. He also emphasized the need for an economic study of Filipino housing conditions so that benefits that could be derived from improved design criteria may be analyzed. With regards to the coming Regional Conference by mid-next year, he expressed the desire of Dr. Ning of Taiwan to attend it. Other countries are also interested to participate in the working sessions.

8:04 Dr. Marshall reviewed the status of the Wind Tunnel Tests: Further discussions on these tests will have to be taken up during the Regional Conference. He gave a brief summary of the results collected from the test sites since Sept. of 1973. He cited the problems presently being felt. Most of these have stemmed from the recent typhoons which have caused some damage on materials and equipment. The damage caused in the Q.C. test site apparently was done by rats eating into the plastic tubing used to protect the wiring system of the test instruments. He passed some parts of the tubing to the body for inspection. He also gave a report on the Wind Tunnel results and stated that they are about six months behind schedule. He reminded the body that there should be power sharing in order to facilitate 50% cut from time in order to get back in schedule. Another setback was caused by the departure of one of the trained technicians assigned to the Wind Tunnel tests. He proposed remedies and solutions to some of the problems encountered. The Wind Tunnel needs a new voltage regulator. Dr. Tabujara proposed to convene engineers in a form of a subcommittee, and the PAGASA personnel to help gather and evaluate data to facilitate analysis and evaluate the results.

8:05 The body was informed that the following are needed by the NBS:

A. Building Code Standards.
B. Literature on Housing.
C. Progress Report on the First four months of the Project for FY 1974. The latter has to be furnished before Mr. Raufaste, Jr. leaves for abroad on Nov. 21, 1974.

8:06 Mr. Littlewood expressed satisfaction for the job being undertaken considering the social and economic aspects involved. The results of the findings will not only benefit the Philippines but also other countries within the typhoon belt such as Bangladesh, Jamaica in the Carribean Area. He commented that this Research Project is one of the most successful so far.

8:07 The Committee was unanimous in deciding to host the Regional Conference. It was also decided that it is most convenient to hold it here in Manila or in the Suburbs.

8:08 At his juncture, Engr. Caliwara informed the body of the International Civil Engineers' Convention slated on May 20-24, 1975. The theme is "Civil Engineering and Disaster Prevention and Control". The committee could make arrangements whereby there could be integration of objectives.

8:09 Upon the suggestion of Mr. Littlewood it was agreed that the Regional Conference will be a back-to-back Meeting, slated for May 16-17, 1975. One day is for actual dissemination and another day for recomendations and/for comments.

8:10 Dr. Tabujara appointed a sub-committee of five members to decide on the details of the proposed seminar. The members are Engr. Soriano, Dr. Ramos, and Mr. de la Cruz. Mr. Raufaste, Jr. was invited to attend their meeting on Monday Nov. 18 at 2 p.m. at the GSIS.

8:11 During the Regional Conference, a 15 minute colored video presentation of the activities for the past 18 months will be presented. Part of this movie was actually shot during this particular meeting of the Advisory Committee.

8:12 Mr. Raufaste, Jr. stated that they are still in the process of making a study on timber and masonry connectors used in Philippine construction and any information and data regarding this would be highly appreciated. Mr. Raufaste, Jr. also stated their interest regarding economic studies of Filipino houses and housing needs in the Philippines between 1980-85; also to develop definitions of certain terms such as "Low-Cost house" or "Low-Rise Building".

8:13 Before adjourning, Dr. Tabujara thanked Dr. Roman Kintanar and the PAGASA for hosting this 8th Meeting. The Meeting was adjourned at 4:30 P.M.

(Sgd.) Geronimo V. Manahan
Secretary

(Sgd.) Ernesto G. Tabujara
Chairman

[illegible] by:

[illegible] Enrique[illegible]

MINUTES of the 9th MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DEVELOPMENT OF DESIGN CRITERIA AND METHODOLOGY FOR LOW-COST/LOW-RISE BUILDINGS TO BETTER RESIST EXTREME WINDS".

Held on 12 December 1974 at the National Hydraulic Research Center Conference Room, College of Engineering, U.P., Diliman, Quezon City at 2:30 P.M.

Present: Dr. Ernesto G. Tabujara, Presiding
Mr. Catalino P. Arafiles
Engr. Ambrosio R. Flores
Dean Aurelio T. Juguilon
Prof. Geronimo V. Manahan
Engr. Jose P. Orola
Dr. Josefina M. Ramos
Engr. Joaquin O. Siopongco
Engr. Modesto D. Soriano, Jr.

Mr. Ruben Bucas (representing Col. M. Rebueno)
Mr. Peter Paul Castro
Mr. Samuel R. Coran

9:01 The Minutes of the previous meeting were read. Comments and corrections included: Mr. R. de Guzman cited Item 8:04, 11th line; as improperly phrased. He made the necessary suggestion for improvement and the new statement was re-phrased as follows: "There was a 50% cut on the schedule". The Minutes were then approved as corrected.

9:02 Dr. Tabujara introduced Mr. Ruben Bucas who represented Col. Rebueno. He also welcomed the six Pagasa members of the Committee.

9:03 Dr. Tabujara mentioned that the Sub-committee Meeting was held at Sulo Hotel to tresh out details for the forthcoming Regional Conference on May. The Meeting was hosted by Engr. Soriano, Jr.

9:04 An updated list of members of the Advisory Committee was distributed. Mr. de Guzman made corrections on the designations of his colleagues.

9:05 Engr. Siopongco suggested that Miss Lydia Tansinsin of NSDB be invited to be member of the Advisory Committee. Mr. Arafiles recalled that Gen. Singson had expressed interest to be represented in the Advisory Committee.

9:06 Dr. Tabujara stated that the primary purpose of the Meeting was to follow-through Item 8:07 of the previous Meeting. He said that the Body is committed to host the Regional

Conference. He then presented the Tentative program prepared by the Program sub-committee for further comments, and/or revisions for final approval. (See attached)

9:07 Mr. Hugo de la Cruz informed the body that Dr. Kintanar will not be available on May 16 and 17, 1975. The keynote address has to be delivered by somebody else. Dean Juinio's name was suggested by Engr. Soriano, Jr. This was approved unanimously.

9:08 The Project Background and Summary will be presented by Dr. Tabujara. Another suggestion on the program was the inclusion of a local group to discuss Structural Connection Details together with Dr. E. Pfrang. Suggested names were: Jose Ma. de Castro, Fiorello Estuar and Romeo Estañero. Engr. Flores was requested to prepare handouts for his part in the program.

9:09 As suggested by Dean Juguilon, the time for Registration should start at 8:00 a.m. instead of 8:30 and the rest of the schedule is as follows:

International Conference on the Dessimination of Project Results of the Research on "Development of Improved Design Criteria to Better Resist the Effects of Extreme Winds for Low-Rise Buildings in Developing Countries"

TENTATIVE PROGRAM

Friday, May 16, 1975

Part A: Opening Ceremony

Master of Ceremonies: Director Angel A. Alejandrino

8:00 Registration

9:00 Philippine National Anthem

Keynote Address .... Dean Alfredo L. Juinio

Project Background and Summary .... Dr. Ernesto G. Tabujara

Part B: Presentation of Results

9:30 Distribution of Extreme Winds .... Mr. Rodolfo A. de Guzman

10:00 Break

10:30	Draft Criteria for Wind Loading	Dr. Richard D. Marshall
11:20	Structural Connection Details and Improved Architectural Practices	Mr. Noel J. Raufaste, Jr.
12:00	L U N C H	
2:00	Economic Analysis and Socio-Economic Considerations	Mr. Noel J. Raufaste, Jr.
2:30	Information Transfer	Mr. Noel J. Raufaste, Jr.
3:15	Break	
3:45	Effects of Research on Bay of Bengal Countries	Dr. Jamilur R. Choudhury
4:15	Implementation of Results ..	Engr. Ambrosio R. Flores Engr. Andres O. Hizon
4:45	Social Hour	

Saturday, May 17, 1975

Part C: Discussions

Master of Ceremonies: Engr. Joaquin O. Siopongco

9:00	Panel Discussion	Dr. Richard D. Marshall Mr. Noel J. Raufaste, Jr. Mr. Rodolfo A. de Guzman Engr. Ambrosio R. Flores Engr. Modesto D. Soriano, Jr.
10:30	Break	
11:00	General Discussion by Participants	
11:45	Closing Remarks and Future Projections	Dr. Ernesto G. Tabujara Mr. Noel J. Raufaste, Jr.
12:00	L U N C H	
2:00	Field Trip to PAGASA Science Garden	Col. Alberto R. Sanchez, Marshal
3:30	Refreshments	

9:10 Appointment of Committee Chairmen and Members for each of the working Committees was made tentatively:

Overall Chairman:	Dr. Ernesto G. Tabujara
Finance Committee:	Engr. Modesto D. Soriano, Jr., Chairman Dr. Ernesto G. Tabujara Col. Alejandro R. Kabiling Engr. Joaquin O. Siopongco
Arrangements Committee:	Engr. Jose P. Orola, Chairman Engr. Modesto D. Soriano, Jr. Engr. Rosalio A. Mallonga Mr. Catalino P. Arafiles
Documentation Committee:	Engr. Ambrosio R. Flores, Co-Chairman Prof. Geronimo V. Manahan, Co-Chairman Dean Aurelio T. Juguilon Mr. Rodolfo A. de Guzman
Reception and Hospitality Committee:	Col. Alberto R. Sanchez, Chairman Arch. Cesar H. Concio Dean Aurelio T. Juguilon Col. Manuel R. Rebueno Mr. Wellington A. Miñoza
Program and Invitation Committee:	Mr. Manuel C. Bonjoc, Chairman Engr. Andres O. Hizon Prof. Angel A. Alejandrino Engr. Miguel V. Paala
Publicity Committee:	Engr. Octavio A. Kalalo, Chairman Dr. Ernesto G. Tabujara Engr. Cesar A. Caliwara Mr. Hugo de la Cruz

9:11 There were three suggested places for the Conference. The SSS, NCDB and the Population Center. The SSS was finally preferred due to its proximity and convenience to most of the participants. In this connection, the help of Engr. Paala was to be solicited.

9:12 The documentation and Secretariat expenses will be shouldered by the NBS as before.

9:13 The Meeting was adjourned at 3:30 P.M.

(Sgd.) GERONIMO V. MANAHAN
Secretary

Prepared by:
(Sdg.) Mrs. Cynthia S. Enriquez

(Sgd.) ERNESTO G. TABUJARA
Chairman

MINUTES of the 10th MEETING of the ADVISORY COMMITTEE formed in connection with the Research on "DEVELOPMENT OF IMPROVED DESIGN CRITERIA TO BETTER RESIST THE EFFECTS OF EXTREME WINDS FOR LOW-RISE BUILDINGS IN DEVELOPING COUNTRIES".

Held on March 19, 1975 at the Seminar Room, 4th floor, Melchor Hall, University of the Philippines, Diliman, Quezon City at 2:15 P.M.

Present: Dr. Ernesto G. Tabujara, Presiding
Prof. Geronimo V. Manahan, Secretary
Engr. Modesto D. Soriano, Jr.
Mr. Catalino P. Arafiles
Mr. Manuel C. Bonjoc
Mr. Hugo de la Cruz
Engr. Ambrosio R. Flores
Mr. Rodolfo A. de Guzman
Engr. Andres O. Hizon
Col. Alberto R. Sanchez
Engr. Joaquin O. Siopongco

Mr. Peter Paul M. Castro
Mr. Sammy Coran
Mr. Bayani Lomotan

10:01 The Minutes of the 9th Meeting were not mimeographed on time, but was read by Dr. Tabujara. The Minutes was approved as corrected. The Tentative Program for the Regional Conference to be held on May 13-17, 1975 in Manila was reviewed.

10:02 Dr. Tabujara announced that this meeting was convened to finalize the plans for the Regional Conference. The coming conference is a follow through of the successful November 1973 Workshop. During that year, the Committee had only two weeks of preparation. In this Regional Conference Dr. Richard D. Marshall and Mr. Noel J. Raufaste, Jr. will be presenting two important papers.

10:03 Since the SSS auditorium and the NSDB Hall will not be available on May 13, 1975 it was agreed that another place be chosen, instead of changing the agreed dates. Suggested places were the Population Center and the World Health Organization auditorium. However, upon the suggestion of Engr. Soriano it was agreed that the GSIS Social Hall would be a better place to hold the conference especially since there is an adjacent canteen and the hall's maximum seating capacity is 400 persons. Some members were apprehensive of the parking conditions in the area. The parking space problem will be worked out by Engr. Soriano. Any other related problem would be threshed out by the Arrangements Committee which shall convene on the 24 March 1975.

10:04 The Chairmen and members of the Sub-Committees for this Regional Conference were read. In addition, Col. Sanchez was appointed member of the Reception and Hospitality Committee and Mr. Bonjoc as Chairman of the Program Committee. The Program Committee may work out plans for a guided tour for the foreign delegates. Individually, the Chairmen were advised to call upon their members to coordinate details and work out problems.

10:05 The Finance and Arrangement Committees would meet on Monday, March 24, 1975 and have luncheon at the office of Engr. Orola at the GSIS, Manila. Dr. Tabujara offered to host the meeting, but Engr. Soriano insisted to do this instead.

10:0[illegible] Dr. Tabujara reported that by next week, the Tentative Program, the Minutes of the previous meetings as well as the up-dated list of the Philippine Advisory Committee members will be sent out. To be included as members of the Philippine Advisory Committee are the representative of the Civil Aeronautics Administration and Miss Lydia Tansinsin of NSDB. Gen. Singson had previously recommended Engr. Salita as one of his representatives.

10:07 Engr. Flores wanted clarification on the meaning of: "Implementation of Results" as indicated on the Tentative program. Dr. Tabujara explained that the first phase of this research ends on January 1976 and how the results can be used have to be discussed. He also stated that the title is still tentative and can still be made more explicit.

10:08 On the Tentative Program the phrase "Where do we go from here?" could be changed to "Future plans or Programs" or "Projections" as suggested by Mr. Arafiles and Engr. Flores.

10:09 The Meeting was adjourned at 3:30 P.M.

(Sgd.) [illegible] V. [illegible]
Secretary

(Sgd.) [illegible] C. [illegible]
Chairman

Prepared by:
(Sgd.) Mrs. Cynthia S. Enriquez

MINUTES of the 11th MEETING of the ADVISORY COMMITTEE convened in connection with the Research on "DEVELOPMENT OF IMPROVED DESIGN CRITERIA FOR LOW-RISE BUILDINGS IN DEVELOPING COUNTRIES TO BETTER RESIST THE EFFECTS OF EXTREME WINDS".

Held on May 8, 1975 at the Office of Dir. Rosalio A. Mallonga, Bureau of Public Works, Quezon City at 2:30 p.m.

Present: Dr. Ernesto G. Tabujara, Presiding
Prof. Geronimo V. Manahan, Secretary
Prof. Angel A. Alejandrino
Mr. Catalino P. Arafiles
Mr. Manuel C. Bonjoc
Archt. Cesar H. Concio
Engr. Ambrosio R. Flores
Mr. Rodolfo A. de Guzman
Col. Alejandro R. Kabiling
Engr. Jose P. Orola
Engr. Miguel V. Paala
Engr. Joaquin O. Siopongco
Engr. Modesto D. Soriano, Jr.
Atty. Jacobo S. de Vera
Engr. Ramon R. Veto

Dr. Richard D. Marshall
Mr. Noel J. Raufaste, Jr.
Engr. Isidro Jarabelo, Jr. (Representing Dir. Rosalio A. Mallonga)

11:01 The Minutes of the previous Meeting was read and approved.

11:02 The Tentative Program of the Regional Conference was also read and reviewed. On the Tentative Program, "Panel Discussion" was changed to "Open Forum" and "Panel Discussion Members" to "Discussants" as suggested by Dean Concio and Mr. Arafiles. Dean Concio also suggested that "General Discussion by Participants" in the Tentative Program be changed to "Continuation of Open Forum" in order to encourage more participation. Dr. Tabujara mentioned the difficulties of getting a keynote speaker. He also mentioned that he has invited Gen. Florencio Medina of the NSDB and in case Gen. Medina is not available, the keynote speaker will be one of the members of the Phil. Advisory Committee. The Closing Remarks will be delivered by Mr. Raufaste, Jr. Dr. Tabujara also announced that the discussants will have to prepare a 10-minute comment and observation. The Program as corrected will go to press immediately.

11:03 Dr. Tabujara welcomed and introduced to the body two new members from PHHC, Atty. Jacobo de Vera and Engr. Ramon Veto who took the place of Col. Manuel R. Rebueno who had retired.

11:04 Reports from the different sub-committees were asked by Dr. Tabujara. The Reception and Hospitality Committee informed the body that during the sub-committee meeting, they agreed that the Social Hour will be sponsored by the GSIS. It was also reported that the envelopes for the Conference are ready. Dr. Tabujara suggested that the envelopes be printed at the same time with the program. Name plates for participants are being prepared by Mr. Miñoza's staff. Engr. Soriano mentioned that some GSIS girls will help the hospitality sub-committee.

11:05 Engr. Orola, Chairman of the Arrangements Committee reported that the GSIS Social Hall is airconditioned and with complete facilities. Another member of the Arrangements Committee, Engr. Soriano, Jr. , suggested that car stickers for parking should be sent out together with the invitations. Banners to be placed in front of the GSIS Building are also ready.

11:06 The Chairman of the Finance Committee, Engr. Soriano, Jr., reported that a check for ₱800.00 was issued to Mrs. Cynthia Enriquez as cash advance for pertinent Conference expenses.

11:07 Mr. Bonjoc of the Program & Invitation Committee informed the body that most of the participants who are to be invited are developers. Their addresses in the list in the previous Workshop are incomplete. Dr. Tabujara announced that members may invite anybody they think is interested in the forthcoming Regional Conference.

11:08 Dr. Tabujara also informed the body that International Secretariat Services has submitted a quotation of ₱1,600.00. This is composed of 6 stenographers and one Documentation Specialist. The Publicity Committee expects a press release regarding this Regional Conference in two newspapers.

11:09 At 3:30 p.m. Mr. Raufaste, Jr. showed a 16mm. movie entitled "Development of Improved Design Criteria for Low-Rise Buildings in Developing Countries to Better Resist the Effects of Extreme Winds" about this research project and informed the group that one copy of this film will be left with Dr. Tabujara.

11:10 Dr. Marshall announced that the Wind Tunnel activities is behind schedule by approximately one year and he asked the Committee how they may continue Wind Tunnel studies.

11:11 The funding problem of this activity was cited although Dr. Tabujara expressed his appreciation of the value of technology transfer and took responsibility on some short-comings of the Committee. However, he expressed the Committee's desire to continue with this very important undertaking and wanted Dr. Marshall to spell-out areas of concern and suggest a Time Frame of Work.

11:12 It was decided that with regards to funding, a project proposal would be submitted to NSDB.

11:13 Engr. Flores suggested:

a) To extend full scale data with regards to field instrumentation.
b) To pinpoint technical gaps in the Wind Tunnel tests.
c) Establish a center capable of carrying Wind Tunnel tests in general.

11:14 Mr. Raufaste, Jr. stated that the Committee has now the necessary equipment and the only missing part is the "person or persons who'll press those buttons". According to Dr. Marshall it would take a year to train such a person and he can afford to be in the Philippines an aggregate of only six weeks a year.

11:15 Dr. Tabujara mentioned that this project is indeed more useful and important to us Filipinos. Engr. Paala also mentioned that materials emanating from this project were already incorporated in SSS amended Manuals. He also suggested solicitation of funds from private corporations. Dir. Alejandrino suggested that a Trust Fund Foundation like the NHRC would be better.

11:16 Dr. Marshall commended the Pagasa personnel who have worked closely with him.

11:17 The Meeting was adjourned at 5 p.m. with Dr. Tabujara thanking Dir. Mallonga and Asst. Dir. Isidro Jarabelo, Jr. and his staff for hosting the Meeting.

(Sgd.) GERONIMO V. MANAHAN
Secretary

(Sgd.) ERNESTO G. TABUJARA
Chairman

Prepared by:

(Sgd.) Mrs. Cynthia S. Enriquez

APPENDIX B

Low-Rise Low-Cost Housing and Extreme Wind Related Problems in Bangladesh

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

Report No. 2

Prepared by

Dr. Jamilur R. Choudhury

Associate Professor of Civil Engineering

Bangladesh University of Engineering and Technology, Dacca.

For

National Bureau of Standards

U.S. Department of Commerce

Washington D.C.

April 1975

CONTENTS

1. INTRODUCTION

1.1 Scope

The first report on "Low-rise Low-cost Housing and Extreme Wind-related Problems in Bangladesh", presented at the International Workshop held in Manila, Phillipines from November 14-17, 1973, dealt with the overall housing conditions in the country and gave an outline of the extreme wind related problems. The present report furnishes further information on Socio-economic factors, the present conditions of urban and rural housing, and housing needs for the next ten years. It also provides data on available wind speed records and wind damage statistics. Finally, some special problems unique to Bangladesh are discussed.

1.2 Limitations

Originally it was intended to include in this report all the Bay of Bengal (Indian Ocean) countries (viz. India, ~~Ceylon~~ Sri Lanka, Burma and Bangladesh) facing extreme wind problems. The author's efforts to obtain data from the first three countries have not been successful. The scope of this report is therefore limited to Bangladesh only. Some information regarding the other countries is included in Appendix .

2. SOCIO-ECONOMIC FACTORS

2.1 Gross Domestic Product (GDP)

The GDP of Bangladesh was estimated to be Takas 42.94 billion (equivalent to US $ 5.3 billion, at official rate of exchange*) at the beginning of FY73[1]. The contribution of housing to this GDP was Ta. 2.36 billion or 5.5% of total. The First Five Year Plan formulated by the Planning Commission of Bangladesh Government envisaged a growth of GDP to Ta. 65.42 billion in FY78 with an average annual rate of growth of 8.8%. The contribution of housing is expected to go upto Ta. 2.88 billion - increasing at 4.1% annually - but its share in total GDP would be going down to 4.4%. The per capita GDP is expected to grow from Ta. 580 to Ta. 766 increasing at the rate of 5.7% annually**.

2.2 Population

Although a census of population was conducted in early 1974, the details are yet to be made public. However, various official and unofficial estimates of the population and rates of growth have been made. According to official estimates, the present population should be around 78 million[1]. The density of population would be about 1415 persons per square mile.

The estimated rate of natural increase of population in 1973 was about 3% (with 47 births and 17 deaths per thousand). Inspite of efforts to popularize family planning programs in the country, this rate of increase has shown very little change. The Five Year Plan of the Government, however, assumes that the rate of increase of

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* 1 US Dollar = 8.08 Bangladeshi Takas.
** All values are calculated at FY73 prices.

population will fall by 0.05% every year(1). Using this as a basic, the projected population in 1985 will be around 100 million.

2.3 Income distribution

The Urban Housing Survey(2) carried out in 1970 revealed the gross inequalities in income distribution among urban households. Table 1 shows the details of income distribution among the representative sample of 2494 households covered by the survey.

Table 1

Income Distribution in Urban Households

Annual income in Takas	Income group designation*	Number of households in the income group expressed in percent of total households in the area		
		Dacca City	Chittagong City	All urban areas
Less than 2,400	Low	45.96	37.73	53.89
2,400 - 5,999	Lower middle	29.63	35.96	30.51
6,000 -11,999	Middle	13.65	19.30	10.44
12,000 -23,999	Upper middle	8.08	5.26	3.83
24,000 and above	Upper	2.69	1.75	1.33

* This classification into groups is arbitrary.

The survey revealed that at least one-third of the urban households had income between Ta. 100 to Ta. 200 a month. The average annual income of a urban household was estimated to be about Ta. 3900. However, 70% of the households earned less than this average.

No reliable estimate of the income distribution among the rural population is available. In 1963-64, the poorest 20% of the whole population received 7% of the GDP and the average annual income per head of the poorest 20% was (Pakistani)Rupees 157.50 or 6 US cents per person per day(3). Almost the whole of this income was spent in buying food.

3. URBAN HOUSING

3.1 General

Results of a Urban Housing Survey, carried out by the Institute of Statistical Research and Training, University of Dacca, during June to August 1970, have recently been published[2]. The survey included both urban and potentially urban locations, covering 78 cities, towns and townships. A sample of 2500 households was selected from the 'universe' according to a stratified two-stage random sampling design. The discussion which follows is mainly based on the results of the above survey. However, the large-scale dislocation of the whole population during the war of liberation in 1971 and the subsequent mass influx of rural population into the large cities, have changed the housing situation significantly. The population of the cities has greatly increased, in some cases by about 50%. The number of houses has, however, remained almost constant during these years. The scarcity and high cost of building materials has resulted in almost a standstill of new private building construction. Most of the additional urban population, therefore, live in makeshift shacks in squatter settlements. This has made the housing situation even worse than what it was in 1970, when the Survey was carried out. Although a housing census was conducted in late 1973, the results are yet to be made public. It is expected that a more accurate appraisal of the deteriorating housing situation may be made when the results of the census are available.

3.2 Types of Urban Houses

The survey(2) identified six major types of structures used for urban houses:

Type I   All pucca*; floor usually of cement concrete, wall usually of burnt brick and roof usually of reinforced cement concrete.

Type II   Floor and wall pucca; corrugated galvanized iron (C.I.) roofing.

Type III   Floor pucca; wall and roof C.I. sheet.

Type IV   Floor Kutcha*; wall and roof C.I. sheet.

Type V   Floor Kutcha; C.I. sheet roof on walls neither pucca nor C.I. sheet (e.g. of split bamboo thatch)

and

Type VI   Floor Kutcha; roof and wall Kutcha (i.e. material other than 'pucca' or C.I. sheet).

Table 2 shows the number of households occupying different types of houses in urban areas of Bangladesh. As expected, the percentage of households living in all pucca (Type I) houses increases as the income level rises. Only 8% of 'low income group' families live in pucca houses.

It appears that Type V houses, i.e. with Kutcha floor, C.I. sheet roof and walls of various indigenous materials are very popular in all income groups (see Fig. 2, Report no.1).

Houses of Types II, III, IV and V have C.I. sheets as roofing material and these four types account for about 40% of all urban houses.

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* 'pucca' usually means cement concrete, lime concrete or burnt brick. 'Kutcha' usually means mud, thatched-bamboo etc.

Table 2

Percentage of urban households of different income groups living in different types of houses

Type of House / Income groups	I All pucca	II Floor and Wall pucca; roof C.I. sheet	III Floor pucca; Wall and roof C.I. sheet	IV Floor Kutcha; Wall and roof C.I. sheet	V Floor Kutcha; Wall neither pucca nor C.I. sheet; Roof C.I. sheet	VI Floor Kutcha: Wall and roof neither pucca nor C.I. sheet	Others
Low	7.85	2.99	1.27	5.09	28.95	29.39	24.38
Lower middle	24.83	10.57	3.97	7.93	23.87	12.15	16.64
Middle	50.19	18.92	5.79	2.70	5.79	3.47	13.14
Upper middle	69.47	7.37	2.11	1.05	6.32	1.05	12.63
Upper	63.64	6.06	3.03	6.06	6.06	0.00	15.15
All groups	20.57	7.18	2.62	5.57	23.80	19.97	20.29

3.3 Kitchen, Bathroom and Water supply

The survey revealed that only 41% of 'low income group' households have regular kitchens, 4% share kitchen with other family, 34% cook somewhere inside their house, 14% cook in the Verandah and others cook in open spaces outside the house. Only 9% of the households in the 'low income group' had their own bath room; 85% had no bathroom at all (own or shared). They usually take their baths in the rivers or ponds which commonly have a little space enclosed in split bamboo thatch for use by womenfolk. The concept of a closed bathroom is almost non-existent in rural households and is yet to gain popularity even in the towns of Bangladesh. However, with rising income level, the households usually have separate bath rooms.

Only 7% of 'low income group' households had taps for water supply and 57% used manually operated tube-wells.

3.4 Verandahs and Open Spaces

A Verandah around a house is a common feature in a Bangldeshi house. Moreover, it is common to have open spaces around houses even in urban areas. About two-thirds of the houses of 'low income group' had open spaces around them, the average area being 280 sq. ft. and about 41% had verandahs, the average area being 77.3 sq. ft.

3.5 Floor Area

The average floor area per person of a household (excluding detached W.C. and kitchen) for different income groups is shown in Table 3.

Table 3

Floor Area in Urban Households.

Income group	Average floor area per person in square feet		
	Dacca city	Chittagong city	All areas
Low	32.08	39.51	37.55
Lower middle	43.93	45.18	48.93
Middle	57.59	67.21	63.11
Upper middle	86.37	85.34	90.54
Upper	77.34	102.49	94.41
All groups	47.93	53.03	48.98

The overall average floor area of 48.98 sq. ft. shown above shows the poor condition of urban housing in Bangladesh.

About 50% of the surveyed households informed the investigators that their present accommodation was not sufficient. In Dacca city, 71% of the households said that they needed additional space. The survey found that the overall average of the desired norm (existing space plus the space demanded) of the floor area was 80 sq. ft. per person. However, this value showed a remarkable variation according to the income level as shown in Table 4.

Table 4

Desired "norm" of Floor area

Income group	Desired norm of floor area (average) in sq. ft.		
	Dacca city	Chittagong city	All areas
Low	68.3	71.6	68.3
Lower middle	79.3	77.3	79.4
Middle	92.0	112.2	97.0
Upper middle	125.1	112.5	127.9
Upper	113.0	102.5	131.0
All classes	83.6	88.0	80.3

One interesting feature revealed by the survey was that the desired norm for Upper middle income group was higher than the Upper income group, both in Dacca and Chittagong cities.

It may be concluded from data in Table 4 that the 'low income group' household, with an average of 5.7 persons per household, needs about 390 sq. ft. of floor area (excluding kitchen and latrine) on the average.

3.6 Rent

Out of 2494 households interviewed, 1077 (43%) lived in rented houses. The monthly average rent paid by the 'low income group' households was only Ta. 12.42. Table 5 shows the rent for all the income groups. It is seen that the average rent for the 'upper income group' is at most 10% of their total income.*

Among the total of 1417 households who lived in their own houses, it was found that 52% of households of 'low income group' inherited their houses, 20% got their houses built and 16% bought their houses from others. According to the owners' estimate, the average price (at the time of procurement) of a house for 'low income group' was Ta. 7,800.

Table 5

House rents in Urban areas.

Income group	Average monthly rent (Takas)
Low	12.42
Lower middle	34.58
Middle	73.31
Upper middle	154.21
Upper	218.91

* Rents have gone up by around 100% during the last three years.

3.7 Urban Housing Demand

The already appalling urban housing situation is further deteriorating due to the large-scale migration of landless rural population into the large cities. This has naturally resulted in an increase in the number of slum dwellers and squatters. The situation in Dacca City reached a stage where at least a fifth of the population were living in slums and squatter settlements. These were mostly concentrated in and around the old railway track (which passed through the heart of the city) after it was abandoned due to the construction of a new track by-passing the centre of the city. The Government has recently evicted these unauthorized settlers and has started resettling a small fraction of them in the outskirts of the city.

The urban population was estimated to be 2.92 million in 1961 (5.2% of total) and around 6 million (8% of total) in 1973. Assuming that the urban population is increasing at a rate between 6-7% every year, the urban population in 1985 would be around 12 million. This means an increase of 6 million over the 1973 urban population.

During 1961-73, the urban population increase of about 3 million required the construction of 0.5 million new houses (at the rate of 6 persons per household). But during this period, not more than one fifth of the requirement was satisfied and there was a backlog of around 0.4 million houses. By 1985 the urban population increase of around 6 million would require the construction of about one million new houses (assuming the same modest rate of one house for six persons). It is almost inconceivable how a poor country like Bangladesh can solve this gigantic problem.

3.8 Urban Housing Development Plans

The First Five Year Plan (1973 - 1978) of the Government has recognized the enormity of the problem and has directed its efforts towards achieving short-term objectives by undertaking the following programs[1]:

(i) building of multi-storied apartment houses within the urban areas for low and lower middle income groups in the public sector.

(ii) building of 'minimum shelters' in a planned environment

(iii) development of 'sites and services' schemes through the Urban Development Agencies and local bodies for building apartment houses

(iv) organization and financing of Co-operative apartment houses

(v) providing planned environments for temporary settlements with a view to developing these into proper housing estates in future.

(vi) framing adequate legislation and building bye-laws, housing codes for guiding and controlling the development.

The Government views the construction of multi-storied flats and 'minimum' shelters for the low income groups as the desirable long-term solution especially in view of the extreme scarcity of buildable urban land. The Five-year Plan envisages two components in the immediate solution of low income urban housing problem:

(i) multi-storied apartment housing

and (ii) 'nuclear' shelters providing pucca accommodation - of a basic sort at a much lower unit cost than the apartments. These will seek to house about 40 families per acre in shelters within 80 square yards of space.

In view of the rising inflation all over the world, Bangladesh, which has to import a substantial fraction of foodgrain and industrial raw material requirements, is being forced to spend more and more on feeding its starving population. This has adversely affected its housing program discussed above and it is doubtful whether the 115.6 million takas (2.8% of the total public sector outlay of the plan) allocated to the Housing Sector in the Five-year Plan can be made available.

4. RURAL HOUSING

4.1 General

The population of Bangladesh is predominantly rural with about 69 million people (92% total) living in roughly 64000 rural settlements scattered all over the country.

Very little quantitative information is available on rural housing except that furnished by the 1960 Housing Census.

4.2 Structural Conditions of Rural Houses

A brief description of the structural conditions was given in Sec. 2.2.2 of the First Report. Table 6 gives further details regarding the materials used in rural houses. It is felt that although 15 years have elapsed since the Census was conducted, the qualitative characteristics of the houses have not changed significantly.

Table 6

(a) Principal Materials used in Roofs of Houses, (shown as percentage of total houses in each District)

District	Principal material used in Roof: Cement Concrete/ Baked brick/ Stone	Baked Tiles	CI./ Asbestos sheets	Wood	Bamboo Thatch	Mud Thatch	Others
1. Dacca	1.1	0.1	63.1	0.3	1.2	29.6	4.5
2. Chittagong	0.3	0.8	22.4	0.2	1.2	70.6	4.5
3. Dinajpur	0.4	0.1	11.1	0.1	0.7	87.0	0.4
4. Rangpur	0.2	0.4	21.3	0.2	2.6	74.4	0.8
5. Bogra	0.3	0.3	43.0	0.1	0.2	55.4	0.7
6. Kushtia	2.2	0.7	26.4	0.1	0.6	68.8	1.1
7. Rajshahi	0.9	1.1	24.7	*	1.4	71.5	0.4
8. Pabna	0.4	0.1	44.4	1.5	0.3	49.0	4.2
9. Khulna	4.5	1.4	9.9	0.3	0.9	29.9	53.3
10. Jessore	2.5	1.5	19.2	0.2	0.5	70.7	5.3
11. Barisal	0.5	0.6	37.1	0.5	1.0	33.3	27.0
12. Mymensingh	0.2	0.1	38.0	0.2	1.1	53.5	7.0
13. Faridpur	0.6	0.7	44.8	0.2	0.6	44.2	8.9
14. Sylhet	0.3	0.8	20.6	0.2	2.4	70.5	5.3
15. Comilla	0.4	0.1	45.8	0.3	1.2	42.8	9.2
16. Noakhali	0.2	0.2	39.5	0.2	0.9	46.9	12.1
17. Chittagong Hill Tracts	*	*	2.0	*	3.5	75.0	19.5

* Negligible

Table 6

(b) Principal materials used in Walls of Houses (shown as percentage of total houses in each District)

District	Principal material used in Walls							
	Concrete/ Baked brick/ stone	Stone in Mud	Earth/ Kutcha Bricks	C.I./ asbestos sheets	Wood	Bamboo	Thatched	Others
1. Dacca	1.4	0.2	13.3	13.5	1.1	31.2	23.1	16.4
2. Chittagong	0.9	0.2	32.8	0.5	0.5	63.7	1.1	0.4
3. Dinajpur	1.1	0.3	41.3	0.3	0.2	36.3	19.7	0.7
4. Rangpur	0.5	0.2	6.7	2.4	0.6	49.8	37.0	2.8
5. Bogra	0.6	0.1	54.9	2.2	1.6	24.3	12.1	4.3
6. Kushtia	3.3	0.8	38.8	0.9	0.4	42.2	7.9	5.5
7. Rajshahi	1.4	0.2	53.8	0.4	0.1	25.1	16.2	2.8
8. Pabna	0.7	*	2.4	6.5	1.9	22.8	24.6	41.0
9. Khulna	3.0	0.9	30.3	1.7	6.9	21.9	5.3	30.1
10. Jessore	3.8	1.0	30.0	1.4	3.9	44.0	3.0	12.7
11. Barisal	0.6	0.1	0.7	14.5	6.6	16.3	34.1	27.2
12. Mymensingh	0.3	0.1	3.5	8.6	1.0	29.4	30.4	26.6
13. Faridpur	0.6	*	0.4	11.2	4.0	24.6	27.9	31.3
14. Sylhet	1.4	0.1	2.0	2.9	1.5	28.9	56.8	6.8
15. Comilla	0.8	0.1	4.8	9.8	0.8	27.6	37.5	18.6
16. Noakhali	0.4	0.1	2.1	3.7	0.5	49.8	28.0	15.4
17. Chittagong Hill Tracts	0.1	*	0.8	*	0.1	98.7	0.2	0.1

* = Negligible

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

4.3 Rural Housing Demand

It is estimated that the population of Bangladesh in 1985, would be about 100 million. Of these, a little less than 90% would still be living in the rural areas. The rural population would, therefore, increase by about 20 million during the next ten years. At the modest rate of 6 person per dwelling unit, this would mean the construction of 3.33 million new rural homes. It was estimated that 3 million houses needed replacement due to damage, destruction and natural dilapidation upto the end of 1971. Out of these about 0.4 million have been reconstructed with the help of voluntary relief organizations. Therefore, the total number of rural houses needed in the next ten years would be about 6 million.

4.4 Rural Housing Development Plans

The Government plans are only to provide supporting environmental facilities like drinking water supply and sanitation and to provide institutional support in the organization of co-operatives at 'Thana' (small administrative unit composed of a number of villages) level. The Government envisages the creation of Co-operative Housing Finance Corporation with an authorized share capital of Ta. 250 million to marshall and channel funds for a non-profit housing program. A principal function of the CHFC will be to mobilize savings through a network of branches throughout the country. Seventeen model villages - 5 in the coastal areas and 12 in other regions - are planned to be built by the Government. Each village would be a 400 family nucleated settlement, the estimated cost (1973) being Ta. 3 million on average.

5. SPECIAL SOCIO-CULTURAL CHARACTERISTICS

The urban housing survey(2) revealed that the Bangalees share baths but rarely share kitchen. Toilet and kitchen are often preferred by the Bangalees to be detached from the main house. Taking bath in community ponds outside the house is quite popular.

Religious factors play an important role in the orientation of houses. The population of Bangladesh is predominantly Muslim. A Muslim is supposed to pray five times a day facing the direction of Mecca (viz. West) and to avoid any confusion regarding direction, almost all the houses in Bangladesh have sides either in the North-South or East-West direction. A Muslim is not supposed to recline or lie with his feet pointing towards Mecca - it is, therefore, more usual to have beds in North-South direction. The sitting arrangement in a latrine has also to be North-South and never East-West. These are important considerations in the architectural design of a Bangladeshi house.

6. WIND SPEED RECORDS

The location of wind-measuring meteorological stations are shown in Fig. 1. ~~Four~~ of these are equipped with P.T. anemometers, but these are not capable of measuring wind speeds in excess of 70 mph. Table 7 shows the available annual maximum wind speed records. ~~Some~~ of these values are based on eye observations of experienced meteorologists. Using the data in Table 7 and applying the Lieblein Fitting Technique[5], the wind speeds for return periods of 20, 50 and 100 years have been calculated and is shown in Table 8.

Due to insufficient data, it has not been possible to include the tropical frequency factor[5]. It is hoped that a more detailed investigation of the meteorological records will throw more light on their aspect of the problem. Another anomaly in the data supplied is that some of the readings from anemometers are taken at heights varying from 37 ft. to 84 ft. above surrounding ground level, whereas other readings are estimated at ground level. A further drawback of these records is that some of the values extracted from pen-recorder plots are probably gust values (of the order of 15 seconds) whereas the others are estimates of sustained wind speeds. The values tabulated in Table 8, therefore, only give an idea about the magnitude of the wind speeds involved. However, before recommending these values for use in the design of buildings, it is suggested that a more thorough analysis of existing wind data should be made. The instruments used in measuring wind speed should also be modernised.

Table 7

Annual Maximum Wind Speed in Miles per Hour

Year / Station	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Dacca	90	77	78	62	100	74	46	75	90	100
Chittagong	50	61	125	70	72	74	60	66	62	138
Cox's Bazaar	50	51	100	52	131	75	81	75	82	78
Bogra	22	36	32	64	52	59	38	49	41	56
Jessore	53	44	17	56	52	68	63	40	32	43
Ishundi	N.A.	N.A.	N.A.	58	58	62	52	52	63	63
Banisal	N.A.	N.A.	N.A.	35	28	51	58	24	52	60
Sylhet	N.A.	N.A.	46	52	58	73	65	81	69	81

N.A. = data not available

Source: Meteorological and Geophysical Centre, Bangladesh Meteorological Department, Chittagong.

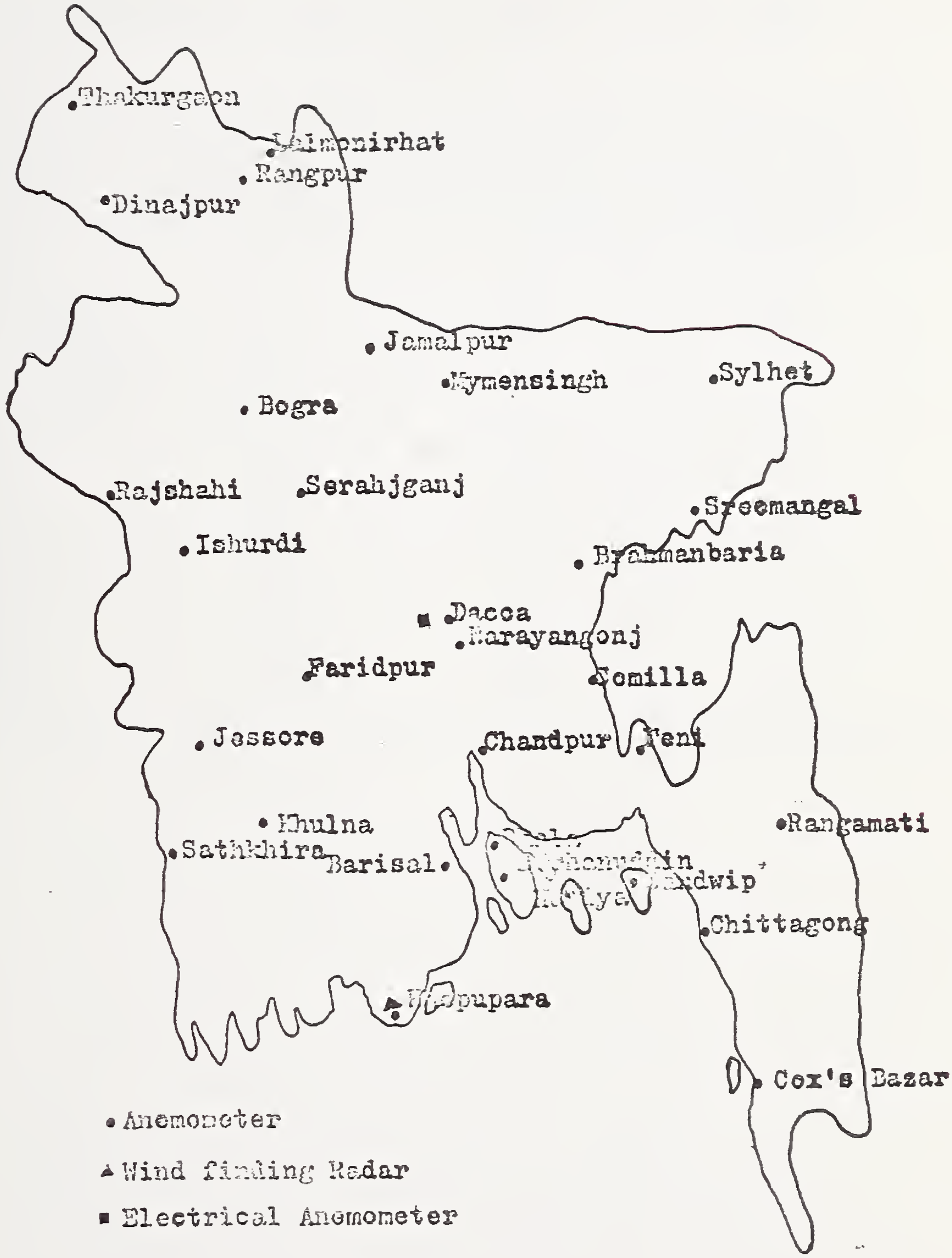


Fig. 1 Location of Wind-measuring Meteorological Stations in Bangladesh

Table 8

Wind Speeds for Return Periods of 20, 50 and 100 years.

Station	Wind Speed in miles per hour for Return Periods of		
	20 years	50 years	100 years
Dacca	123	140	153
Chittagong	122	140	153
Cox's Bazaar	109	121	131
Bogra	73	84	93
Jessore	86	101	113
Ishurdi	65	67	69
Barisal	69	79	87
Sylhet	88	96	103

7. WIND DAMAGE STATISTICS

Table 9 shows the available statistics of damaging cyclones over Bangladesh since 1795. It is extremely difficult to assess the damage to houses, particularly in the rural areas. Most of the houses are blown away by even moderate storms. Attempts have, however, been made to gather some quantitative data regarding the damage to housing. Since the cyclonic storms are usually accompanied with storm surges, these data show the combined effect of wind and storm surge damage.

Between 1960 and 1966, the total loss to crops, buildings, lives and development works was estimated at more than (Pakistani) Rupees 1334 million (equivalent to US $ 281 million), or an average of US $ 40.1 million annually. This was about 1.2% of the GNP. The total annual damage including damage other than mentioned above was estimated at about 2% of GNP of Bangladesh (then known as East Pakistan)[7].

Of the many cyclones which have affected Bangladesh in the recent past, available quantitative data regarding the most severe cyclones are discussed below.

Table 10 shows the area and population affected by the 1960 cyclones (October 9 - 10 and October 30 - 31).

Table 9

Damaging Cyclones over Bangladesh

Year	Month	Location	Maximum wind speed, mph.	Storm wave (feet)	Human lives lost	Remarks
1795	May - June	Chittagong	-	-	-	Only five brick built houses survived in Chittagong town
1797	-	Chittagong	-	-	-	Every native hut in Chittagong levelled to the ground
1822	May	Barisal	-	-	40,000	-
1831	October	Barisal	-	-	-	Storm wave hit Barisal coast
1872	October	Cox's Bazaar	-	-	-	-
1876	October	Meghna Estuary	-	10-45	100,000[1]	Affected the whole of southern coast from Barisal to Chittagong
1895	October	Sunderban	-	-	-	Affected Bagerhat sub-division
1897	October	Chittagong	-	-	14,000[2]	Dykes along sea board washed away
1919	September	Barisal	-	-	-	-
1926	May	Cox's Bazaar	-	-	-	-
1941	May	Eastern Meghna Estuary	-	-	-	-
1960	October 9-10	Eastern Meghna Estuary	-	10	3,000	Severely affected the offshore islands
	October 30-31	Chittagong	130	20[3]	8,149[4]	
1961	May	Western Meghna Estuary	90[5]	8-10	11,468	Several buildings with C.I. sheet roofs destroyed

1. Another 100,000 died in the epidemic that followed. 2. 18,000 died in the epidemic that followed. 3. 40 ft. wave estimated by Liberty Ship Charles Dunaif. 4. Another estimate shown in Table 11 puts the figure at 16,857. 5. Measured at Dacca.

1963	May	Sitakunda	125 [6]	8-12	11,520	Inundation by storm wave along coast upto 30 miles north of Chittagong and off-shore islands.
1965	May	Barisal	100 [7]	12	19,279	-
1966	October	Sandwip	90 [6]	20-22	850	Area affected: 2727 sq. miles. Inundation higher than October 31, 1960 cyclone in Chittagong.
1970	October	Khulna-Patuakhali coast	> 73	-	-	Some low lying areas of Patuakhali Barisal and Khulna were inundated by storm surge of slight to moderate intensity
	November	Meghna Estuary	138 [8]	10-30	224,000 [9]	The entire belt from Khulna to Chittagong and off-shore islands experienced hurricane winds for about 9 hours accompanied by storm surge.

6. Measured at Chittagong.
7. Measured at Dacca.
8. Reported by Naval ship.
9. Ref. 8.

(The above Table has been furnished by Mr. S.M. Hussain, Deputy Director, Meteorology)

Table 10

Area and Population affected by 1960 Cyclones(4)

	Severely affected *	Moderately affected *	Slightly affected *	Total
Area affected (sq. miles)	660	1,110	960	2,730
Estimated population	650,000	1,230,000	1,350,000	3,230,000

* By 'severely affected' areas, it is meant that these areas were either covered by the tidal flood or that they were devastated by the ravaging winds. In these areas, the number of casualties was very high, and the majority of houses collapsed or were washed away. In the 'slightly affected' areas, roofs and temporary structures experienced minor, reparable damages.

The number of houses destroyed in the three affected districts is given in Table 11. The 'slightly affected' areas in table 10 have not been included in preparing this table.

Table 11

Areas in District of	Estimated population in 1960	Number dead	Estimated number of houses	Houses Destroyed	Houses partially damaged
Noakhali	790,000	4,742	157,000	21,100 (13.4%)	96,600 (61.5%)
Chittagong	840,000	9,163	181,700	26,700 (14.7%)	81,200 (44.7%)
Barisal	250,000	2,952	50,000	N.A.	N.A.

In the areas affected by the cyclone in the districts of Noakhali and Chittagong, 14.1% of the houses were completely destroyed and 52.5% of the houses were partially damaged.

These high figures of damage to housing are attributable partly to the extremely poor quality of houses themselves, as mentioned in Sec. 4.2. The cost of a house for each family was between Rs. 30 and Rs. 50 and the house consisted of four thin tree or bamboo trunks, anchored in the floor, on which a number of straw mats or old C.I. sheet are fixed and which supports a primitive light bamboo grate and the thatch roof. The houses were of such low quality that the District Magistrate, Noakhali, estimated the average damage per house completely destroyed or partially affected at Rs. 62 (U.S. $ 13) only.[(4)]

The November 12-13, 1970 cyclone has been termed as the most destructive in living memory. About 2000 sq. miles, containing a pre-cyclone population of 1,700,000, were severely affected. According to a survey carried out in early 1971[(8)], of the 206,500 houses in the area, about 85.3% were severely damaged by the cyclone. At least 224,000 persons perished in the cyclone. In the worst-affected off-shore island, Manpura, about 98% of the houses were almost completely destroyed.

According to figures obtained from the Ministry of Relief and Rehabilitation, Govt. of Bangladesh, about 5 million houses were damaged due to cyclones and tornadoes during the 14 years from 1960 to 1973. The estimated value of the houses was Takas 1188.07 million. During the same period, floods damaged 2.58 million houses with an estimated value of Takas 850 million. The detailed statistics is given in Table 12.

Table 12

Number of Dwelling Houses Damaged due to Cyclones & Tornadoes 1960 - 1973

Year	Number of houses damaged	Estimated value of damages to housing (million takas)
1960	347,700	69.54
1961	232,292	106.46
1963	443,737	88.75
1964	15,644	3.13
1965	2,602,004	520.40
1966	273,250	54.65
1968	6,110	2.24
1969	166,361	13.56
1970	639,012	183.01
1973	269,031	146.33
Total	4,995,141	1188.07 million Takas

8. SPECIAL PROBLEMS

The rural houses in the coastal areas are usually the worst-hit by cyclones. One of the special problems in this region is the simultaneous occurrence of storm surges and high winds. The wave heights may be 10 - 15 ft. above the ground level. One solution which has been suggested for minimizing damage to property and lives is the building of houses on stilts which allow water to flow underneath. In fact, some of the multi-purpose cyclone shelters, planned to be build in these regions would be two or three storied structures, supported on R.C. columns with the ground floor left open. The wind load response of these structures would be different from ordinary structures, with all the faces, including the bottom one, being exposed to wind.

The commonly used corrugated galvanized iron sheet roofs perform poorly as heat insulating material. With the summer temperature around 80°-90°F, it becomes very uncomfortable to live in such houses. The houses are therefore built with large number of windows and openings at eaves level, which results in a highly permeable structure. Moreover, it is common to have Verandahs (about 5 ft. wide covered projections) on at least one side of the house. These projections probably adversely affect the wind load characteristics of the structure.

9. CONCLUDING REMARKS

An attempt has been made in this report to discuss the housing situation in Bangladesh. With the major thrust of the development efforts directed towards the agricultural sector and related activities, the planners in Bangladesh accord a low-priority to housing development sector. It is unlikely that the standard of housing would show any appreciable improvement in the years to come. It is anticipated that owner-built houses, with traditional materials like bamboo posts, bamboo-thatch walls and C.I. sheet roofs would retain their popularity in the rural sectors while the urban areas, particularly Dacca and Chittagong City, may have a few 5-storied blocks of small flats for low-income housing.

The amount of wind damage to houses could be minimized by proper detailing of the connection of roof structure to the supporting wall and proper connection of the roofing sheets (usually corrugated galvanized iron) to the roof structure. Proper application of design criteria developed for construction of low-rise buildings to resist extreme wind loads would go a long way in minimizing the immense loss to housing almost every year.

APPENDIX

PROBLEMS IN OTHER INDIAN OCEAN COUNTRIES

(a) INDIA

(i) Housing

The total population of India, according to the 1971 census, was 547.95 million of which 109 million (19.9%) constituted urban dwellers. Between 1961 and 1971, the growth rate of population was 24.8%.

According to late 1972 estimates, the total shortage of housing in rural areas, including huts, was around 72 million dwelling units(9). The urban housing shortage, according to statistics computed in 1965, was estimated to be around 12 million units. The total requirement of new dwelling units to be constructed in urban areas during 1961-76 has been estimated at 25 million units inclusive of an estimated 12 to 13 million units required to meet the increase in urban population during the same period. The Fourth Five Year Plan (1966-71) allocated about Rs. 2420 million to housing (about 1.6% of the total public sector investment). During the First Plan, housing outlay constituted 16% of the total public sector investment, decreasing to 8% in the second plan and 7% in the third plan. This shows that the India planners are according a very low priority to housing development plans.

(ii) Wind Loads

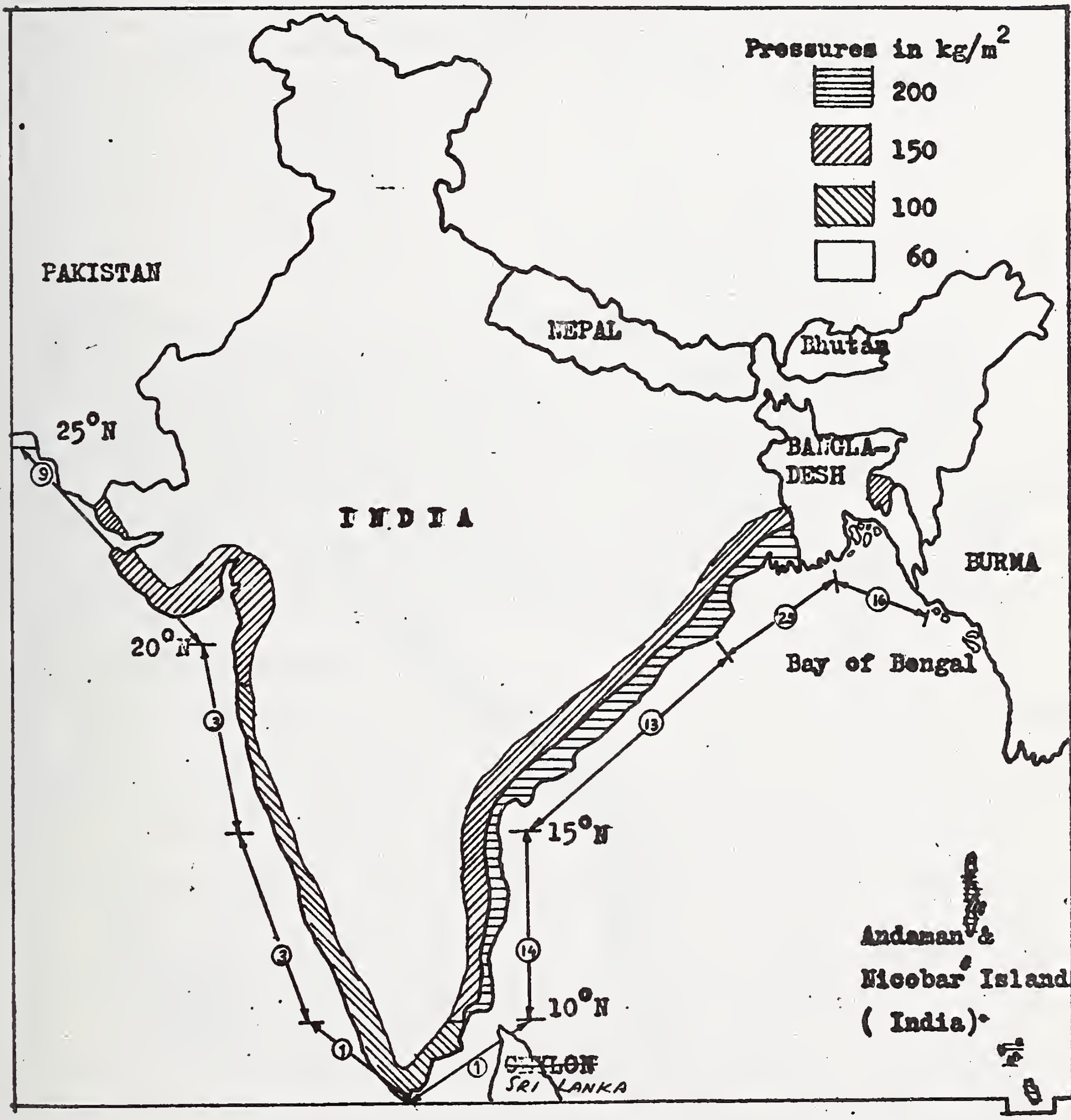
The West Bengal, Orissa and Madras coast, lying on the eastern side of the peninsula, are often affected by cyclones originating in the Bay of Bengal.

The Indian Standards Institution has well-defined wind-load codes for the design of buildings(10). Figure 2 shows a map of India showing the basic wind pressures recommended in the design of structures. The formula $p = KV^2$ has been used in arriving at these pressures, with

$K = 0.006$, V being in Km/hr and p in Kg/m^2. The code recommends a basic wind pressure of 200 Kg/m^2 (40.94 lb/ft^2) along the coastal belt upto a height of 30 metres above the retarding surface. This is equivalent to a wind speed of 182.6 Km/hr or 113.5 mph.

The number of severe cyclones which crossed the coasts during 1891 to 1960 is indicated in Fig. 2 by circles in 5° latitude zones. A severe cyclone has been defined as one in which the wind speed exceeds 89 Km/hour corresponding to a wind pressure of 48 Kg/m^2.

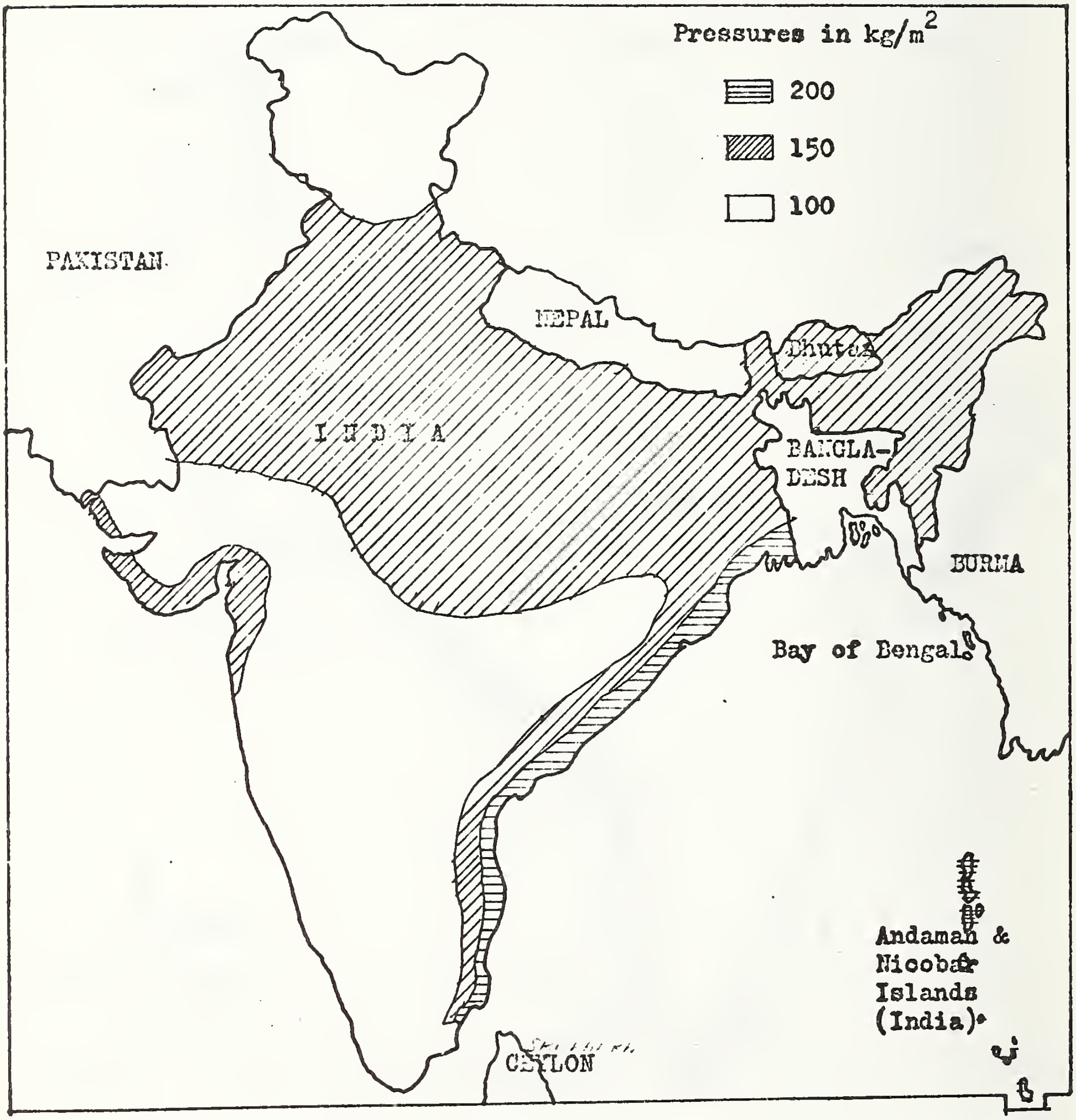
Fig. 2 Basic Maximum Wind Pressure Map of India, Excluding Winds of Short Duration*



The number of severe cyclones which have approached or crossed the coasts during 1891 to 1960 is indicated in circles in 5° latitude zones. (A severe cyclone is one in which the wind speed exceeds 89 km/h) The influence of a severe cyclone may be taken to extend from the coast line up to the line demarcating 60 kg/m² zone.

* Source : Ref. 10

Fig. 3 Basic Maximum Wind Pressure Map of India, Including Winds of Short Duration as in Squalls*



For purposes of this map, a short duration wind is that which lasts only for a few minutes, generally less than 5 minutes

* Source Ref 16

(b) BURMA AND CEYLON

From available records, it appears that cyclone damage to housing in these two countries is not as severe as that in Bangladesh.

Although approximately one out of ten cyclonic storms that occur in the Bay of Bengal strike the Arakan coast of Burma, the presence of Arakan mountain ranges and the Chin hills near the coast results in appreciable reduction of wind speeds as the cylcone moves inland. The maximum wind speed of the cyclones before striking the coast was estimated to be 70 miles per hour or less.(7) The damage caused by cyclonic storms was almost negligible when compared to other countries. However, in 1939, a cyclonic storm crossed the Arakan coast near Kyaukpyu and caused slight damage, About 300 human lives were lost in the storm surge. Again in 1948, a storm crossed the Arakan coast near Akyab causing appreciable damage to crop and structures due to accompanying floods. The damage was about 10 million Kyats (equivalent to US $ 2.1 million).

In the last few decades, only two cyclones have affected Ceylon causing appreciable damage. One was in the early thirties and the other in December 1964. In the December 1964 cyclone which hit Trincomalee, the average maximum wind velocity was about 70 m.p.h. with 100 m.p.h. gusts. The cyclone affected a 70 mile wide area. The roofs of most houses in Trincomalee were blown off.(7)

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APPENDIX C

Manila Regional Conference

Program

REGIONAL CONFERENCE

on the

Dissemination of Project Results of the Research

on

"Development of Improved Design Criteria for
Low-Rise Buildings in Developing Countries
to Better Resist the Effects of Extreme Winds."

Jointly Sponsored

by

U.S. National Bureau of Standards
U.S. Agency for International Development Mission in Manila

Philippine Advisory Committee

to be held on

May 16 and 17, 1975

at the

GSIS Auditorium
Arroceros, St., Manila

M ....

(This serves as an invitation)

R.S.V.P. by Thursday, May 15, 1975
Cynthia — Tel. 97-60-61 Loc. 566
Vivian — Tel. 98-46-89; 96-11-85
Dr. Tabujara — Tel. 99-82-60

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Mr. GUNTER P. STEITZ, Project Manager, RP-US Bayanihan School Reconstruction Project, Office of Capital Development, U.S. Agency for International Development

PROGRAM

FRIDAY, MAY 16, 1975

Part A: Opening Ceremony

Master of Ceremonies		Director ANGEL A. ALEJANDRINO National Hydraulic Research Center
8:00	Registration	
9:00	Philippine National Anthem Keynote Address	Chairman FLORENCIO A. MEDINA National Science Development Board
	Project Background and Summary	Dr ERNESTO G. TABUJARA U.P. Building Research Service

Part B: Presentation of Results

9:30	Distribution of Extreme Winds	Mr. RODOLFO A. DE GUZMAN Philippine Atmospheric Geophysical and Astronomical Services Adminis. tration
10:00	Break	
10:30	Draft Criteria for Wind Loading	Dr. RICHARD D. MARSHALL U.S. National Bureau of Standards
11:30	Structural Connection Details and Improved Architectural Practices	Mr. NOEL J. RAUFASTE, JR. U.S. National Bureau of Standards
12:00	L U N C H	
Master of Ceremonies		Engr. JOSE P. OROLA Government Service Insurance System
2:00	Economic Analysis and Socio-Economic Consideration	Mr. NOEL J. RAUFASTE, JR. U.S. National Bureau of Standards
2:30	Information Transfer	Mr. NOEL J. RAUFASTE, JR. U.S. National Bureau of Standards
3:15	Break	
3:45	Effects of Research on Bay of Bengal Countries	Dr. JAMILUR R. CHOUDHURY
4:15	Implementation of Results	Engr. AMBROSIO R. FLORES PHILSA Engr. ANDRES O. HIZON NSSEEP
4:45	Social Hour	

PROGRAM

SATURDAY, MAY 17, 1975

Part C: Discussions

Master of Ceremonies — Engr. JOAQUIN O. SIOPONGCO
National Science Development Board

9:00 Open Forum .... **DISCUSSANTS:**
Dr. Richard D. Marshall
Mr. Noel J. Raufaste, Jr.
Mr. Rodolfo A. de Guzman
Engr. Ambrosio R. Flores
Engr. Modesto D. Soriano, Jr.
Engr. Rosalio A. Mallonga

10:30 Break

11:00 Continuation of Open Discussion or Future Projections

11:45 Closing Remarks .... Dean CESAR H. CONCIO
National Building Code Committee

Mr. NOEL J. RAUFASTE, JR.
U.S. National Bureau of Standards

12:00 L U N C H

2:00 Field Trip to PAGASA Science Garden .... Col. ALBERTO R. SANCHEZ
Land Housing & Development Corporation
Marshal

3:30 Refreshments

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APPENDIX D

Estimation of Extreme Wind Speeds in the Philippines

ESTIMATION OF EXTREME WIND SPEEDS -- APPLICATION TO THE PHILIPPINES

by

Emil Simiu

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

Report Presented at Regional Meeting on Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds

ESTIMATION OF EXTREME WIND SPEEDS -- APPLICATION TO THE PHILIPPINES

by

Emil Simiu

ABSTRACT

Theoretical and practical considerations are presented that are pertinent to the estimation of probabilistically defined design wind speeds. Results of the statistical analysis of extreme wind data in the Philippines are presented and interpreted. Recommendations based on these results are made with regard to the possible redefinition of wind zones, and tentative conclusions are drawn regarding the adequacy of design wind speeds currently used in the Philippines.

KEY WORDS: Building Codes; hurricanes; probability distribution functions; risk; statistical analysis; storms; structural engineering; tropical storms; wind loads; wind speeds.

ACKNOWLEDGMENTS

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ESTIMATION OF EXTREME WIND SPEEDS -- APPLICATION TO THE PHILIPPINES

1. INTRODUCTION

In modern building codes and standards [1, 2] basic design wind speeds are specified in explicitly probabilistic terms. At any given station a random variable can be defined, which consists of the largest yearly wind speed. If the station is one for which wind records over a number of consecutive years are available, then the cumulative distribution function (CDF) of this random variable may, at least in theory, be estimated to characterize the probabilistic behavior of the largest yearly wind speeds. The basic design wind speed is then defined as the speed corresponding to a specified value F_o of the CDF or, equivalently (in view of the relation $\bar{N} = 1/(1-F_o)$, in which $\bar{N}$ = mean recurrence interval), as the speed corresponding to a specified mean recurrence interval. For example, the American National Standard A58.1 [1] specifies that a basic design wind speed corresponding to a 50-year mean recurrence interval (i.e., to a value F_o of the CDF equal to 0.98, or to a probability of exceedance of the basic wind speed in any one year equal to 0.02) be used in designing all permanent structures, except those structures with an unusually high degree of hazard to life and property in case of failure, for which a 100-year mean recurrence interval (F_o = 0.99) must be used, and structures having no human occupants or where there is negligible risk to human life, for which a 25-year mean recurrence (F_o = 0.96) may be used. A wind speed corresponding to a $\bar{N}$-year recurrence interval is commonly referred to as the $\bar{N}$-year wind.

The mean recurrence intervals specified by building codes, rather than being based on a formal risk analysis--which is in practice not feasible in the present state of the art--are selected in such a manner as to yield basic wind speeds which, by professional consensus, are judged to be adequate from a structural safety viewpoint. Nevertheless, it is generally assumed that adequate probabilistic definitions of design wind speeds offer, at least in theory, the advantage of insuring a certain degree of consistency with regard to the effect of the wind loads upon structural safety. This is true in the sense that, all relevant factors being equal, if appropriate mean recurrence intervals are used in design, the probabilities of failure of buildings in different wind climates will, on the average, be the same.

In the practical application of the probabilistic approach to the definition of design wind speeds, certain important questions arise. One such question pertains to the type of probability distribution best suited for modeling the probabilistic behavior of the extreme winds. The provisions of the National Building Code of Canada [2] are based upon the assumption that this behavior is best modeled by a Type I (Gumbel) distribution. The American National Standard A58.1 [1], on the other hand, assumes that the appropriate models are Type II (Frechet) distributions with location parameters equal to zero and with tail length parameters dependent only upon type of storm. Finally, Thom [3] has proposed a model consisting of a mixed probability distribution, the parameters of which are functions of (a) the frequency of occurrence of tropical cyclones in the 5° longitude-latitude square under consideration and (b) the maximum average monthly wind speed recorded at the station investigated. The question of selecting the most appropriate distribution is one that deserves close attention: indeed, as indicated in Refs. 4 & 5, the magnitude of the basic design wind speed may depend strongly upon the probabilistic model used.

Assuming that the type of probability distribution best suited for modeling the behavior of the extreme winds is known, a second important question arises, viz., that of the errors associated with the probabilistic approach to the definition of design wind speeds. Such errors depend primarily upon the quality of the data and upon the length of the record (i.e., the sample size) available for analysis.

These questions will be dealt with in this work, which will also present results of statistical analyses of wind speed data recorded in the Philippines. In the light of the material presented herein, possible approaches will be examined to the definition of extreme wind speeds for purposes of structural design in the Philippines.

2. WIND SPEED DATA

For the statistical analysis of extreme wind speeds to be meaningful, the data used in the analysis must be reliable and must constitute an homogeneous set.

The data may be considered to be reliable if:

-The performance of the instrumentation used for obtaining the data (i.e., the sensor and the recording system) can be determined to have been adequate.

-The sensor was exposed in such a way that it was not influenced by local flow variations due to the proximity of an obstruction (e.g., building top, ridge or instrument support).

A set of wind speed data is referred to herein as homogeneous if all the data belonging to the set may be considered to have been obtained under identical or equivalent conditions. These conditions are determined by the following factors, which will be briefly discussed below:

-type of instrumentation used

-averaging time (i.e., whether highest gust, fastest mile, one-minute average, five-minute average, etc. was recorded).

-height above ground

-roughness of surrounding terrain (exposure)

-in the case of tropical cyclone winds, distance inland from the coastline.

Type of instrumentation. If, during the period of record, more than one type of instrument has been employed for obtaining the data, the various instrument characteristics (anemometer and recorder) must be carefully taken into account and the data must be adjusted accordingly.

Averaging Time. If various averaging times have been used during the period of record, the data must be adjusted to a common averaging time. This can be done using graphs such as those presented in Ref. 6 and included in Fig. 1 in which Z_o is a parameter defining the terrain roughness (see, for example, Ref. 7).

Height Above Ground. If, during the period of record, the elevation of the anemometer had been changed, the data must be adjusted to a common elevation as follows: Let the roughness length and the zero plane displacement be denoted by Z_o and Z_d, respectively (Z_o, Z_d are parameters which define the roughness of terrain. see Ref. 7). The relation between the mean wind speeds $U(Z_1)$ and $U(Z_2)$ over horizontal terrain of uniform roughness at elevation Z_1 and Z_2 above ground, respectively, can be written as

$$\frac{U(Z_1)}{U(Z_2)} = \frac{\ln \dfrac{Z_1 - Z_d}{Z_o}}{\ln \dfrac{Z_2 - Z_d}{Z_o}} \qquad (1)$$

Suggested values of the roughness length Z_o are given in table 1 (see Refs. 7, 8, 9). For example, at Sale, Australia, for terrain described as open grassland with few trees, at Cardington, England, for open farmland broken by a few trees and hedge rows, and at Heathrow Airport in London, $Z_o \approx 0.08$m [7, 8]. At Cranfield, England where the ground upwind of the anemometer is open for a distance of half a mile across the corner of an airfield, and where neighboring land is broken by small hedged fields, $Z_o = 0.095$ m [10]. It is noted that Eq. 1 is applicable to mean winds and should not be used to represent the profiles of peak gusts.

Table 1 - Suggested Values of Z_o for Various Types of Exposure

Type of Exposure	Z_o (meters)
Coastal	0.005 - 0.01
Open	0.03 - 0.10
Outskirts of towns, suburbs	0.20 - 0.30
Centers of towns	0.35 - 0.45
Centers of large cities	0.60 - 0.80

The zero plane displacement Z_d may in all cases be assumed to be zero, except that in cities (or in wooded terrain) $Z_d = 0.75$ h, where h = average height of buildings in the surrounding area (or of trees) [7, 11]. Thus, for example, if in open terrain with $Z_o = 0.05$ m, U(23) = 30 m/s, then adjustment of this value to the height $Z_2 = 10$m, using Eq. 1, gives

$$U(10) = U(23) \frac{\ln \frac{10}{0.05}}{\ln \frac{23}{0.05}} = 30 \frac{5.30}{6.13} = 25.9 \text{ m/s.}$$

It is noted that, in most cases, the roughness parameters Z_o, Z_d must be estimated subjectively, rather than being determined from measurements. Good judgment and experience are required to keep the errors inherent in such estimates within reasonable bounds. In conducting statistical studies of the extreme winds, it is advisable that for any particular set of data, an analysis be made of the sensitivity of the results to possible errors in the estimation of Z_o and Z_d.

In the case of winds associated with large-scale extratropical storms, the mean wind U(Z) at height Z in terrain of roughness Z_o, Z_d is related as follows to the mean wind $U_1(Z_1)$ at height Z_1 in terrain of roughness Z_{o1}, Z_{d1} [8]:

$$U(Z) = \beta\, U_1(Z_1) \frac{\ln \dfrac{Z - Z_d}{Z_o}}{\ln \dfrac{Z_1 - Z_{d1}}{Z_{o1}}} \qquad (2)$$

The quantity, β, may be obtained from Fig. 2, which was developed in Ref. 8 on the basis of theoretical and experimental work reported by Csanady [14] and others [15]. (Note that $Z_{o1} < Z_o$.)

Eq. 2 may be applied if the roughness of the terrain is homogeneous over a horizontal distance from the anemometers of about 100 times the anemometer elevation [12, 13].

Let, for example, $U(Z_1)$ = 29m/s, Z_1 = 10m, Z_{o1} = 0.05m, Z_{d1} = 0. The corresponding speed U(Z) at Z = 40m, say, in open terrain of roughness Z_o = 0.25m, Z_d = 0 is

$$U(10) = 1.12 \times 29 \frac{\ln \dfrac{40}{0.25}}{\ln \dfrac{10}{0.05}} = 31.1 \text{ m/s}$$

where 1.12 is the value of β for Z_{o1}= 0.05m, Z_o = 0.25m, obtained from Fig. 2.

It is pointed out that, just as in the case of Eq. 1, errors are inherent in Eq. 2 that are associated with the subjective estimation of the roughness parameters. Also, recent research suggests that in the case of tropical cyclone winds Eq. 2 underestimates wind speeds over built-up terrain, calculated as functions of speeds over open terrain, by amounts of the order of 15% or more [27].

Distance Inland from the Coastline. The intensity of hurricane or typhoon winds is a decreasing function of the distance inland from the coastline. Hurricane wind speeds may be adjusted to a common distance from the coastline by applying suitable reduction factors. Such reduction factors have been proposed by Malkin, according to whom the ratios of peak gusts at 48, 96 and 144 km from the coastline to peak gusts at the coastline are 0.88, 0.82 and 0.78, respectively [16, 17].

3. PROBABILISTIC MODELS OF EXTREME WIND SPEEDS

The nature of the variate suggests that an appropriate model of extreme wind behavior is provided by probability distributions of the largest values, the general expression for which is [18]:

$$F(v) = \exp\{-[(v-\mu)/\sigma]^{-\gamma}\} \qquad \begin{array}{l} \mu < v < \infty \\ -\infty < \mu < \infty \\ 0 < \sigma < \infty \\ \gamma > 0 \end{array} \tag{3}$$

where v = wind speed, μ = location parameter, σ = scale paramter, γ = tail length parameter. Eq. 3 may be regarded as representing a family of distributions, each characterized by a value of the tail length parameter γ. As γ becomes larger, the tail of the probability curve becomes shorter, i.e., the probability of occurrence of large values of the variate becomes smaller. In particular, as $\gamma \to \infty$, Eq. 6 may be shown to become

$$F(v) = \exp\{-\exp[-(v-\mu)/\sigma]\} \qquad \begin{array}{l} -\infty < v < \infty \\ -\infty < \mu < \infty \\ 0 < \sigma < \infty \end{array} \tag{4}$$

The distributions given by Eqs. 3 and 4 are known as the type II and the type I distributions of the largest values, respectively.

Two basic procedures for estimating probabilities of occurrence of extreme winds are currently in use. The first procedure consists in estimating the parameters of a probability distribution of the largest values from the series of annual highest wind speeds at the station considered. This procedure has been applied by various authors as follows:

(a) In Ref. 4, estimates are made of all three parameters, μ, σ and γ in Eq. 3, no specific value being assigned a priori to any of these parameters.

(b) In Refs. 19 and 20, the location parameter is assumed to have the value $\mu = 0$. Estimates are then made of the remaining parameters, σ and γ. The arbitrary assumption that $\mu = 0$ entails a sacrifice in goodness of fit; the justification for using this assumption is that it makes possible the application of Lieblein's well-known estimation procedure

[21] to obtain values of σ and γ [19]. However, in view of the recent development of alternative estimation procedures applicable to type II distributions with $\mu \neq 0$ [4], the assumption that $\mu = 0$ becomes unnecessary.

(c) Court in the United States [22], Davenport in Canada [23] and Kintanar in the Philippines [25] have assumed the universality of the type I distribution, i.e., that the tail length parameter is always $\gamma = \infty$. Estimates are then made of the parameters μ and σ.

The second procedure assumes the universal validity of the mixed distribution

$$F(v) = p_E \exp\left[-\left(\frac{v}{\sigma}\right)^{-9}\right] + p_T \exp\left[-\left(\frac{v}{\sigma}\right)^{-4.5}\right] \qquad (5)$$

proposed by Thom in Ref. 3. The first and the second term in the sum of Eq. 5 represent the probabilities that the winds associated with extratropical storms and with tropical cyclones, respectively, will not exceed the value, v, in any one year. The scale parameter, σ, is an explicit function of the maximum of the average monthly wind speeds recorded at the station considered. The second parameter of the mixed distribution, p_T, is an explicit function of the frequency of occurrence of tropical cyclones in the 5° longitude-latitude square under consideration, and $p_E = 1 - p_T$. Thus, in this second procedure, the series of annual highest winds is not used for estimating distribution parameters.

An assessment of the models described in this section will now be presented.

4. ASSESSMENT OF PROCEDURES BASED ON THE ANNUAL HIGHEST SPEEDS

To assess the validity of current probabilistic models, statistical analyses of annual highest speeds were carried out using a computer program described in Ref. 4. The results of the analyses, which are reported in detail in Ref. 4, lend credence to the belief that a sufficiently long record of annual largest speeds will provide an acceptable basis for probabilistic estimates of the N-year winds -- even for large values of N, such as are of interest in structural safety calculations -- if the following conditions are satisfied. First, the value of opt (γ) for that record is large, say $\gamma \geq 40$ (opt (γ) = value of γ [see Eq. 3] for which the best distribution fit of the largest values is obtained). Second, meteorological information obtained at the station in question, as well as at nearby stations at which the wind climate is similar, indicates that winds considerably in excess of those reflected in the record cannot be expected to occur except at intervals many times larger than the record length. Wind climates which satisfy these two conditions will be referred to as well-behaved.

Assuming that the wind speed data are reliable, lower bounds for the sampling error in the estimation of the N-year winds in a well-behaved climate may be calculated on the basis of a mathematical result, viz., the Cramer-Rao relation, which states that for the type I distribution [see Ref. 18 , p. 282]

$$\text{var}(\hat{\mu}) \geq \frac{1.10867}{n} \sigma^2 \qquad (6)$$

$$\text{var}(\hat{\sigma}) \geq \frac{0.60793}{n} \sigma^2 \qquad (7)$$

where var $(\hat{\mu})$, var $(\hat{\sigma})$ are the variances of $\hat{\mu}$ and $\hat{\sigma}$, where $\hat{\mu}$ and $\hat{\sigma}$ are the estimated values of μ and σ, respectively, obtained by using any appropriate estimator consistent with basic statistical theory requirements; σ is the actual value of the scale parameter and n is the sample size. Using Eqs. 6 and 7, lower bounds for the standard deviation of the N-year wind, SD[v(N)], can be approximated as follows. Eq. 4, in which the parameters μ, σ are replaced by their estimates $\hat{\mu}$, $\hat{\sigma}$, is inverted to yield

$$v(N) = \hat{\mu} - G(1-\frac{1}{N})\hat{\sigma} \qquad (8)$$

where

$$G(1-\frac{1}{N}) = -\ell n[-\ell n(1-\frac{1}{N})]. \qquad (9)$$

Then

$$SD[v(N)] \geq \{\text{var}(\hat{\mu}) + [G(1-\frac{1}{N})]^2 \text{var}(\hat{\sigma})\}^{1/2} \qquad (10)$$

Eq. 10 is based on the assumption that the error involved in neglecting the correlation between $\hat{\mu}$ and $\hat{\sigma}$ is negligible. The validity of this assumption was verified by using Monte Carlo simulation techniques.

Since the actual value of σ is not known, in practical calculations the estimated value $\hat{\sigma}$ is used in Eqs. 6 and 7. For example, the distribution parameters corresponding to the wind speed data at Davao (n = 24, see Table 2), estimated by using the technique described in Ref. 4, are $\hat{\mu} = 38.89$ km/hr, $\hat{\sigma} = 9.40$ km/hr. It follows from Eq. 8 that v(50) = 75 km/hr and from Eqs. 6, 7, and 10 that $SD[v(50)] \geq 5.18$ km/hr. Subsidiary calculations not reported here have shown that Eq. 10 provides a good indication of the order of magnitude of the sampling errors.

<u>Wind Climates Characterized by Small Values of opt (γ)</u>. Occasionally, a record obtained in well-behaved wind climates may exhibit small values of opt (γ); this will occur if that record contains a wind speed that corresponds to a large mean recurrence interval. There are regions, however, in which, as a rule, the statistical analysis of extreme wind records taken at any one station yields small values of opt(γ). This is the case if, in the region considered, winds occur that are meteorologically distinct from, and considerably stronger than the usual annual extremes. Thus, in the regions where tropical cyclones occur, opt (γ) will in general be small, unless most annual extremes are associated with tropical cyclone winds. An example of a record for which γ(opt) is small is given in Fig. 3a, which represents the probability plot with γ = opt (γ) = 2 for the annual extreme fastest-mile speeds recorded in 1949-73 at the Corpus Christi, Texas, airport. For purposes of comparison, the same data have been fitted to a type I distribution [opt (γ) = ∞, or Eq. 4]; the fit in this case is seen to be exceedingly poor, i.e., the plot deviates strongly from a straight line (Fig. 3b). (As shown in Ref. 4, a measure of the goodness of fit is given by the extent to which the probability plot correlation coefficient is close to unity; this coefficient is printed out in Figs. 3a and 3b.)

To small values of the tail length parameter there frequently correspond implausibly high values of the estimated speeds for large recurrence intervals. In the case of the 1912-48 record at Corpus Christi, for example, opt(γ) = 2 and the estimated 5- minute average is 327 mph (155 m/s) for a 1000-year wind, which is highly unlikely on meteorological grounds. For 20-year records, the situation may be even worse: thus, for the 1917-36 Corpus Christi record, which contains an exceptionally high wind speed due to the 1919 hurricane [22, 24], opt (γ) = 1 and the calculated 1000- year wind is 1952 mph (873 m/s) [4], a ridiculous result. Also, the situation is not likely to improve significantly if the record length increases. From a 74-year record, a plot quite similar to Fig. 3 would presumably be obtained, with twice as many points similarly dispersed, to which there would correspond a similar least squares line on probability paper.

It may be stated, consequently, that while in the case of well-behaved climates it appears reasonable to infer from a good fit of the probability curve to the data that the tail of the curve adequately describes the extreme winds, such an inference is not always justified if opt (γ) is small.

It may be argued that one could avoid obtaining unreasonable extreme values by postulating that the annual largest winds are described by a probability distribution of the type I, i.e., by assigning the value $\gamma = \infty$ to the tail length parameter. This has been done by Court [22] and Kintanar [25]. As can be seen in Fig. 4, the corresponding fit may be quite poor. However, the estimated extremes at the distribution tails will be reduced. The drawback of this approach is that unresonably low estimated extremes may be obtained. For example, at Key West, Florida, if all three parameters of Eq. 3 are estimated as in Ref. 4, to the 1912-48 record there corresponds opt $(\gamma) = 3$, $v(50) = 83$ mph (37 m/s), $v(100) = 99$ mph (44.2m/s) and $v(1000) = 188$ mph (84 m/s) - see Ref. 4. If it is postulated that $\gamma = \infty$, then $v(50) = 71$ mph (31.7 m/s), $v(100) = 77$ mph (34.4 m/s) and $v(1000) = 97$ mph (38.8 m/s) [4], an unlikely result in view of the high frequency of occurrence of hurricanes (about 1 in 7 years) at Key West.

It may also be argued that since the estimated extremes resulting from small values of γ (say $\gamma \leq 4$) may be too large, and those corresponding to $\gamma = \infty$ may be too small, a probability distribution that might yield reasonable results is one in which γ has an intermediate value, say $4 \leq \gamma \leq 9$. Such an approach has been proposed by Thom and will now be examined.

5. ASSESSMENT OF PROCEDURE BASED ON THE HIGHEST AVERAGE MONTHLY SPEED

The procedure for estimating extreme winds in hurricane-prone regions on the basis of annual highest winds at a station was seen to have the following shortcomings. First, because hurricane winds are relatively rare events, the possibility exists that the available data do not contain wind speeds associated with major hurricane occurrences and are therefore not representative of the wind climate at the station considered (see the case of Calapan in Section 7 of this report). Second, in regions subjected to winds that are meteorologically distinct from, and considerably stronger than the usual annual extremes, implausible estimates may be obtained.

The model proposed by Thom [Eq. 5] in Ref. 3 represents an attempt to eliminate these shortcomings. It can be easily shown by applying the intermediate value theorem, that if this model is assumed, the estimated extreme winds may be obtained by inverting an expression of the form:

$$F(v) = \exp[(-v/\sigma)^{-\gamma(v)}]$$

in which $4.5 < \gamma(v) < 9$. If the mean rate of arrival of tropical cyclones in the region considered is high, then $\gamma(v)$ will be closer to 4.5. Otherwise, $\gamma(v)$ will be closer to 9; in regions where hurricanes cannot be expected to occur, $\gamma(v) = 9$. In order that estimates not be based upon possibly unrepresentative annual extreme data, Thom's model does not make use of annual extreme speeds. Rather, the parameter σ is estimated from the maximum of the average monthly wind speeds on record at the location considered, presumably a quantity for which the variability is small.

A few specific cases to which Thom's model was applied were considered in Ref. 5, in which it was shown that estimates based on this model do not appear to be always sufficiently reliable for structural design purposes. Also, it was shown in the preceding section that the approach which utilizes the series of annual largest speeds may fail in regions in which hurricanes occur. For such regions, therefore, it may be that alternative approaches need to be developed. Among such approaches is one in which estimates of extreme winds are based upon the following information:

- average number of hurricanes affecting the coastal sector considered (per year)
- probability distribution of hurricane intensitites
- radial dimensions of hurricanes
- dependence of wind speeds upon central pressure and distance from hurricane center.

This approach appears to provide useful estimates of extreme winds corresponding to large recurrence intervals - which are of interest in ultimate strength calculations - and is currently under study at the National Bureau of Standards.

6. STATISTICAL ANALYSIS OF EXTREME WIND DATA IN THE PHILIPPINES

Through the courtesy of the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), 16 sets of data were obtained consisting of maximum yearly wind speeds recorded during at least 14 consecutive years. The data for each of the 16 stations are listed in Table 2. Table 3 includes subjective station descriptions provided by PAGASA personnel and the results of the analysis. In Table 3 are listed $V_N^{opt(\gamma)}$ = N-year wind based on the distribution for which the best fit of the largest values is obtained and V_N^{∞} = N-year wind based on the type I distribution, N = mean recurrence interval in years.

7. INTERPRETATION OF RESULTS

The results will be grouped into three classes, according to the wind zone (as defined in Ref. 26) in which the stations considered are located (Table 3).

Zone III. It is noted that for all three Zone III stations listed in Table 3,opt $(\gamma) = \infty$. It is convenient to adjust the speeds at Davao and Cagayan de Oro to open terrain exposure. On the basis of the terrain descriptions of Table 3, if it is assumed $Z_o = 0.30$m, $Z_d = 0$, $Z_{o1} = 0.08$m, $Z_{d1} = 0$, it follows from Eq. 2 that

$$\frac{U(10)}{U_1(10)} \simeq 0.8$$

where $U(10)$, $U_1(10)$ are mean speeds above ground in open and town exposure, respectively. Thus, in Davao and Cagayan de Oro the calculated 50-year mean speeds at 10m above ground in open terrain are 94 km/hr and 76 km/hr. respectively, versus 88 km/hr in Zamboanga. If the corresponding highest gusts are obtained by multiplying the one-minute means by a factor of, say, 1.20 (see Fig. 1), the estimated highest 50-yr gusts at Davao, Cagayan de Oro and Zamboanga are at most 94 x 1.20 = 113 km/hr, i.e., considerably lower than the value specified for design purposes by the National Structural Code of the Philippines [26] for Zone III, viz.,153 km/hr. This suggests that the requirements of Ref. 26 regarding wind loading in the Zone III portion of Mindanao are conservative and might be somewhat reduced. (It can be easily shown, on the basis of Eq. 2 and Fig. 1, that this statement holds even if it is assumed that the errors in the estimation of the parameter values $Z_o = 0.30m$ and $Z_{o1} = 0.08m$ are of the order of as much as 50%.) To validate such a conclusion it would however be necessary to determine, from long-term records of tropical cyclone occurrences, that the 1950-73 data at the three stations analyzed are indeed representative for southern Mindanao.

Zone II. Several difficulties arise in interpreting the results for the Zone II stations in Table 3. It is noted, first, that the results obtained at stations in and near Manila (stations 4, 5, 6 in Table 3) are widely divergent. The discrepancies between the results for Pasay City and Manila may be due to the different elevations of the respective anemometers. It may also be conjectured that the discrepancies between these results and those obtained from the 1902-1940 Manila Central record are due to differences in the averaging times and in the exposure, elevation and calibration of the instruments, as well as to possibly inaccurate estimates of the maximum speed in Manila and Pasay City in 1970 (200 km/hr, see Table 2).

The estimated wind speeds at Baguio based upon the 1950-73 record are higher than those obtained from the 1914-40 data. No explanation is offered for these differences; an investigation into their causes seems warranted.

The record at Calapan illustrates the limitations of the approach to the definition of design wind speeds based on the statistical analysis of the highest annual winds. From the data covering the period 1961-72, the estimated 50-yr wind based on a Type I distribution is 141 km/hr [25], versus 209 km/hr, as obtained if the data covering the period 1959-1973 are used (see Table 3). Since wind loads are proportional to the square of the wind speeds, the ratio between the respective estimated wind loads is $(209/141)^2 = 2.2$.

Although the record at Pasay City is best fitted by a type II distribution with opt $(\gamma) = 2$, it is unlikely, as noted previously, that such a distribution correctly describes the behavior of the extreme winds. This is obvious, particularly in the case of the 1000-yr wind, which, on physical grounds, could not possibly attain 820 km/hr (Table 3).

The National Structural Code of the Philippines specifies, for Zone II and elevations under 9.15m, a design wind of 175 km/hr. In the light of the data shown in Table 2, the value appears to be reasonable. It will be noted that Tables 2 and 3, and Fig. 13 of Ref. 26, indicate that the extreme speeds and the frequency of occurrence of tropical cyclones, are considerably higher at Laoag than at Cebu. This suggests that Zone II could be divided, accordingly, into two subzones, with wind load requirements higher in the northern than in the southern subzone.

Zone I. As indicated previously, if γ(opt) is large, i.e., if the differences among maximum wind speeds recorded in various years are large, the probability distributions that best fit the data may not describe correctly the extreme wind speeds for large recurrence intervals. The minimum and the maximum winds for the period of record are. at Legaspi, 40 km/hr and 204 km/hr, respectively, and, at Tacloban, 42 km/hr and 194 km/hr, respectively. In the writer's opinion, the reliability of the N-year wind estimates obtained at these stations for N=50. 100 and 1000 is therefore doubtful. The same comment applies to the estimates for Infanta, where the record length is quite insufficient (14 years). The writer therefore believes that the results of Table 3 should not be used to assess the adequacy of the design wind speed requirement for Zone I specified in Ref. 26. Rather, it is reasonable to base such an assessment on a comparison between wind speeds in Zone I and in areas affected by hurricanes in the United States. In the light of U.S. experience, it is the opinion of the writer that from such a comparison it follows that the 200 km/hr wind speed requirement for Zone I and elevations under 9.15 m is adequate for structural design purposes.

8. CONCLUSIONS

From the analysis of available extreme speed data in the Philippines, the following conclusions may be drawn:

1. The design wind speeds specified by the National Structural Code of the Philippines for the Zone III part of Mindanao appear to be conservative and might be somewhat reduced. For this conclusion to be validated, it would be necessary to determine, from long-term records of tropical cyclone occurrences, that the data analyzed herein are representative for southern Mindanao.

2. Methodological difficulties and uncertainties with regard to the reliability of the data preclude, at this time, the estimation for Zones II and I of N-year extreme winds that could be used, with a sufficient degree of confidence, as design values within the framework of an explicitly probabilistic code.

3. According to the data included herein, Zone II can be divided into two subzones, with wind load requirements higher in the northern than in the southern subzone.

4. The data included herein suggest that the wind speed requirement specified by the National Structural Code of the Philippines for Zone I is adequate for purposes of structural design, except as noted below.

5. Higher wind speed values than those specified by the National Structural Code of the Philippines should be used--except perhaps in the Zone III part of Mindanao--in open, and in coastal exposure.

6. Improved design criteria for Zones II and I, including possible redefinitions of these zones, could in the future be achieved by applying the methodology briefly described at the end of the section "Assessment of Procedure Based on the Highest Average Monthly Speed". This would require, in addition to data on the frequency of occurrence of tropical cyclones at various locations in the Philippines, that the following data be available:

a. Reliable wind speeds, carefully defined with respect to terrain roughness, averaging time and distance from shore line.

b. Approximate radial dimensions of tropical cyclones.

c. Approximate dependence of tropical cyclone speeds upon minimum central pressure and distance from storm center.

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TABLE 2 - MAXIMUM ANNUAL WINDS (one minute averages)

No.	Station	Period of Record	Maximum Annual Winds for Each Year of Record (km/hour)
1	Davao	1950-73	39,52,40,39,40,37,35,35,32,40,40,40,80,48,48,48,56,46,52,50,46,52,46,46
2	Cagayan de Oro	1950-73	47,24,19,13,19,19,12,12,12,19,16,14,21,6,24,17,19,37,37,46,37,48,41,41
3	Zamboanga	1950-73	48,64,40,39,48,61,43,40,48,45,48,72,48,48,50,56,68,67,70,56,61,74,61,78
4	Pasay City	1950-73	89,103,89,92,72,72,64,72,97,72,81,66,69,74,130,65,80,111,83,74,200,80,111,56
5	Manila	1949-70	72,105,97,89,101,97,100,105,81,72,97,89,121,105,100,168,74,89,107,111,96,200
6	Manila Central	1902-40	46,56,65,80,73,55,77,70,41,68,50,69,64,68,42,41,67,54,70,83,58,53,60,51,45, 63,50,70,52,55,58,37,100,60,45,52,103,53,56
7	Mirador Baguio	1914-40	79,79,70,79,121,102,94,72,105,107,122,58,89,107,93,63,77,92,63,53,93,73,75, 49,39,68,83
8	Baguio	1950-73	97,105,56,97,97,81,64,64,61,48,97,48,53,98,111,107,80,144,107,102,137,85,89,133
9	Calapan	1959-73	145,185,97,72,40,68,40,96,109,41,33,111, 102, 111, 83
10	Surigao	1952-73	105,43,113,40,40,40,43,48,64,64,89,39,74,52,78,104,167,111,96,107,96,74
11	Laoag	1949-73	34,72,118,71,108,100,64,81,81,64,81,79,64,105,90,144,144,78,120,137,100,67, 89,67,70
12	Iloilo	1949-73	97,106,64,64,97,64,64,97,64,64, 64,72,74,64,78,78,89,74,161,52,61,89,56,74
13	Cebu	1950-73	97,56,121,48,81,64,48,48,48,43,48,43,64,64,56,48,56,70,93,65,56,100,74,59
14	Legaspi	1955-73	40,97,97,48,129,185,97,82,89,104,74,89,148,74,70,174,148,204,81
15	Tacloban	1949-73	137,58,106,113,56,68,60,47,48,69,87,42,105,93,74,111,70,194,133,167,63,81,155, 104,67
16	Infanta	1960-73	60,43,45,50,128,39,133,126,46,46,189,85,104,83

TABLE 3 - STATION DESCRIPTIONS AND ESTIMATED EXTREME WIND SPEEDS

No.	Station	Wind Zone - See Ref. 26	Period of Record	No. of Years	Anemometer Elevation (meters)	Description of Terrain	opt(γ)	$V_N^{opt(\gamma)}$ [e,f] (km/hr) N=50	N=100	N=1000	V_N^{∞} [f] (km/hr) N=50	N=100	N=1000
1	Davao	III	1950-73	24	10	Town	∞				75	82	105
2	Cagayan de Oro	III	1950-73	24	10	Town	∞				61	69	94
3	Zamboanga	III	1950-73	24	10	Open	∞				88	95	117
4	Pasay City	II	1950-73	24	10	Airport	2	220	292	820	164	180	234
5	Manila	II	1949-70	22	Top of 5-story building	Port Area	7	208	238	365	192	212	276
6	Manila Central	II	1902-40	39	6[a]	Open (Park)	35	103	112	144	101	110	138
7	Mirador Baguio	II	1914-40	27	10[b]	Mountain top (1500 m above sea level)	∞				139	151	192
8	Baguio	II	1950-73	24	10	Mountain top (1500 m above sea level)	∞				164	180	230
9	Calapan	II	1959-73	15	10	Top of hill; town on one side.	∞				209	234	316
10	Surigao	II	1952-73	22	7	Large City Top of 40 m hill	40	170	191	262	167	187	250
11	Laoag	II	1949-73	25	12	Open	∞				174	192	252
12	Iloilo	II	1950-73	24	25 (5m above 20m bldg.)	Town	2	180	235	640	138	152	192
13	Cebu	II	1950-73	24	10	Airport	∞				127	140	185
14	Legaspi	I	1955-73	19	12	Airport[c]	90	235	264	350	235	264	340
15	Tacloban	I	1949-73	25	12 (3m above 9m bldg.)	Top of 15m hill Military Camp [d]	14	213	242	352	204	228	306
16	Infanta	I	1960-73	14	10	Town; Residential area	6	242	290	488	214	242	333

[a] 3 cup anemometer; mean speed averaged over one minute.

[b] Mean speed averaged over one minute.

[c] Trees at East side of anemometer.

[d] North and East: sea exposure.

[e] Omitted if opt (γ) = ∞ .

[f] One minute averages.

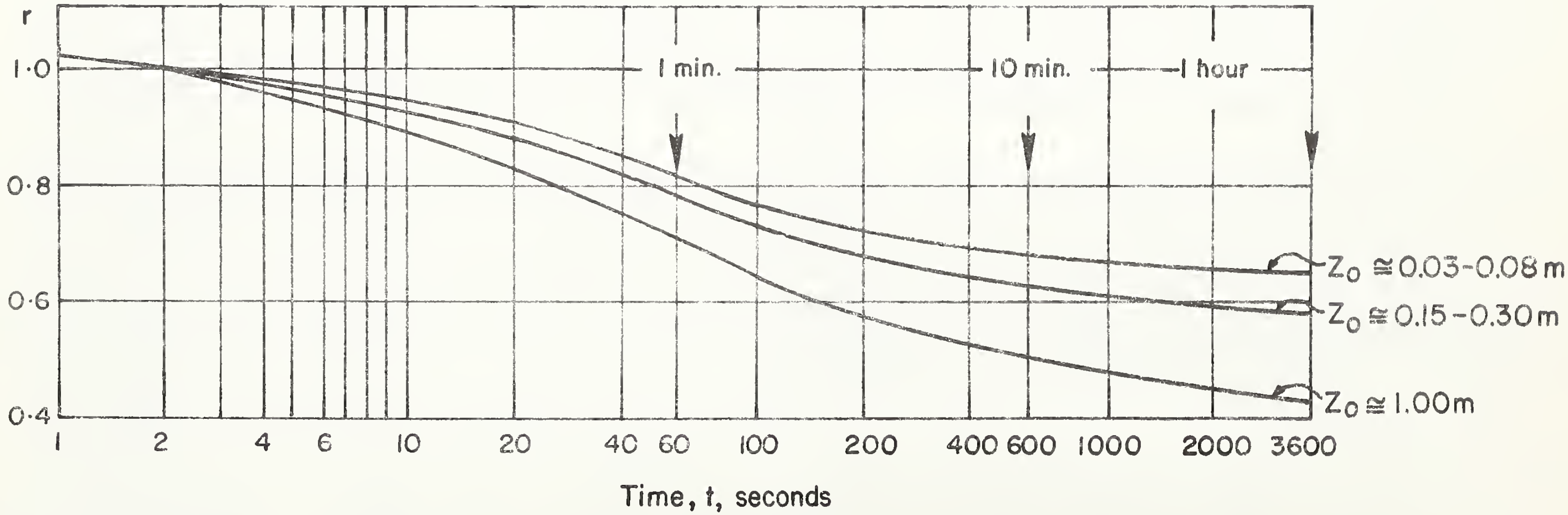


Fig. 1 Ratio, r, of Maximum Probable Wind Speeds Averaged over t seconds to Those Averaged over 2 sec.

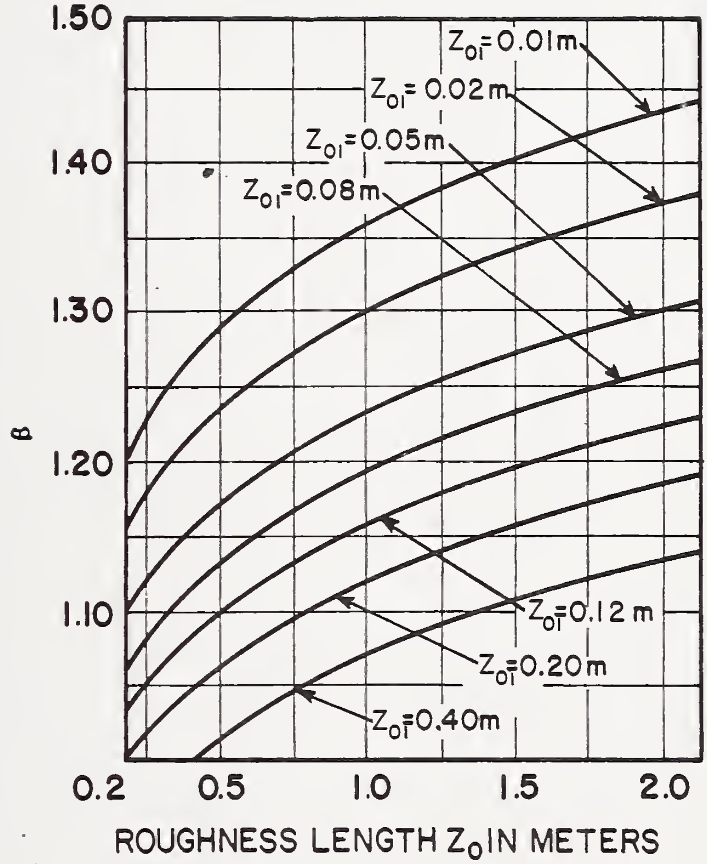
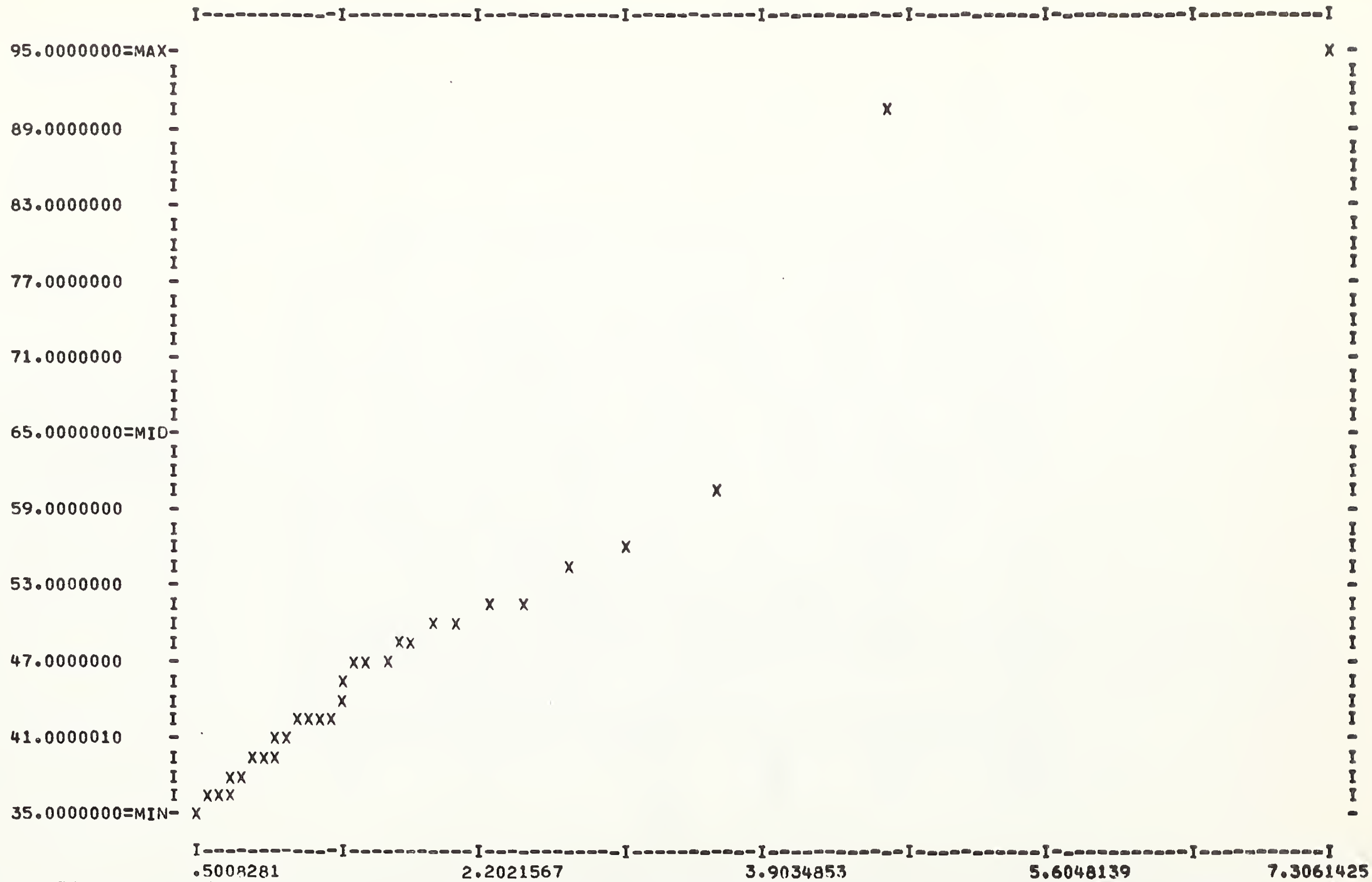


Fig. 2 Quantity β



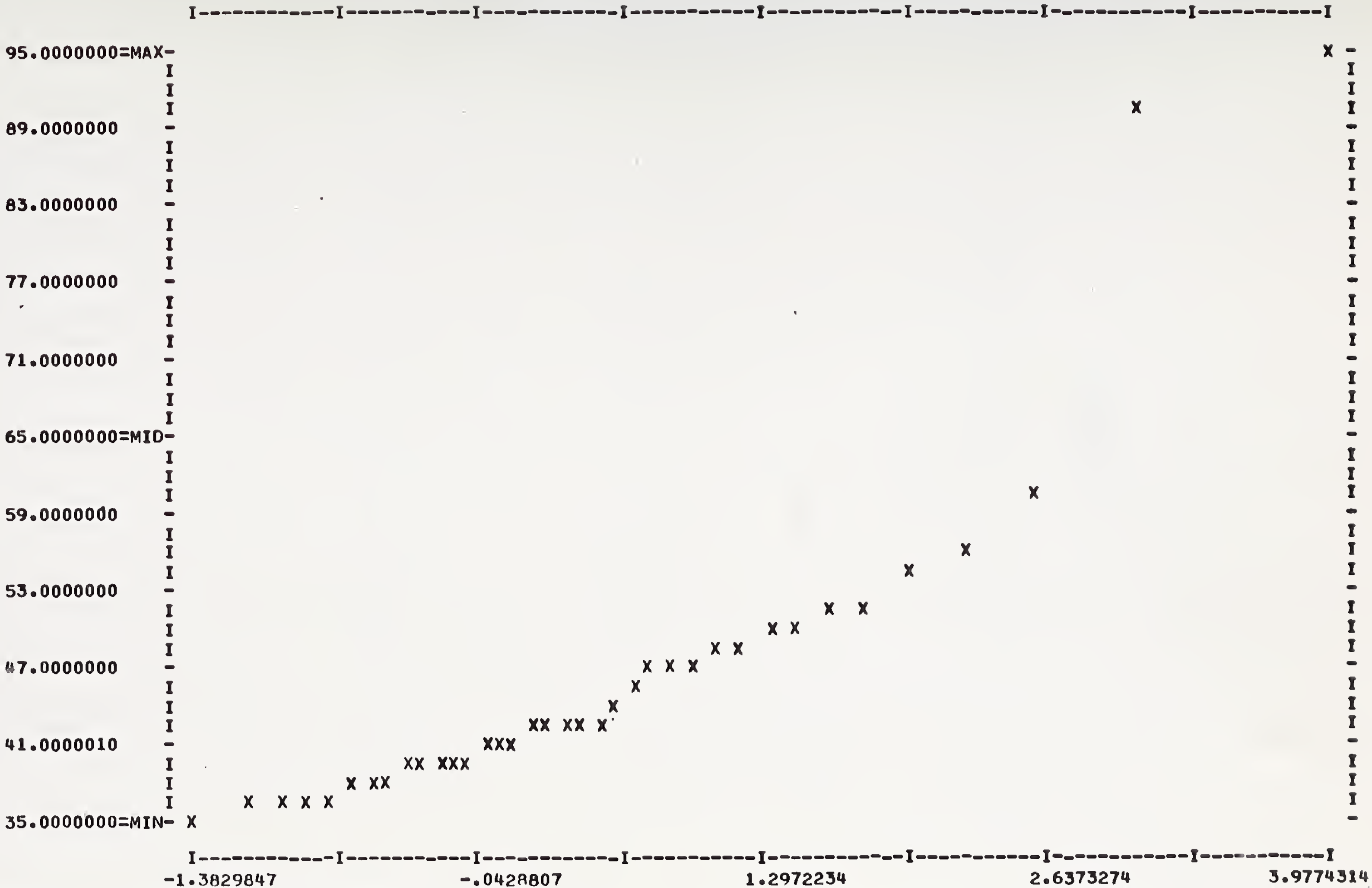
EXTREME VALUE TYPE 2 (CAUCHY TYPE) PROB. PLOT WITH EXP. PAR. = 2.000000000 SAMPLE SIZE N = 37
PROBABILITY PLOT CORRELATION COEFFICIENT = .97191 ESTIMATED INTERCEPT = 31.071809 ESTIMATED SLOPE = 9.3875747

(a)

Figure 3 Probability Plots:

(a) Type II Distribution, $\gamma = 2$

(b) Type I Distribution



EXTREME VALUE TYPE 1 (EXPONENTIAL TYPE) PROBABILITY PLOT THE SAMPLE SIZE N = 37
PROBABILITY PLOT CORRELATION COEFFICIENT = .90104 ESTIMATED INTERCEPT = 41.033329 ESTIMATED SLOPE = 9.4928209

(b)

APPENDIX E

A Guide to the Determination of Wind Forces

A GUIDE TO THE

DETERMINATION OF WIND FORCES

by

R.D. Marshall

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Report Presented At Regional Meeting on Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds

List of Figures

List of Tables

A GUIDE TO THE
DETERMINATION OF WIND FORCES

TABLE OF CONTENTS

ABSTRACT

This paper briefly describes some of the more common flow mechanisms which create wind pressures on low-rise buildings and the effects of building geometry on these pressures. It is assumed that the basic wind speeds are known and a procedure is outlined for calculating design wind speeds which incorporates the expected life of the structure, the mean recurrence interval, and the wind speed averaging time. Pressure coefficients are tabulated for various height-to-width ratios and roof slopes. The steps required to calculate pressures and total drag and uplift forces are summarized and an illustrative example is presented.

DETERMINATION OF WIND FORCES

1.0 INTRODUCTION

This paper deals with the nature of wind flow around buildings, the pressures generated by wind and the determination of forces acting on building elements as well as on the overall structure. It is assumed that buildings designed in accordance with the procedures outlined in the following sections and the tables in Appendix A do not exceed 10 meters in height or 50 meters in plan dimension and have a height to width ratio (h/w) not exceeding four.

2.0 AERODYNAMICS OF BUILDINGS

The flow of wind around buildings is an extremely complex process and cannot be completely described by simple rules or mathematical formulae. Wide variations in building size and shape, type of wind exposure, local topography and the random nature of wind all tend to complicate the problem. Only by direct observation of full scale situations or by resorting to properly conducted wind-tunnel tests can the characteristics of these flows be established. In spite of these complications, guidance can be provided by considering some typical flow situations.

2.1 Typical Wind Flow Around Buildings

A typical flow situation is illustrated in Figure 1 where the wind is blowing face-on to a building with a gable roof. The flow slows down or decelerates as it approaches the building, creating a positive pressure on the windward face. Blockage created by the building causes this flow to spill around the corners and over the roof. The flow separates (becomes detached from the surface of the building) at these points and the pressure drops below atmospheric pressure, creating a negative pressure or suction on the endwalls and on certain portions of the roof.

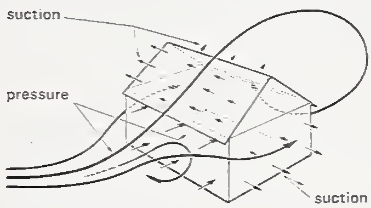


Fig. 1 Typical Flow Pattern and Surface Pressures

A large low-pressure region of retarded flow is created downwind of the building. This region, called the wake, creates a suction on the leeward wall and leeward side of the roof. The pressures are neither uniform nor steady due to the turbulent character of the oncoming wind and varying size and shape of the wake. However, it has been established that the patterns of wind flow around bluff bodies such as the building in Figure 1 do not change appreciably with a change in wind speed.

This allows dimensionless pressure coefficients (to be discussed later) determined for one wind speed to be applied to all wind speeds. In general, the wind pressure is a maximum near the center of the windward wall and drops off rapidly near the corners. Pressures on the side or endwalls are also nonuniform, the most intense suctions occurring just downstream of the windward corners.

2.2 Effect of Roof Slope

The pressures acting on a roof are highly dependent upon the slope of the roof, generally being positive over the windward portion for slopes greater than 30 degrees. For slopes less than 30 degrees, the windward slope can be subjected to severe suctions which reach a maximum at a slope of approximately 10 degrees. Under extreme wind conditions, these suctions can be of sufficient intensity to overcome the dead weight of the building, thus requiring a positive tiedown or anchorage system extending from the roof to the foundation to prevent loss of the roof system or uplift of the entire building.

Intense suctions are likely to occur along the edges of roofs and along ridge lines due to separation or detachment of the flow at these points. For certain combinations of roof slope and wind direction, a conical vortex can be developed along the windward edges of the roof as shown in Figure 2. This is a "rolling up" of the flow into a helical pattern with very high speeds and, consequently, very intense suctions. If not adequately provided for in the design, these vortices along the edges of the roof can cause local failures of the roofing, often leading to complete loss of the roof. Areas where intense suctions can be expected are shown in Figure 3.

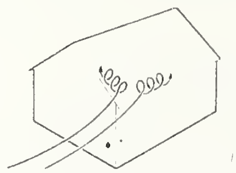


Figure 2 Vortices Along Edge of Roof

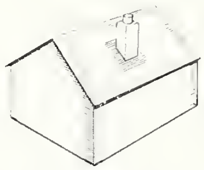


Figure 3 Areas of Intense Suctions

2.3 Roof Overhangs

In calculating the total uplift load on a roof, the pressure acting on the underside of roof overhangs must also be included. These pressures are usually positive and the resultant force acts in the same direction as the uplift force due to suction on the top surface of the roof. Pressures acting on the inside of the building (to be discussed later) can also contribute to the total uplift force and must likewise be accounted for.

3.0 DESIGN WIND SPEED

Several factors must be considered in selecting a wind speed on which to base the design loads for a building or other structure. These include the climatology of the geographic area, the general terrain roughness, local topographical features, height of the building, expected life of the building and acceptable level of risk of failure. The assessment of climatological wind data and the procedure for obtaining basic wind speeds are discussed in Ref. 1. The selection of the basic wind speed and the determination of modifying factors to obtain the design wind speed are discussed in the following sections.

3.1 Mean Recurrence Interval

The selection of a mean recurrence interval, with which there is associated a certain basic wind speed, depends upon the intended purpose of a building and the consequences of failure. The mean recurrence intervals in Table I are recommended for the various classes of structures.

3.2 Risk Factor

There is always a certain risk that wind speeds in excess of the basic wind speed will occur during the expected life of a building. For example the probability that the basic wind speed associated with a 50-year mean recurrence interval will be exceeded at least once in 50 years is 0.63. The relationship between risk of occurrence during the expected building life and the mean recurrence interval is given in Table II. It should be noted that the risk of exceeding the basic wind speed is, in general, not equal to the risk of failure.

3.3 Averaging Time and Peak Wind Speed

It is well known that the longer the time interval over which the wind speed is averaged, the lower the indicated peak wind speed will be. The calculated design loads will thus depend upon the averaging time used to determine the design wind speeds. In this document, it has been assumed that all speeds used in pressure and load calculations are based upon an averaging time of 2 seconds. Wind speeds for averaging times other than 2 seconds can be converted into 2-second average speeds using the procedure described in Ref. 1.

4.0 DESIGN PRESSURES

4.1 Dynamic Pressure

When a fluid such as air is brought to rest by impacting on a body, the kinetic energy of the moving air is converted to a dynamic pressure q, in accordance with the formula

$$q = 1/2\ \rho U^2 \qquad (1)$$

where $q = N/m^2$, ρ is the mass density of air in kg/m^3 and U is the free-stream or undisturbed wind speed in m/s. The mass density of air varies with temperature and barometric pressure, having a value of 1.225 kg/m^3 at standard atmospheric conditions. In the case of tropical storms, the mass density may be 5 to 10 percent lower. However, this is offset somewhat by the effect of heavy rainfall and the value quoted above should be used for all wind pressure calculations, i.e.,

$$q = 0.613\ U^2 \qquad (2)$$

4.2 Mean and Fluctuating Components of Pressure

As in the case of wind speed, pressures acting on a building are not steady, but fluctuate in a random manner about some mean value. A typical recording of wind speed and pressure at a point on the roof of a house is shown in Figure 4.

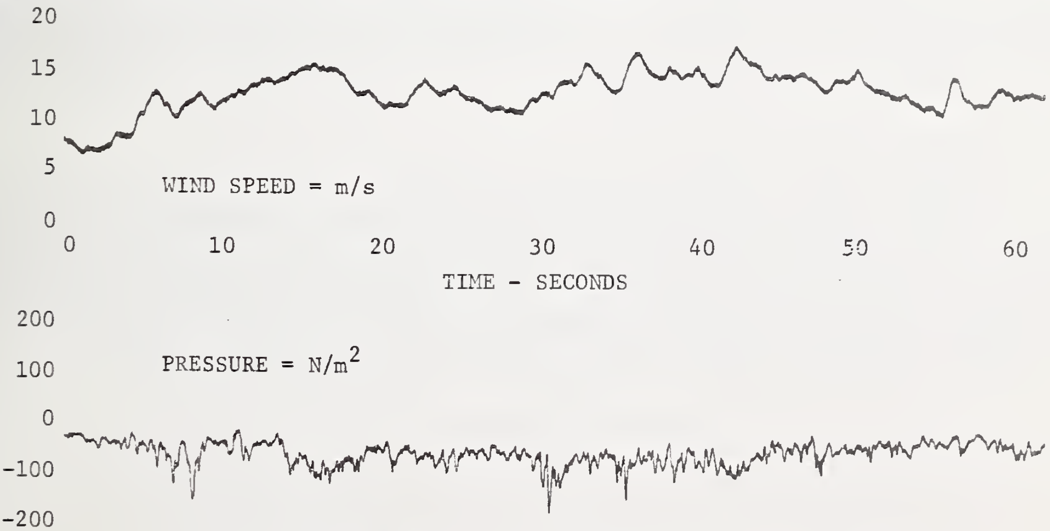


Fig. 4 Typical Record of Wind Speed and Surface Pressure

A close inspection of Figure 4 reveals the following characteristics:

a) The average or mean pressure is negative (suction)

b) Pressure fluctuations tend to occur in bursts

c) Maximum departures from the mean are in the negative (suction) direction

d) The peak values far exceed the mean value

To quantify these pressures, it is essential that a sufficiently long time interval be used to obtain a stable mean, $\bar{p}$. The fluctuations are described by their standard deviation or root-mean-square, p_{rms}, taken about the mean. Finally, the peak pressure fluctuations are described by a peak factor, g, which indicates the number of standard deviations that the peak pressure deviates from the mean. Thus, the peak pressure can be expressed as

$$p_{max} = \bar{p} + g\, p_{rms} \text{ or } p_{min} = \bar{p} - g\, p_{rms} \qquad (3)$$

It should be noted that the peak factor, g, is a random variable and has a probability distribution function that depends on the geometry of the building and turbulent structure of the wind. The values of g are selected so that the associated probabilities of being exceeded are in line with the expected building life.

4.3 Pressure Coefficients

It is convenient to express pressures acting on the surfaces of a building in terms of the dynamic pressure as follows

$$p = C_p q \qquad (4)$$

where C_p is a pressure coefficient whose value depends upon the geometry of the building and local flow conditions. Pressure coefficients are specified for particular surfaces or elements of a building and, when multiplied by the surface area and dynamic pressure, give the wind loads acting in a direction normal to those surfaces or elements. The total resultant forces and moments acting on a building can then be determined by considering the appropriate components of these loads acting on each of the surfaces or elements.

As discussed in the previous section, the instantaneous peak pressure can be expressed in terms of the mean pressure and a fluctuating component. Since pressure fluctuations are limited in spatial extent, it is necessary to consider the size of the building surface or element when selecting the pressure coefficient.

4.3.1 Pressures on Extended Areas

For the purpose of determining wind loads acting on sizeable surface areas such as the walls and roof of a building, the pressure coefficients listed in Tables III and IV should be used. These coefficients have been determined experimentally from measurements taken on full-scale buildings and from wind-tunnel tests and they represent an upper limit of conditions likely to occur on the indicated building surfaces.

4.3.2 Pressures on Localized Areas

It is to be expected that the smaller the area considered, the larger the effective peak pressure will be. In addition, there are certain surface areas where intense suctions occur as pointed out in sections 2.1 and 2.2. To provide for these cases, pressure coefficients for localized areas are included in Tables III and IV. These coefficients are for the purpose of assessing wind loads on local cladding and roofing elements and should not be used to calculate overall loads on buildings. They should be used in conjunction with the internal pressure coefficients (where appropriate) as described in the following section.

4.3.3 Internal Pressures

As indicated in section 2.3, the net load or force acting on the roof or walls of a building depends not only on the external surface pressures, but on the internal pressure as well. The magnitude of the internal pressure depends upon the building geometry, size and location of openings, and wind speed and direction. As with external pressures, it is convenient to express internal pressures in terms of the dynamic pressure and a pressure coefficient C_{pi}. These coefficients can be positive or negative as indicated in Table V. The net pressure acting on a building element is the algebraic sum of the external and internal pressures

$$p = q\ (C_p - C_{pi}) \tag{5}$$

Thus a positive internal pressure will increase the loading on those areas of roofs and walls subjected to external suction.

4.4 Correction Factor for Height of Building

The pressure coefficients described above are based on building heights of 10 meters and peak wind speeds at 10 meters above ground, averaged over 2 seconds. Overall loads calculated for buildings appreciably less than 10 meters in height (measured to eaves or parapet) will thus be overestimated if these coefficients are used without modification. On the other hand, tributary areas such as doors, windows, cladding and roofing elements will respond to pressure fluctuations with duration times considerably less than 2 seconds. To account for this, the pressures must be multiplied by the correction factors, R, in Table VI. Thus the expression for the net pressure acting on a building surface becomes

$$p = q\ (C_p\ R - C_{pi}\ R_i) \tag{6}$$

and the force acting normal to a surface of area A is

$$F = q\ (C_p\ R - C_{pi}\ R_i)A \tag{7}$$

where R and R_i are correction factors for external and internal pressures, respectively.

5.0 Procedure for Calculating Wind Forces

The procedure for calculating wind forces on a building is summarized in the following steps.

1. Select the appropriate mean recurrence interval from Table I

2. Check the associated factor of risk in Table II and select a longer mean recurrence interval if appropriate.

3. Determine the basic wind speed for this mean recurrence interval and the appropriate terrain roughness and type of exposure as outlined in Ref. 1.

4. Convert the resulting basic wind speed to a 2-second mean speed using the procedure described in Ref. 1.

5. Calculate the dynamic pressure q using the expression

$$q = 0.613\ U^2$$

6. Select the appropriate pressure coefficients from Tables III, IV and V

7. Select the appropriate correction factors from Table VI

8. Calculate the pressures from the expressions

$$p = q\ C_p\ R$$

or

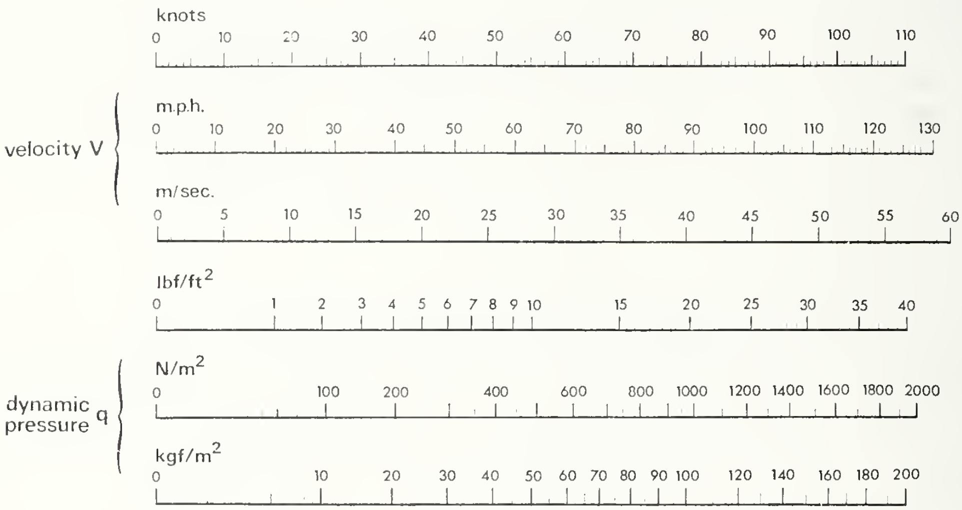
$$p = q(C_p\ R - C_{pi}\ R_i)$$

9. Multiply these pressures by the respective surface areas to obtain the wind forces

10. Sum appropriate components of these forces to obtain net uplift and drag loads.

6.0 REFERENCES

1. Simiu, E., "Estimation of Extreme Wind Speeds in the Philippines." Report presented at Regional Meeting on Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds. Kingston, Jamaica, 6-7 November, 1975.



Conversion chart for wind speed and dynamic pressure head

7.0 ACKNOWLEDGEMENTS

Acknowledgement is made to the Building Research Establishment (UK) for the illustration used in this document. The writer also wishes to acknowledge useful comments and suggestions provided by members of the Philippine Advisory Committee and by Emil Simiu of the Center for Building Technology.

APPENDIX A

TABLE I
MEAN RECURRENCE INTERVAL

Class of structure	Mean recurrence interval years
All structures other than those set out below	50
Structures which have special post-disaster functions, e.g. hospitals, communications buildings, etc.	100
Structures presenting a low degree of hazard to life and other property in the case of failure	20

TABLE II
RELATIONSHIPS BETWEEN RISK OF OCCURRENCE, MEAN RECURRENCE INTERVAL AND EXPECTED LIFE OF BUILDING

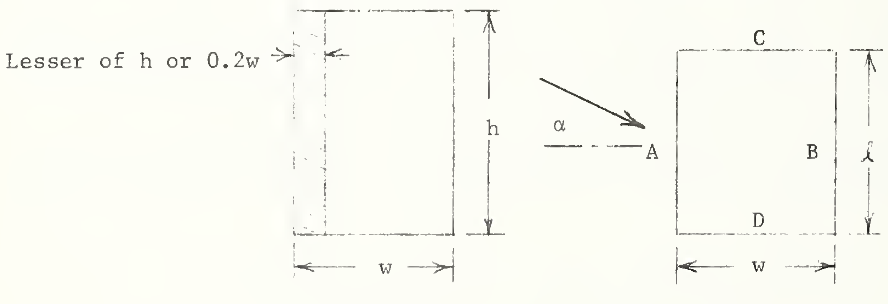
Desired Lifetime N Years	Risk of exceeding in N years the wind speed corresponding to the indicated mean recurrence interval					
	0.632	0.50	0.40	0.30	0.20	0.10
	Mean Recurrence Interval in Years					
10	10	15	20	29	45	95
20	20	29	39	56	90	190
50	50	72	98	140	224	475
100	100	144	196	280	448	949

Note: From this Table it will be seen that there is a 10% risk that the wind speed corresponding to a mean recurrence interval of 475 years will be exceeded in a lifetime of 50 years.

TABLE III

PRESSURE COEFFICIENTS FOR WALLS OF RECTANGULAR BUILDINGS

Building Height/Width Ratio	Building Length/Width Ratio	Wind Angle α (Degrees)	C_p for Face A	C_p for Face B	C_p for Face C	C_p for Face D	Local C_p
$h/w<0.5$	$1\le \ell/w<1.5$	0	0.8	-0.5	-0.6	-0.6	-1.2
		90	-0.6	-0.6	0.8	-0.5	
	$1.5\le \ell/w<4$	0	0.8	-0.5	-0.8	-0.8	-1.3
		90	-0.4	-0.4	0.8	-0.4	
$0.5\le h/w<1.5$	$1\le \ell/w<1.5$	0	0.8	-0.5	-0.7	-0.7	-1.4
		90	-0.7	-0.7	0.8	-0.5	
	$1.5\le \ell/w<4$	0	0.8	-0.6	-0.9	-0.9	-1.4
		90	-0.4	-0.4	0.8	-0.3	
$1.5\le h/w<4$	$1\le \ell/w<1.5$	0	0.8	-0.5	-0.8	-0.8	-1.5
		90	-0.8	-0.8	0.8	-0.5	
	$1.5\le \ell/w<4$	0	0.8	-0.6	-0.9	-0.9	-1.5
		90	-0.4	-0.4	0.8	-0.3	



ELEVATION

PLAN

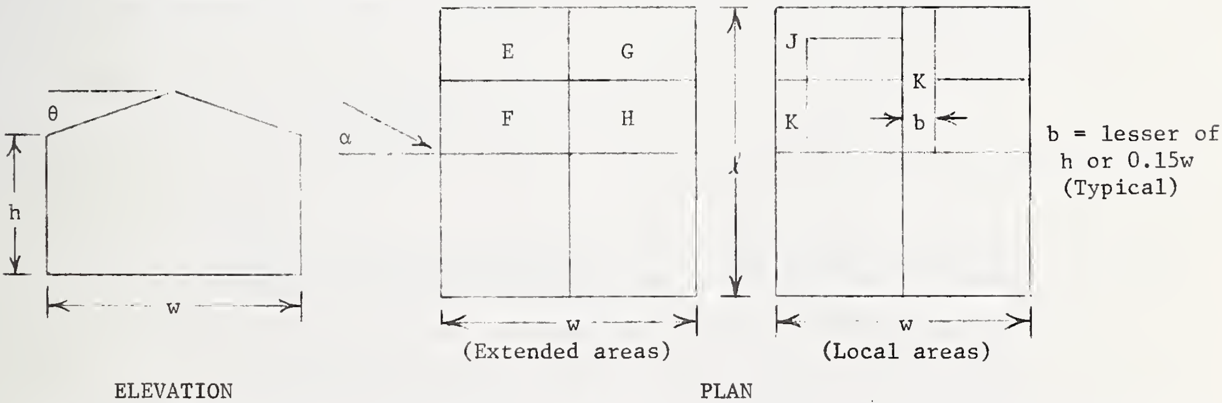
Notes: 1) h is the height to eaves or parapet, ℓ is the greater plan dimension of the building and w is the lesser plan dimension.

2) Local C_p values (last column) should be used in conjunction with correction factors for overall areas in Table VI.

TABLE IV

PRESSURE COEFFICIENTS FOR ROOFS OF RECTANGULAR BUILDINGS

Building Height/Width Ratio	Wind Angle α (Degrees)	Area Designation	Roof Slope θ (Degrees) 0	10	20	25
h/w<0.5	0	EF	-1.0	-1.0	-0.4	*
		GH	-0.6	-0.6	-0.8	
		J	-1.6	-1.9	-1.9	
		K	-1.4	-1.4	-2.0	
	90	EG	-1.2	-1.1	-1.0	*
		FH	-0.6	-0.6	-0.6	
		J	-2.0	-1.8	-1.8	
		K	-1.4	-1.4	-2.0	
0.5<u><</u>h/w<1.5	0	EF	-1.0	-1.0	-0.6	-0.4
		GH	-0.6	-0.6	-0.8	-0.8
		J	-1.8	-1.8	-1.8	-1.8
		K	-1.4	-1.4	-2.0	-1.6
	90	EG	-1.2	-1.1	-1.0	-0.8
		FH	-0.6	-0.6	-0.5	-0.4
		J	-1.8	-1.8	-1.6	-1.6
		K	-1.4	-1.6	-1.6	-1.6
1.5<u><</u>h/w<4	0	EF, GH, J, K	*	*	*	*
	90	EG, FH, J, K	*	*	*	*



Notes: 1) The pressure coefficient on the underside of roof overhangs should be taken as that on the adjoining wall surface.

2) Local C_p values (J and K) should be used in conjunction with correction factors for overall areas in Table VI.

3) * Indicates coefficients unavailable at time of publication.

TABLE V

INTERNAL PRESSURE COEFFICIENTS FOR RECTANGULAR BUILDINGS

Condition	Internal pressure coefficient C_{pi}
1. Two opposite walls equally permeable, other walls impermeable:	
(a) Wind normal to permeable wall	+0.3
(b) Wind normal to impermeable wall	-0.3
2. Four walls equally permeable	-0.3 or +0.2 whichever is the more severe for combined loadings
3. Dominant opening on one wall, other walls of equal permeability:	
(a) Dominant opening on windward wall, having a ratio of permeability of windward wall to total permeability of other walls and roofs subject to external suction, equal to --	
2	+0.5
3	+0.6
6 or more	+0.8
(b) Dominant opening on leeward wall	value of C_p for leeward external wall surface
(c) Dominant opening on side wall	value of C_p for side external wall surface
(d) Dominant opening in a roof segment	value of C_p for external surface of roof segment

Notes: 1) Internal pressures developed within an enclosed structure may be positive or negative depending on the position and size of the openings.

2) In the context of Table V the permeability of a surface is measured by the total area of openings in the surface under consideration.

3) The value of C_{pi} can be limited or controlled to advantage by deliberate distribution of permeability in the wall and roof, or by the deliberate provision of a venting device which can serve as a dominant opening at a position having a suitable external pressure coefficient. An example of such is a ridge ventilator on a low-pitch roof, and this, under all directions of wind, can reduce the uplift force on the roof.

TABLE VI

CORRECTION FACTORS (R) FOR HEIGHT OF BUILDING

Terrain	Structural System	Area	h<5	5≤h≤10
Smooth Zo≤0.12 m	Walls	Overall	0.85	1.00
		Elements	1.00	1.20
	Roofs	Overall	0.85	1.00
		Elements	1.05	1.25
	Internal Pressure		0.85	1.00
Rough Zo>0.12 m	Walls	Overall	0.75	1.00
		Elements	0.90	1.20
	Roofs	Overall	0.75	1.00
		Elements	0.95	1.25
	Internal Pressure		0.75	1.00

Notes: 1) The term "Overall" refers to the entire area of a given wall or roof slope.

2) The term "Elements" refers to roof and cladding elements, doors, windows, etc.

3) The terrain roughness parameter Z_o must be estimated subjectively. The following values are suggested for various types of exposure.

TYPE OF EXPOSURE	Z_o (meters)
Coastal	0.005-0.01
Open	0.02-0.12
Outskirts of towns, suburbs	0.13-0.30
Centers of towns	0.40

APPENDIX B

ILLUSTRATIVE EXAMPLE

A housing development is to be located in flat, open country on the outskirts of Zamboanga and will ultimately consist of several hundred single-family dwellings of quite similar geometry. The period of construction is anticipated to be from 10 to 15 years. The basic plan dimensions are 6.2 x 7.5 meters and the height to the eaves is 2.7 meters. The gable roof has an overhang of 0.7 meters on all sides and a slope of 10 degrees. Openings for doors and windows are evenly distributed on the exterior walls.

Because the development is to be built over a period of several years, it would not be appropriate to assume a builtup area in selecting the basic wind speed and flat, open country will be assumed here.

From Table I, a mean recurrence interval of 50 years is selected and it is considered that the associated risk of exceeding the basic wind speed (0.632) in Table II is acceptable.

From Ref. 1, the 1-minute average wind speed (N=50) for Zamboanga is 88 km/hr (Type I distribution). Since this is based on data obtained in open country at 10 meters above ground, this speed can be converted directly to the design speed. From Ref. 1 the ratio of the 1-minute speed to the 2-second peak speed is 0.82. Thus the design speed is

$$U = 88/0.82 = 107.3 \text{ km/hr} = 29.8 \text{ m/s}$$

The dynamic pressure is calculated from Eq. 2

$$q = 0.613U^2 = 0.613(29.8)^2 = 544 \text{ N/m}^2$$

Wind pressures are next calculated using Eqs. 4-6 and the coefficients presented in Tables III-VI. Note that

$$h/w = 2.7/6.2 = 0.44$$

and

$$\ell/w = 7.5/6.2 = 1.21$$

WALLS

Inspection of Tables III and V reveals that the worst cases are walls A and C with the wind blowing normal to the ridge. For wall A, $C_p = 0.8$ and for wall C, $C_p = -0.6$. The local C_p is -1.2. The internal pressure coefficients can range from 0.2 to -0.3. Table VI indicates that the reduction factor is 0.85 for walls and internal pressures and 1.00 for cladding elements, doors, windows, etc.

For wall A,

$$\begin{aligned} p &= (544)[0.8-(-0.3)](0.85) \\ &= 509 \text{ N/m}^2 \end{aligned}$$

For wall C,

$$\begin{aligned} p &= (544)[-0.6-(0.2)](0.85) \\ &= -370 \text{ N/m}^2 \end{aligned}$$

For cladding elements, the worst cases are

$$\begin{aligned} p &= (544)[0.8 - (-0.3)(0.85)] \\ &= 574 \text{ N/m}^2 \end{aligned}$$

and

$$p = (544)[-0.6 - (0.2)(0.85)] = -419 \text{ N/m}^2$$

For local pressures acting on strips of width 0.2w = 1.2 meters at each corner,

$$p = (544)(-1.2 - 0.2)(0.85) = -647 \text{ N/m}^2$$

ROOF

Inspection of Table IV reveals that the greatest uplift pressures on extended areas occur when the wind is blowing along the ridge.

For sections E and G,

$$p = (544)[-1.1 - (0.2)](0.85) = -601 \text{ N/m}^2$$

For sections F and H,

$$p = (544)[-0.6 - (0.2)](0.85) = -370 \text{ N/m}^2$$

Pressures acting on roofing elements in sections E and G are obtained as follows:

$$p = (544)[(-1.1)(1.06) - (0.2)(0.85)] = -727 \text{ N/m}^2$$

and for sections F and H,

$$p = (544)[(-0.6)(1.06) - (0.2)(0.85)] = -438 \text{ N/m}^2$$

Localized pressures act on strips of width 0.15w = 0.93 meters as shown in Table IV. The worst case occurs for area J with the wind blowing normal to the ridge. Note that the uplift pressure under the eaves must also be included.

$$p = (544)[-1.9 - (0.8)](0.85) = -1248 \text{ N/m}^2$$

For area K in section F, this negative pressure or suction is slightly less

$$p = (544)[-1.4 - (0.8)](0.85) = -1017 \text{ N/m}^2$$

Along the ridge (area K), the localized pressure is

$$p = (544)[-1.4 - (0.2)](0.85) = -740 \text{ N/m}^2$$

TOTAL UPLIFT FORCE

The total uplift force on the building is calculated for the wind blowing normal to the ridge as follows:

$$\begin{aligned}\text{Area of one roof slope} &= [7.5 + (2)(0.7)][6.2/(2\cos 10^{\circ}) + 0.7] \\ &= (8.9)(3.85) \\ &= 34.2 \text{ m}^2\end{aligned}$$

Note that areas E, F, G and H include areas J and K when calculating overall loads.

$$\begin{aligned} \text{Uplift} &= (544)(1.0 + 0.6)(34.2)(\cos 10^{\circ})(0.85) + (544)(6.2)(7.5)(0.2)(0.85) \\ &= 24{,}918 + 4{,}300 \\ &= 29.2 \text{ kN} \end{aligned}$$

TOTAL DRAG FORCE

The total drag force (neglecting the roof) is calculated as the sum of the loads on the windward and leeward walls.

$$\begin{aligned} \text{Drag} &= (544)(2.7)(7.5)[0.8 - (-0.5)]\ (0.85) \\ &= 12.2 \text{ kN} \end{aligned}$$

COMMENT

The loads calculated above are the loads that can reasonably be expected to occur under the conditions stated in the example. They should be considered as the minimum suitable loads for use with stresses and load factors appropriate for the type of structural material used.

For geographical areas exhibiting large variations in annual extreme wind speeds, the basic wind speed should be selected with caution. The application of probabilistic models of extreme wind speeds and some of their limitations are discussed in Ref. 1.

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APPENDIX F

A Guide for Improved Masonry and Timber Connectors in Buildings

A GUIDE FOR IMPROVED MASONRY AND TIMBER CONNECTIONS IN BUILDINGS

by

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Report Presented at Regional Meeting on Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds

Table of Contents

SI Conversion Units

In view of present accepted practice in this technological area, U. S. customary units of measurement have been used throughout this report. It should be noted that the U. S. is a signatory to the General Conference on Weights and Measures which gave official status to the metric SI system of units in 1960. Readers interested in making use of the coherent system of SI units will find conversion factors in ASTM Standard Metric Practice Guide, ASTM Designation E 380-72 (available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103). Conversion factors for units used in this paper are:

Length

1 in = 0.0254* metre

1 ft = 0.3048* metre

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*Exact Value

ABSTRACT

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).

This report investigates the use of connectors for masonry and timber elements in low-rise buildings. Connector characteristics and construction details that improve a building's response to extreme wind effects are given primary emphasis. Recommendations include improvements through better utilization of connector technology showing good feasibility of introduction in developing countries. The building systems considered in this study fall within the low to moderate cost category.

Key Words: Codes and standards; connectors; fasteners; lowrise buildings; masonry walls; structural design; technology transfer; timber roofs; timber walls; wind effects.

1. BUILDING SYSTEMS

by

S. George Fattal[1/]

1.1 Introduction

This report discusses the use of connectors in houses and other low-rise buildings to improve their structural response characteristics under extreme wind conditions. The report is organized into three main sections. Section 1 presents a general overview of masonry connectors and timber fasteners. Section 2 is devoted to a detailed discussion of connectors in building systems using masonry wall construction. Section 3 treats fasteners used in building of timber wall construction. These two types of buildings are most prevalent in housing for low to middle income occupancy in developing countries located in wind-prone areas [1]. [2/]

These buildings are typically one or two story detached units which are supported by a continuous wall footing made of cast concrete or concrete block masonry or, in flood-prone areas, by wooden poles embedded in the ground. The roof is commonly characterized by a pitched timber frame often projecting up to 5 ft beyond the exterior walls, and topped by corrugated metal cover.

The types of building systems of interest to this study are identified by reference to figures 1.1 through 1.5, which also serve as key visual reference for locating specific connector details discussed in the subsequent sections of this report.

1.2 Roof Systems

Figure 1.1 exhibits the two most commonly used framing systems for the roof: (a) the truss type and (b) the joist-rafter assembly. The truss type construction employs a series of equally spaced trusses spanning between opposite exterior walls. The corrugated metal roof cover is attached to a series of longitudinal purlins connecting the trusses together. The joist-rafter type consists of a system of inclined rafters framing into a ridge beam at the top and attached to ceiling joists spanning between opposite exterior walls at the bottom. Collar beams attached to the rafters provide stiffness to the roof in the vertical plane. The close spacing of the rafters permits direct attachment of roof cover to the rafters thereby eliminating the need to use purlins.

1/ Dr. S. George Fattal is a Structural Research Engineer with the Center for Building Technology.

2/ Numbers in brackets indicate references listed at the end of this report.

The choice of a particular roof system depends on many factors. A joist-rafter assembly allows better utilization of attic space while the truss system permits prior assembly of the individual trusses at the shop where quality control is generally better than in the field. Structurally, both systems can be designed to have the desired diaphragm capability to transmit lateral wind forces to the appropriate shear walls (having the same orientation as the wind as in fig. 2.1, ref. [2]). For instance, diaphragm rigidity can be improved by introducing horizontal cross-bracing in the plane of the joists and vertical cross-bracing in the longitudinal ridge plane (perpendicular to the joists) of both systems shown in figure 1.1. A practical but somewhat more expensive alternate to the horizontal bracing would be to provide wood flooring fastened to the joists in a manner that will insure integral action in the horizontal plane.

The importance of diaphragm action for roof systems in extreme wind regions should be emphasized in the light of the types of roof and wall failures observed that were attributed to a lack of transverse rigidity of the roofing system, as noted in section 2. The use of timber fasteners for connecting roofing elements is discussed in section 3.

1.3 Pole Type Construction

Figure 1.2 shows the structural layout of a pole type construction. The raised floor protects the house against insect infestation and floods. This type of construction provides generally a lower cost housing than either masonry or wood frame wall system since it lends itself more readily to auto-construction (self-help). It also permits utilization of less expensive indigenous products such as nondimensioned timber (logs) for the poles, and cane (i.e. bamboo) framing with rattan or twisted cane connectors as shown in figure 1.3. The figure also illustrates suggestions for adequate joining of members. The poles should be treated against insect infestation and water penetration prior to being embedded into the ground. The length of embedment required to resist wind-induced uplift or overturning and to provide adequate bearing is determined by local soil conditions. Figure 1.2 shows footing schemes for the poles and for the dimensioned timber post used as an alternative. Note that shallower embedment will require more substantial footings for the same level of resistance against wind-induced uplift forces. The design should also account for the additional uplift forces under the exposed floor.

Since the poles are the main pillars of support for the superstructure, they should preferably extend to the top and be provided with adequate connections at the roof and at the floor level. Because of their unsupported length between the raised floor and the ground, these poles should be proportioned to provide adequate flexural resistance to lateral forces induced by extreme winds. If this is not altogether feasible from a practical design standpoint, vertical cross-bracing made of wood, bamboo or wire cable should be introduced to tie the poles together below the floor level. Cables and various tiedown straps used in the United States to protect mobile home installations against extreme winds should also be explored for use in buildings on poles to provide additional stability against uplift and overturning forces. Information on available tiedown and anchoring devices may be acquired from the Manufactured Housing Institute.[3/] Design provisions for mobile home tiedowns are prescribed in Chapter 6 (1974) and appendix D (1975) of ANSI A119.1 [4], and ref. [5] supplies guidelines for their design. Section 3 discusses fasteners used in pole type housing. Supplementary information on pole type construction and the structural use of bamboo may be acquired by consulting references [6] and [7].

1.4 Masonry Bearing Wall System

Figure 1.4 displays the structural layout of a masonry bearing wall building system. The single wythe walls (defined in section 2.2) are built with hollow concrete masonry units which permit the passage of vertical reinforcement without the need of additional wythes. Note that alternate schemes are available for constructing lintels and peripheral (or collar) bond beams. They are indicated in the same figure for generality and convenient referencing purposes.

It was noted earlier that the type of masonry discussed in this report is generally representative of masonry housing construction in developing countries [1]. This makes it unnecessary to consider diverse masonry systems such as multiple wythe construction (to permit vertical reinforcing when solid units are used) or masonry veneers and other non-loadbearing elements. However, Section 2 does consider one additional masonry system (generally referred to as an "infill frame") which consists of a concrete frame with masonry filler walls.

1.5 Timber Wall System

Figure 1.5 shows a partial view of a timber of "stud" wall system. The studs or "verticals" transmit gravity loads and the vertical component of wind-induced loads which may be reversible (bearing or uplift). In addition, the studs provide flexural resistance against direct horizontal wind pressure or suction. The diagonals stiffen the walls in their own planes and increase the capability of the system to resist lateral loads. The specific fastener details for the stud wall system are discussed in Section 3.

3/ Manufactured Housing Institute, P.O. Box 201, Chantilly, Virginia 22021

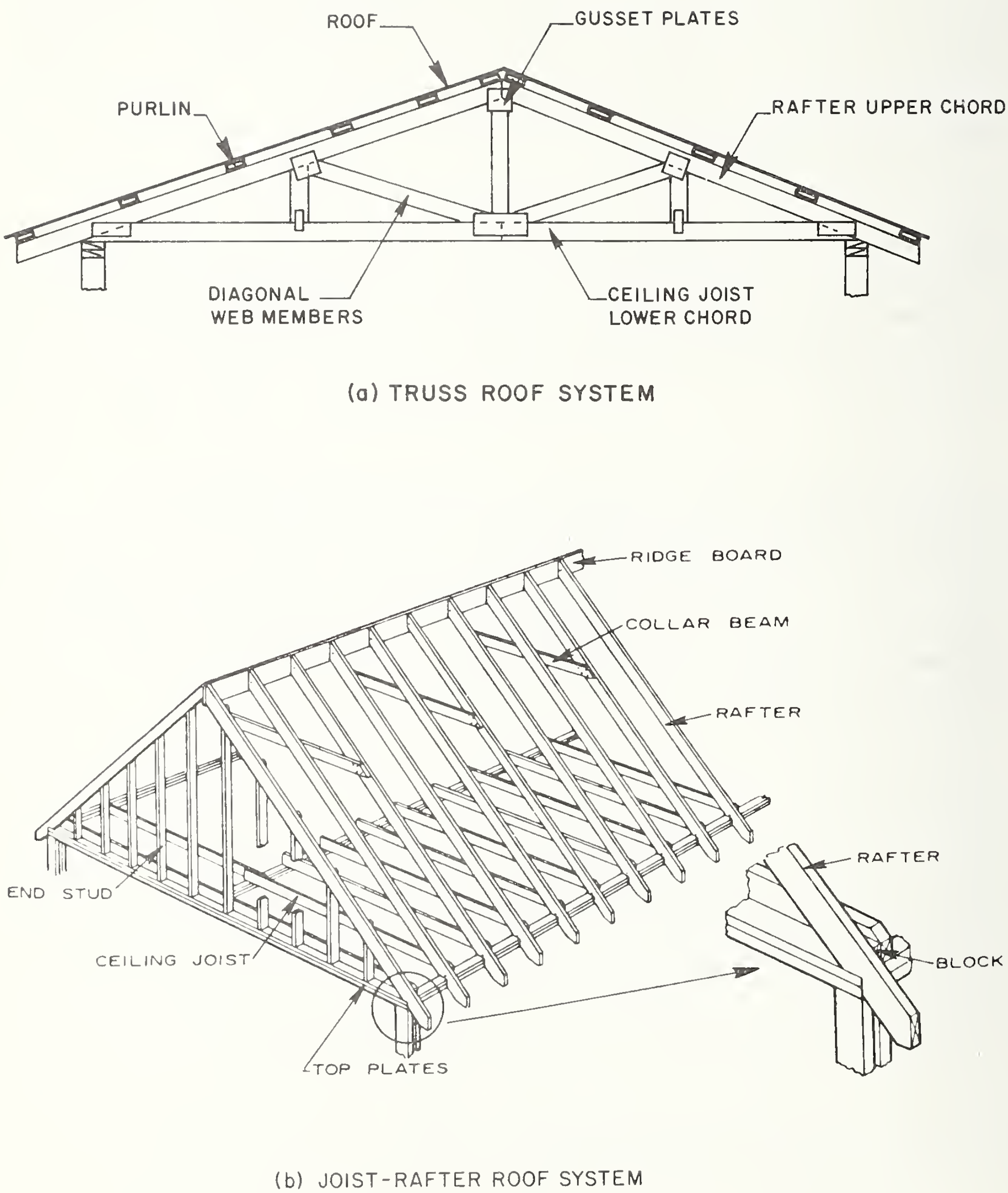

Figure 1.1 Common roof systems for low-rise buildings.

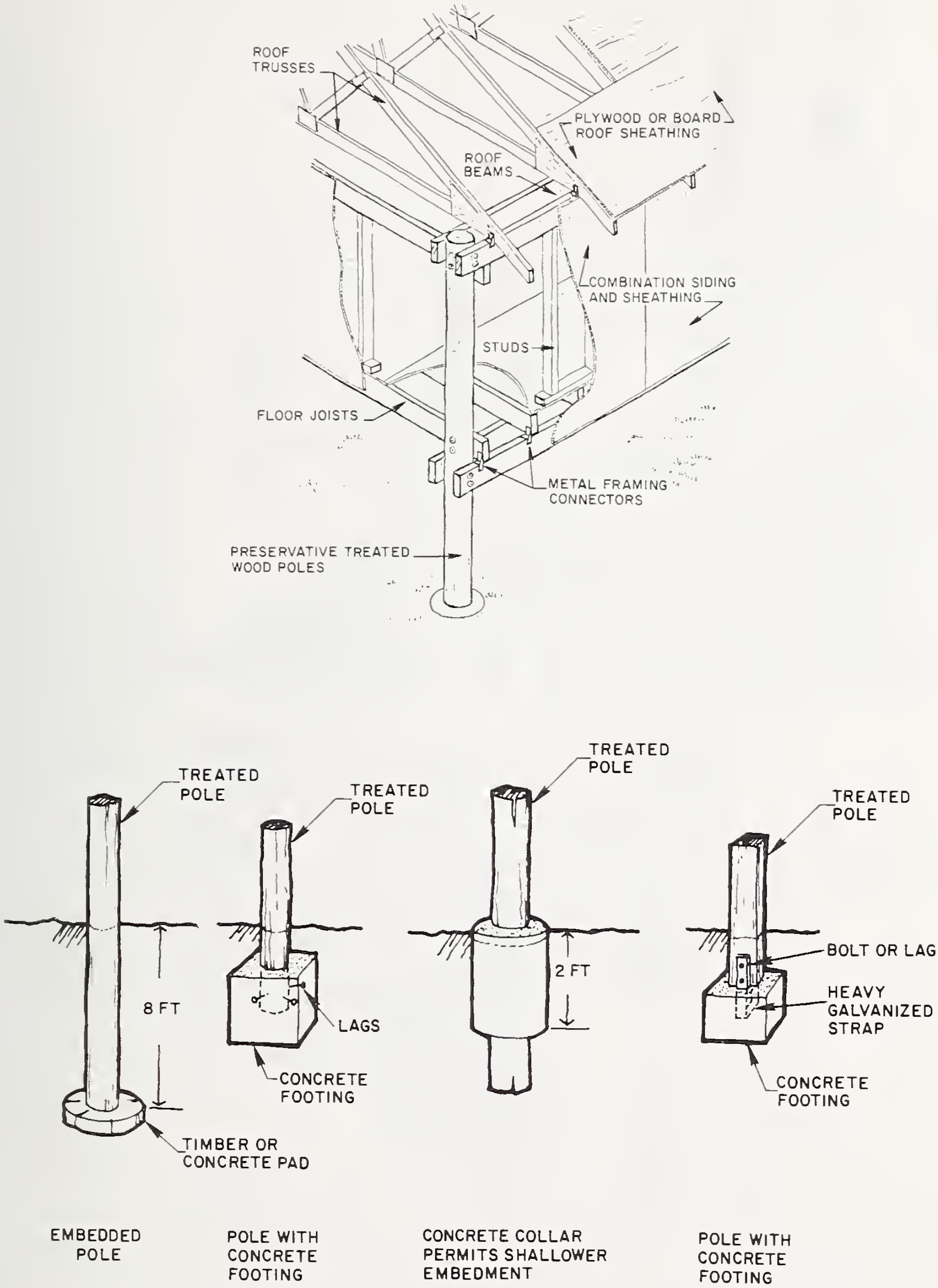

Figure 1.2 Pole type construction.

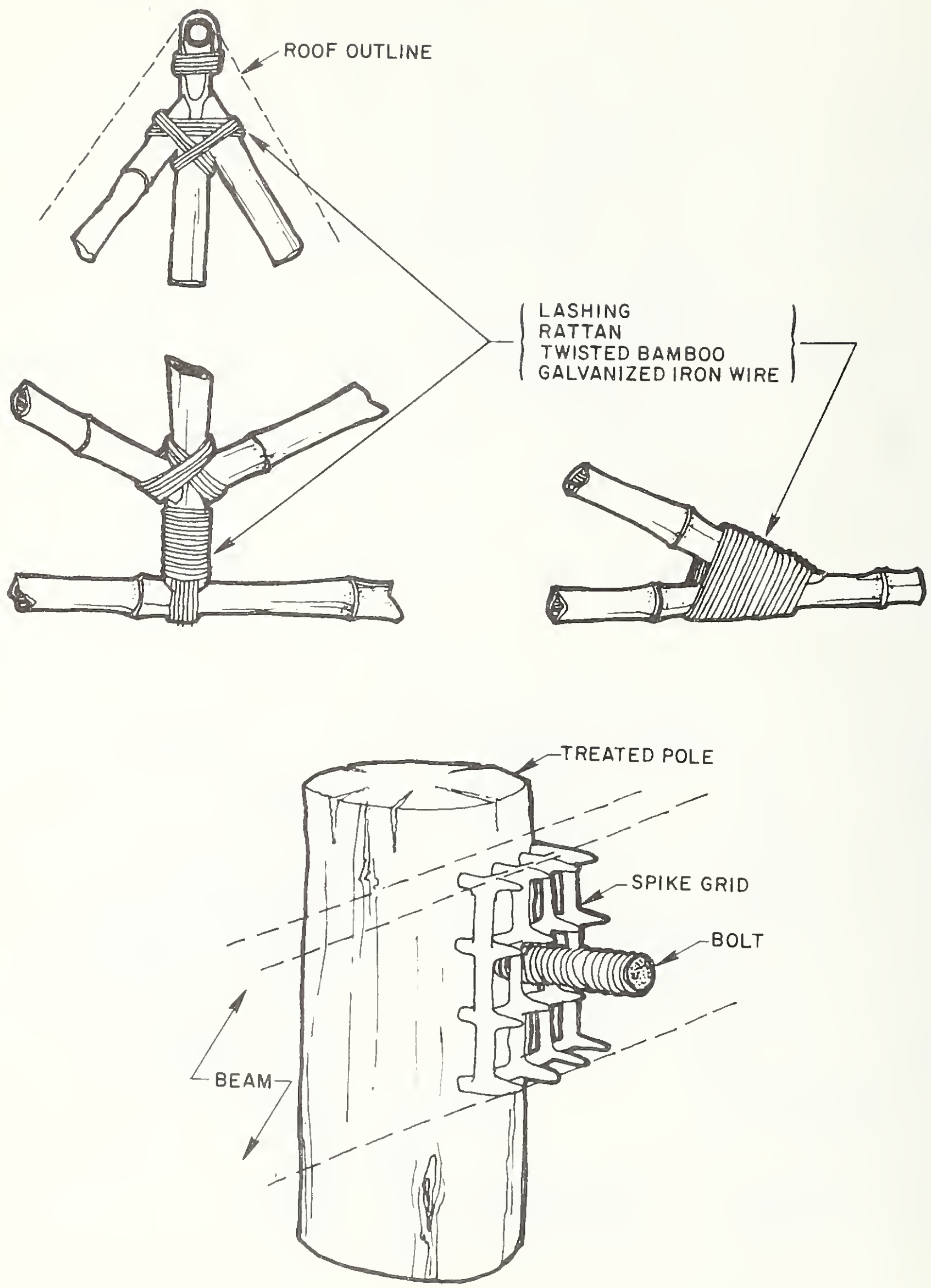

Figure 1.3 Miscellaneous bamboo and non-dimensioned lumber connection details.

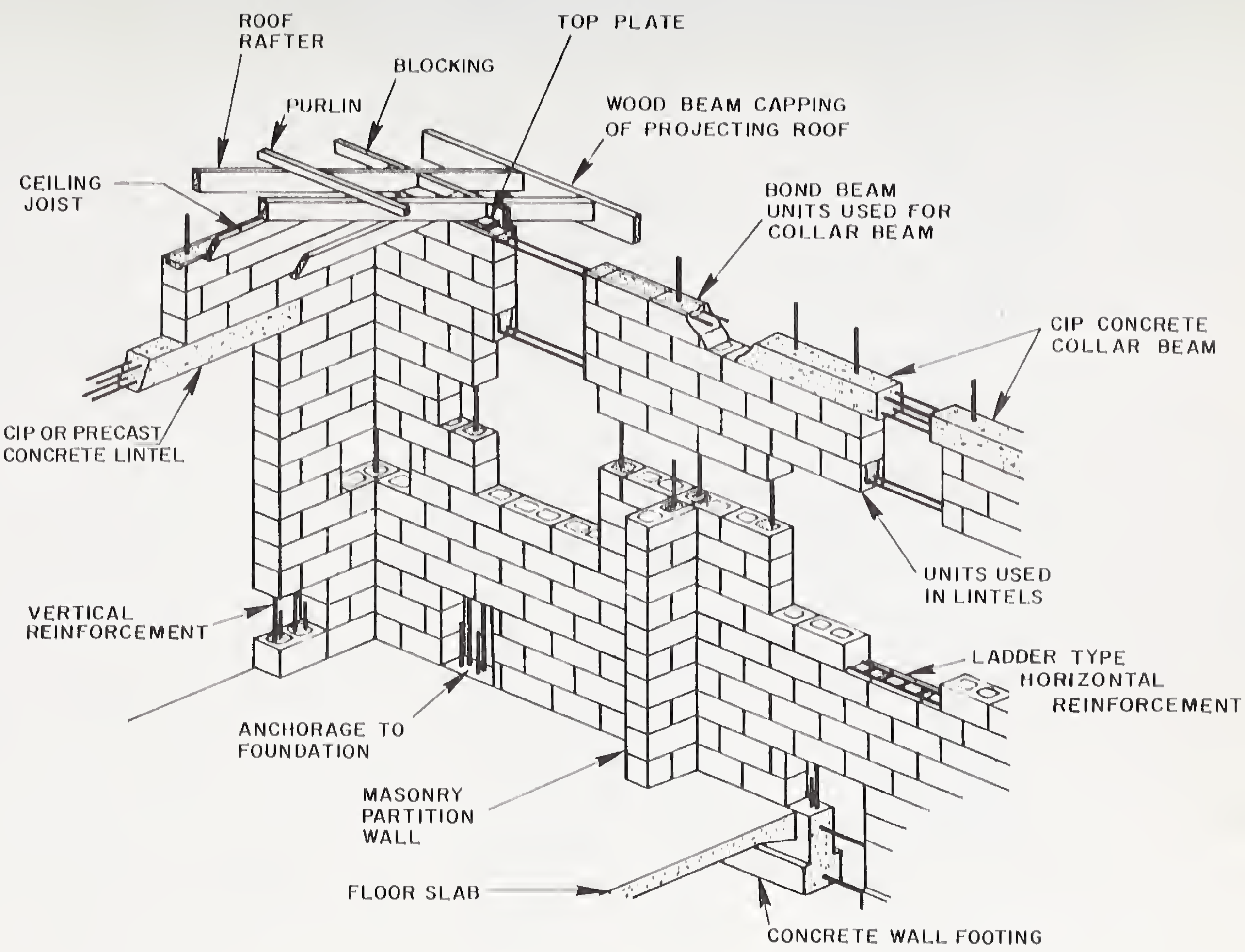

Figure 1.4 Masonry bearing wall construction.

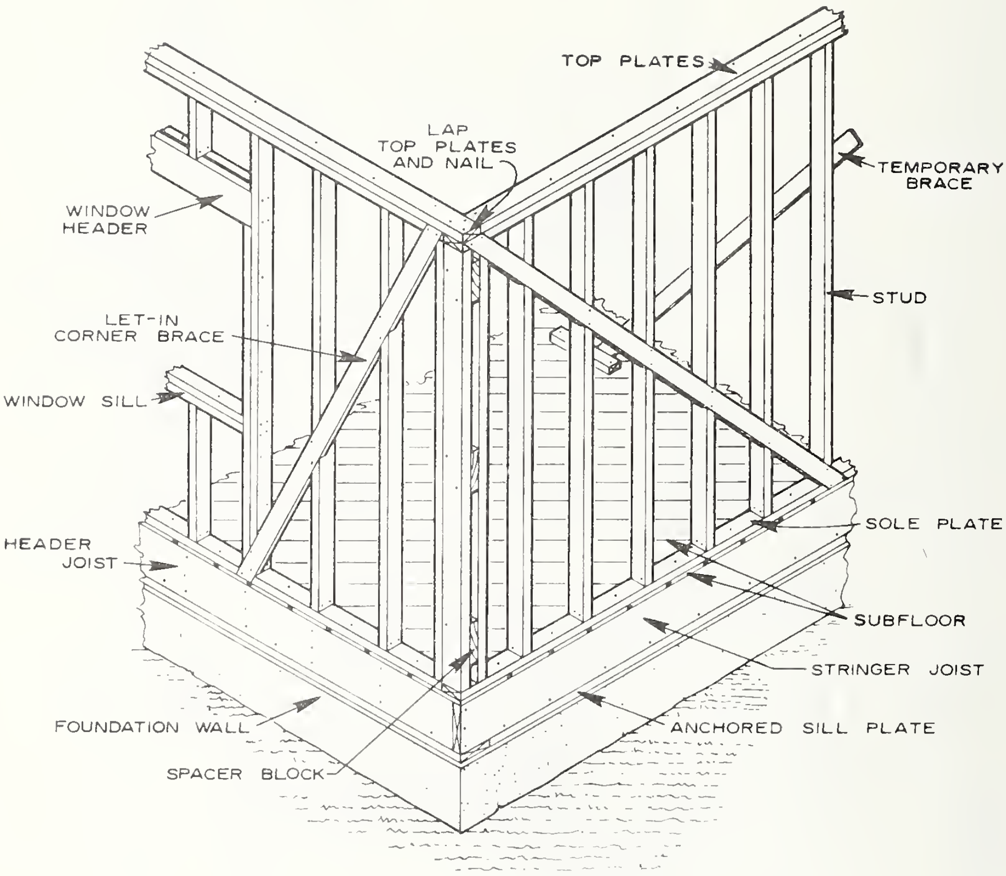

Figure 1.5 Timber wall construction.

2. MASONRY CONNECTORS

by

S. George Fattal

2.1 Introduction

This Section discusses the use of masonry connectors in bearing wall construction for improved structural response under severe wind conditions. The structures considered are low-rise buildings (i.e., dwellings, small business stores, community centers, schools) in developing countries. For the purpose of this section the word "connector" is used to designate any mechanical device, including reinforcing bars, which can be effectively used to connect individual masonry walls to the other elements of the system (walls, columns, beams, partitions, roof or foundation).

The material in this section consists of an introductory discussion giving background information on masonry construction, exhibits and analyses of buildings damaged by extreme winds, a survey and evaluation of current masonry practices in developing countries experiencing high winds, a study of current masonry practices in the United States relating to high winds and earthquakes with a discussion of various types of masonry connectors employed in such construction, and general and specific recommendations for improving high wind response of masonry buildings in developing countries through better utilization of existing connector technology.

2.2 Types of Masonry Construction

Masonry bearing walls used in low-rise buildings in developing countries are commonly built with hollow concrete masonry units. Figure 2.1 shows some of the common types of masonry units used in the United States [8]. Although the standard unit shown has 2 cores, 3-core units are also quite common in the United States as in the Philippines and other developing countries. In running bond construction (vertical joints staggered), it is somewhat easier to place vertical reinforcement through the 2-core units because the cores are in vertical alignment. They are also more modular than the 3-core units (less number of shapes and sizes are required in construction). For additional information, detailed classifications of concrete masonry are found in ASTM Designations C90, C129, C140, C145 and C33 [9].

Masonry units are laid in mortar which acts as their binding agent. Prevailing types of mortar in the United States are cement-line-sand and masonry cement-sand mortars. Different proportions of the constituents in these types will produce different strength properties. Standard mortar designations, such as types M, S or N are used for the appropriate mortar identification according to the range of constituent proportions, by volume, specificed in ASTM Designation C270 [9]. Types M,S, and N are commonly used for structural masonry applications. Types M or S are specified for high flexural strength requirements. Various other specifications for mortar and mortar ingredients are found in ASTM Designations C5, C91, C109, C110, C144, C157, and C207 [9].

Masonry walls are classified according to type of construction and intended use in a building. A single wythe wall has one masonry unit in its thickness. A multiple wythe wall has several masonry units in its thickness. In a composite wall construction, at least one of the wythes is built with masonry units dissimilar from those in the neighboring wythes. Multiple wythe walls without cavity are laid contiguously with the spaces between the wythes, called collar joints, filled with mortar or grout. To insure monolithic action of the assembly, additional bonding is effected by the use of metal ties laid horizontally in bed mortar across the wythes at periodic intervals throughout the height of the wall. A cavity wall is identified by a continuous vertical air space between any two adjacent wythes and by metal ties laid as in composite wall construction and connecting the two wall sections flanking this space. Reinforced masonry walls built with solid units are reinforced by placing steel bars, vertically and/or longitudinally, as needed, in the space between consecutive wythes and by grouting this space. In hollow block walls, such as those studied in this report, vertical reinforcement may be placed as needed, through the hollow cores which are then grouted.

The following types of masonry walls are identified by their intended function in a building. A load bearing wall supports the vertical loads above it, in addition to its own weight, with or without the aid of a vertical load-carrying space frame. A non-load bearing wall supports no vertical loads other than its own weight. A shear wall resists planar forces induced by exterior horizontal loads acting on a building. A curtain wall is a non-load bearing wall, built outside the building frame and not entirely supported at each floor. A panel wall is a non-load bearing exterior wall supported at each floor. A partition is a non-load bearing interior space divider which will function as a shear wall unless isolated along three edges from the rest of the structure. Veneer is the exterior masonry layer of a two-layer wall system, connected to the interior layer and/or to the primary load-supporting structure by horizontal ties. Veneer is generally designed to be non-load bearing. A pier is a masonry wall segment flanked by two adjacent openings or by an opening and the vertical edge of a wall. A lintel is a wall segment above an opening.

A masonry filler wall or infill wall designates a wall fully enclosed within a structural frame or bounded by two columns and wholly supported at each floor level. Filler walls may be load bearing or non-load bearing depending on the type of construction. In the United States, filler walls are generally non-load bearing because they are usually laid after the frame has been erected so that only mortar bond exists at the interface. Figure 2.2 shows another type of filler wall construction where the walls are laid first on top of a wall footing, followed by casting of the concrete columns and peripheral bond beam. This scheme permits extension of horizontal and vertical wall reinforcement into the surrounding frame so that the assembly will act integrally under superimposed loading. This system is widely used in the Latin American countries and has shown good performance under severe earthquakes in the past.

The latter type of infill wall construction and the single wythe masonry bearing wall construction shown in figure 1.4 are the two types of masonry systems considered in this study.

2.3 Analysis of Wind Damaged Buildings

Figures 2.3 to 2.12 exhibit buildings damaged or destroyed by recent hurricanes and typhoons. The buildings shown in figures 2.3 to 2.5 belong to a group of one-story structures in Northern Luzon, the Philippines, which either sustained severe damage or collapsed as a result of the November, 1974. These structures consisted of maosnry walls and wood posts, a pitched roof system of wood trusses, purlins and corrugated iron cover, and a continuous foundation wall of cast concrete.

Figure 2.5 exhibits a typcial failure of the fasteners connecting the purlins to the top chords of the trusses. Most of the roofing was "peeled off" in this manner. Portions of the corrugation iron roofing found on the ground contained the purlins with their metal wire attachments still in place (figure 3.18). Instability of the trusses, few of which were still standing, was attributed to the loss of purlins and the absence of other longitudinal bracing between the trusses. The collapse of the masonry walls as shown in figure 2.3 was likewise attributed to the loss of lateral support at the roof level. However, the extent and severity of wall damage is also attributed to the absence of connections between abutting walls and the ineffectiveness of the vertical anchorage at the base. As indicated in figure 2.4, the only anchorage consisted of steel plates bolted to the wood posts. Close inspection revealed severe corrosion of these plates, especially at the ruptured section through the bolt holts (figure 2.4). The masonry walls in these buildings were non-load bearing as they were stopped short of the roof to provide openings at the top (figure 2.3). Thus the wood posts were the only vertical loadbearing elements and with the loss of the roof many of the corner posts were tipped over (figure 2.3).

Figures 2.6 to 2.8 shows single family housing units of concrete masonry bearing wall construction, located in Central Luzon, the Philippines, that were damaged or destroyed by the November, 1970 typhoon. An inherent weakness of these systems is the absence of peripheral support of the masonry walls at the top because of a local preference for large openings at these locations. This practice reduces the effectiveness of the roof to function as a diaphragm and makes it more susceptible to failure by wind suction or uplift. As indicated in figure 2.6, most of the roofs of these units were removed by the storm. Inspection of figures 2.7 and 2.8 indicates good quality workmanship was used in constructing the masonry walls which contained vertical reinforcement in grouted cores. Note that the nails between the top window frame insert and the wall below or the peripheral wood joist above were not effective in preventing the masonry wall from çaving in (figure 2.8) or in keeping the inserts from falling down (figure 2.7). In fact, there is no evidence that any fasteners were used between the wall panel (in the background of figure 2.7) and the peripheral joist on top which was probably removed together with the roof by the storm.

Figures 2.9 to 2.12 exhibit structures consisting of different types of masonry wall systems that sustained severe damage or were destroyed by the December, 1974 cyclone in Darwin, Australia. These structures represented engineered masonry construction with respect to the quality of workmanship and adherence to Australian masonry codes and standards (which are comparable to those in the United States). The Darwin experience demonstrated that compliance with current standards does not necessarily produce a structure capable of resisting the estimated 150 mph winds experienced during this storm. However, it does indicate the need to reexamine the existing provisions with the objective of developing improved design criteria, connection details, and construction practices in order to mitigate the extent of disaster associated with extreme winds.

A damage study of the Darwin structures reveals some features worthy of note. In figure 2.10, it appears that failure occurred at the fourth bed joint from the top, in the inner concrete masonry wythe of the double-wythe cavity wall. Since the inner wythe is the loadbearing component, its failure was probably caused by an outward thrust of the roof under the action of wind. The tilted position of the inner wythe with its top leaning against the brick facing indicates the absence of ties between the wythes near the roof level. The masonry wall in fiugre 2.9 consists of two concrete block wythes with a cavity in between. The condition of the reinforcement demonstrated the ineffectiveness the light-gage ties in assisting the integral functioning of the two wythes in out-of-plane flexure.

Figure 2.11 shows an infill wall construction with a steel frame and concrete masonry filler walls. There is no visual evidence of any reinforcement having been used in the filler walls. Note the severity of vertical cracking through the wall on the right and also the separation between the steel column and the wall at the left. It is not possible to establish by examination of the figure whether there were any connectors between the steel columns and the filler walls. Figure 2.12 shows the portion of a concrete masonry wall under the sill of a large window opening that has failed. Note that the top course was connected to the window frame with anchor straps embedded into the grouted cores. It is likely that failure was caused by the movement of the window frame, prying the top course loose from the rest of the wall.

2.4 Masonry Construction in Developing Countries

The following discussion pertains to masonry buildings representing the types of construction used in developing countries. Local practices, utilization of building products, standards compliance, etc., are discussed and evaluated with the aid of exhibits of buildings at various levels of completion.

Figures 2.13 and 2.14 show two different stages of construction of a single family house located in Central Luzon, the Philippines. The walls are built with 3-core concrete block units (some of which may be seen lying on the ground in figure 2.13). The units are laid in stacked bond to permit placement of reinforcement through the vertically aligned cores. On the basis of figure 2.14 the quality of masonry construction is deemed inferior by existing masonry standards. Some of the deficincies noted are: (1) use of defective units, (2) partially filled and non-uniform mortar joints, (3) insufficient horizontal reinforcement for stacked bond construction, and (4) insufficient lintel reinforcement above the openings. It should be pointed out, however, that this system utilizes a peripheral concrete bond beam cast directly above the lintel course (see figure 2.13). From the standpoint of overall structural integrity in a severe wind environment, attention is drawn to the practice of using large roof overhangs which are particularly susceptible to wind damage as they are subjected to a positive pressure from below and suction from above [2]. A potentially critical condition also exists in the masonry column supporting a larger overhang at the corner of the landing. Unless substantial top and bottom anchorage and vertical reinforcement is supplied in the column, which is not likely to be the case, given the limited available core space in the single unit section, there is a high probability that the column will fail under the impact of wind-borne missiles and/or uplift forces exerted by the roof in a severe windstorm.

Figure 2.15 shows completed single family houses in another project located in Central Luzon, the Philippines. Figures 2.16 and 2.17 display the infill wall construction of a typical unit which is judged to be superior in the overall quality of construction as well as wind-resistant capacity to that shown in figure 2.13. Structurally sound features include: (1) the use of running bond (vs. stacked bond) masonry construction with vertical and horizontal reinforcement, (2) adequate connections between neighboring elements and (3) the practice of casting the column concrete after completion of the infill walls. With regard to item (2), note for instance, in figure 2.16, that the vertical bars extend beyond the top of the column and the walls to provide connection to the roof. A structurally marginal practice identified by reference to figure 2.17 is the manner in which the lintels are built. A wood form is shored at the top to give the desired height of opening, and the space is filled with broken concrete block remnants and mortar. After setting, the metal window frame is fitted into the opening. Probably the window frame is relied upon to carry the weight of the lintel above it in addition to any loads transmitted form the roof. It is not known whether any horizontal reinforcement was placed in the courses above the lintel; none appear to be projecting into the adjacent corner column.

Another example of reinforced masonry bearing wall construction used in the Central Luzon area of the Philippines is the house shown in figure 2.18. Although it is quite similar to the first systems discussed above (figure 2.13), there are some major differences that make it a more viable system structurally. For instance, the use of lintels cast integrally with the bond beam (figures 2.20 and 2.21) gives better integrity to the system. Likewise, the hip roof is essentially a space truss which has a better diaphragm capability because it is braced in both horizontal directions. Also note that the amount of reinforcement (figure 2.19) is more substantial, the masonry and workmanship is of a better quality and better connections are used between the roof and wall elements. The common inherent weaknesses are: the use of slender columns made by stacking single units (figure 2.18) and excessive projections of the roof overhangs.

Figure 2.22 shows a house built in Bangladesh by CARE, Inc., consisting of walls and pilasters built with cinva-ram[2/] masonry units. The wall footings are built wider than the walls and are raised above ground to protect the house against floodwater. One of the attributes of this house is its low cost because it lends itself to self-help construction since the skills needed to produce cinva-ram is minimal. One disadvantage of this construction is the difficulty of reinforcing it economically. Since cinva-ram units are solid, double wythe walls are needed for the placement of bars. This can be compensated to a certain extent by using thicker walls built with larger units.

The foregoing case studies, which were based on information gathered from field surveys of ongoing construction projects, indicate the need for a broader dissemination of existing literature on building construction practice to the public. The reference section lists some of this information that is available through local sources such as the Philippine Standards Association [15 to 18], the Association of Structural Engineers of the Philippines [20], the Philippine Bureau of Standards [13, 14], and the Carribean Council of Engineering Organizations [27].

2.5 Masonry Practices in the United States

2.5.1 Available Masonry Connectors

Among the broad variety of connectors available for use in masonry construction, a significantly large number are utilized for non-structural applications such as for attachment of facing panels, hangers and miscellaneous appendages. Others are used in dual wall systems such as cavity walls, wood framing with masonry veneer and two-wythe was

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[2/] Units made by pressing a mixture consisting mostly of clay and some cement into rectangular units which are then dried in the sun.

with reinforced and grouted collar joint. Both of these categories are excluded in this study since they do not relate to the single wythe bearing wall construction most commonly used in developing countries.

Figure 2.23 shows a variety of metal anchors used to tie masonry walls to interconnecting elements. Tiebars come in different sizes and shapes for diverse applications. Where used to provide lateral support between abutting bearing walls, 1/4-in tiebars with end hooks are typically placed in alternate courses with the bent ends embedded in cores filled with mortar or grout as illustrated in figure 2.24 (c). A twisted bar without end hooks is used to tie floor or roof joists to the concrete masonry bearing surface as shown in figure 2.24 (b). These joists are supported laterally, at specified intervals, by the masonry walls of the same orientation, with tiebars as indicated in figure 2.24 (a). Tiebars used in pairs provide an effective means of anchoring the roof to the walls. At the top the hooks are lapped and nailed to the rafter or the top chord of the roof truss. At the bottom, they are embedded in the concrete bond beam or, in the absence of a concrete bond beam, into the grouted cores of the concrete blocks in the top course. Steel reinforcing bars can also be used for this purpose. In either case proper care should be exercised to protect exposed metal surfaces against corrosion.

Plain or corrugated dovetail bars shown in figure 2.23(e) and (g) are made of lighter gage metal than the tiebars and are used to tie masonry walls to concrete walls or columns. These anchors require special metal duct inserts in the concrete to receive the dovetail end in interlock. Although dovetail anchors are generally designed for non-load bearing masonry wall connections, they provide some measure of resistance against pullout forces. The corrugated dovetail tie with an end hook shown figure 2.23 (f) provides an effective means of anchoring door and window frames to the masonry walls.

Anchor bolts such as the one shown in figure 2.23 (h) are mainly used to connect wood elements to the masonry. The bent end generally gives more holding power for the same length of embedment than the head of a standard straight bolt. Figure 2.25 illustrates two anchor bolt applications: (a) anchorage of sill to masonry wall and (b) anchorage of stud wall to masonry wall. Also consult figures 3.23 and 3.24 which illustrate the use of anchor bolts to connect a stud wall system cast concrete slab footings and concrete masonry foundation walls.

Figure 2.26 shows reinforcement designed for placement in the horizontal joints of masonry walls. The two common shapes are the truss and the ladder shown in (a) and (b), respectively. This reinforcement is fabricated from light-gage, cold-drawn steel and consists of two longitudinal rods welded together by cross rods. Joint reinforcement is used as a means to avoid or control cracking in masonry walls and to improve their tensile strength in horizontal flexure.

The use of joint reinforcement is strongly recommended in walls of stacked bond construction which are prone to develop cracking in service along the vertically aligned mortar joints. A good practice is to use them in alternate courses in stacked bond construction and in every third course in running bond construction. Special prefabricated units are also available for continuous reinforcement around corners as in figure 2.26(c) and (d), and for anchoring abutting walls and partitions as in figure 2.26(e) and (f).

There are a large number of manufacturers of masonry connectors. The best source of obtaining names of manufacturers is The Thomas Register [26] and the best source of obtaining product information is Sweet's Industrial Consturction Catalog File [3]. The pertinent data supplied by the manufacturer include descriptions of the available products, their application, technical data and level of acceptance by building regulatory agencies.

2.5.2 Available Technical Information

The design and construction of masonry buildings are governed by the provisions of various regulatory documents. Among these, the principal one for concrete masonry is the NCMA Specification [28] which comes with a Commentary [29] giving the rationale behind its provisions. The ACI Committee 531 report [30] contains proposed reocmmendations for concrete masonry structures that have been referenced by Jamaican sources [1]. This committee is currently preparing a revised code for concrete masonry. Provisions for maosnry in general, are prescribed in ANSI A41 [31] and the Uniform Building Code [32].

Information of a less technical nature is contained in reference [33] published by NCMA, which provides guidance for vocational training in concrete masonry. NCMA also published a TEK series [34] which supplies technical information on design, construction and detailing aspects of concrete masonry.

Experimental and analytical research work on concrete masonry conducted at the National Bureau of Standards is described in various publications media with the more recent ones included in the reference list [35 to 39]. Additional sources of information on concrete masonry-related practices are also listed [40 to 46].

2.6 Suggested Improvements in Masonry Construction

2.6.1 Utilization of Available Connectors

Improvements in building construction can be obtained through a better utilization of available masonry connectors. The methods include the use of tiebars as an expedient means of anchoring masonry walls together as well as to roof and foundation elements. Bars of 1/8-to 1/4-inch thickness which should be locally available in many developing countries can be bent or twisted to give them the desired configuration by labor-intensive methods much in the same manner as is employed to hook reinforcing bars in the field.

It was previously noted that connections effected by tiebars may also be accomplished by using plain or deformed reinforcing bars which are generally more readily available than tiebars. To be effective, exposed reinforcing bars should be resistant to corrosive agents. Where used to connect the roof to the masonry walls, reinforcement should have sufficient embedment in concrete or grout-in-core at the bottom, and should preferably extend over and around the connecting roof element and be secured on both sides by straps nailed into the wood.

To provide anchorage between intersecting walls, reinforcing bars formed into a loop or hooked at both ends may be placed in bed mortar for constructions without using bond beams as indicated in figure 2.27(a) and (b). Where bond beams are utilized a more substantial anchorage may be effected by bending and extending the bars into the neighboring walls as indicated in figure 2.27(c) and (d). Likewise, walls may be connected to the foundation by dowels embedded in the footing (bent dowels are preferable) and extending into the grouted core of the wall and lapping with the vertical reinforcement.

2.6.2 Improved Construction Practices in Severe Wind Environment

Improved structural response in a severe wind environment may be achieved through practices which have been identified through past records to be more effective during natural disasters. The more important aspects are:

1. Use of Peripheral bond beam connecting all load-bearing masonry elements together. Alternate construction schemes include the use of a cast concrete beam and the use of bond beam masonry units through the top course (figure 1.4). Both schemes permit placement of horizontal reinforcement to achieve better integrity at the top. It should also be mentioned that a substantial bond beam relieves the walls from resisting forces in out-of-plane flexure and supplements the diaphragm rigidity of the roof.
2. Use of appropriate lintels and connections between lintels and the rest of the walls. Alternate cast-in-place and precase lintels are indicated in figure 1.4. A most effective means of achieving continuity of lintels is to cast them integrally with the bond beam as indicated in figure 2.20.
3. The need for adequate diaphragm capability of the roof cannot be overemphasized. The roof system should preferably be braced in both directions to achieve a measure of diaphragm rigidity which is needed to transmit lateral wind loads to the appropriate shear walls below.

4. The use of slender vertical elements such as those built with single stacked concrete masonry units to provide columns for the support of large roof overhangs at reentrant corners or landings should be avoided in a severe wind environment. This restriction is necessary because these elements are highly susceptible to impact by flying debris and uplift transmitted from the roof.
5. Large roof overhangs serve as vehicles for attracting and transmitting higher uplift forces on to the system and therefore require more substantial construction provisions against high winds. Considerations such as aesthetics, shading provisions and social preferences of dwelling environment should be traded off against precticality of design and increased costs associated with such practices to arrive at a reasonable compromise.
6. Overall integrity of the system should be assured by providing continuity between vertical wall reinforcements and the roof and foundation through appropriate utilization of reinforcing bars and anchor bolts and by providing continuity between intersecting walls by means of tiebars and/or horizontal reinforcement grouted within a bond beam course and extending into the neighboring walls and partitions.
7. The use of infill wall construction in building systems under a severe wind environment should be encouraged. The masonry infill walls should be laid first on top of a cast concrete wall footing and attached to it by means of dowels lapped a sufficient distance with the vertical reinforcement placed into the grouted cores of the hollow blocks. Horizontal and vertical reinforcement should project from the sides and top of the filler walls to achieve continuity with the surrounding concrete frame which should be cast last.

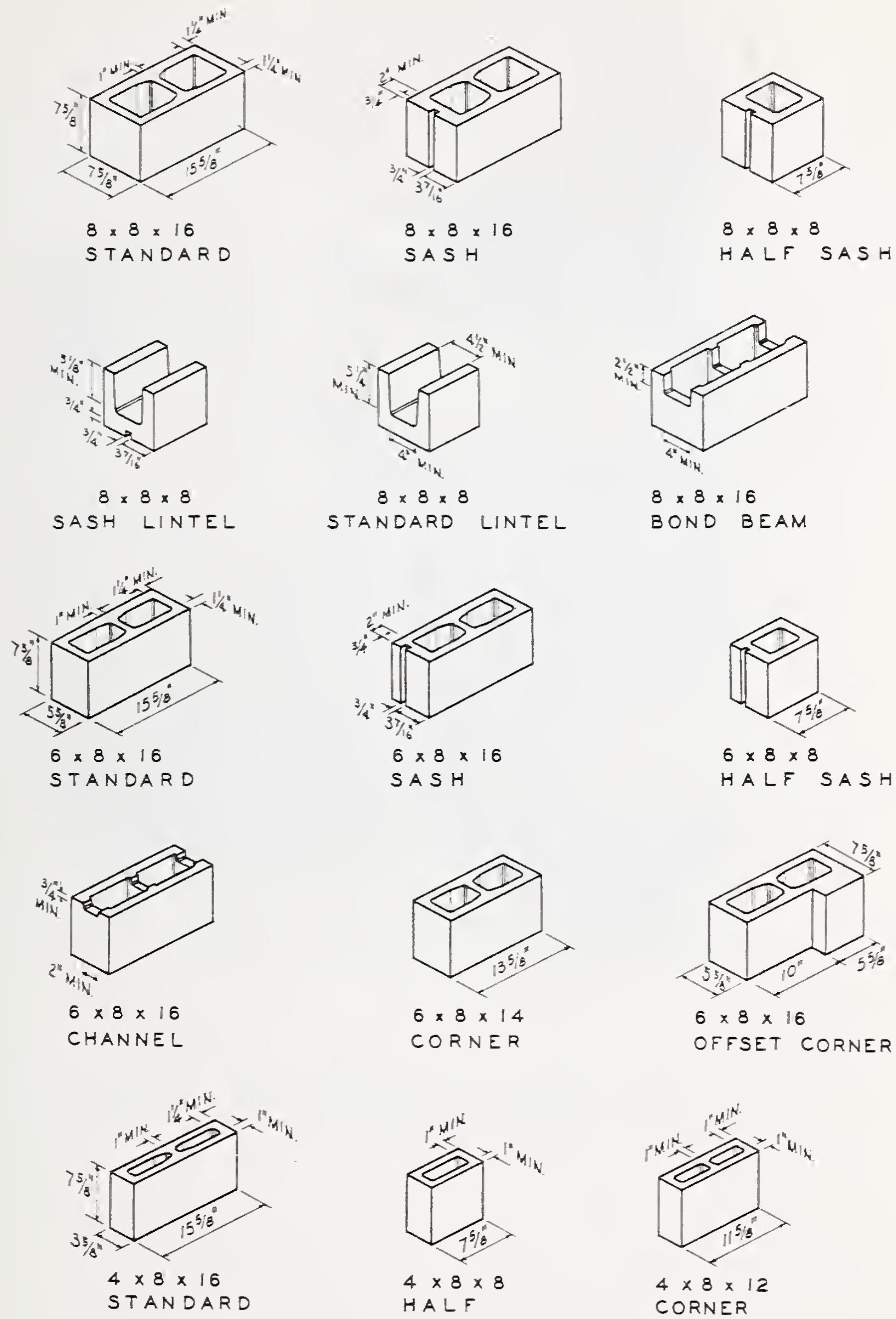


Figure 2.1 Concrete masonry units

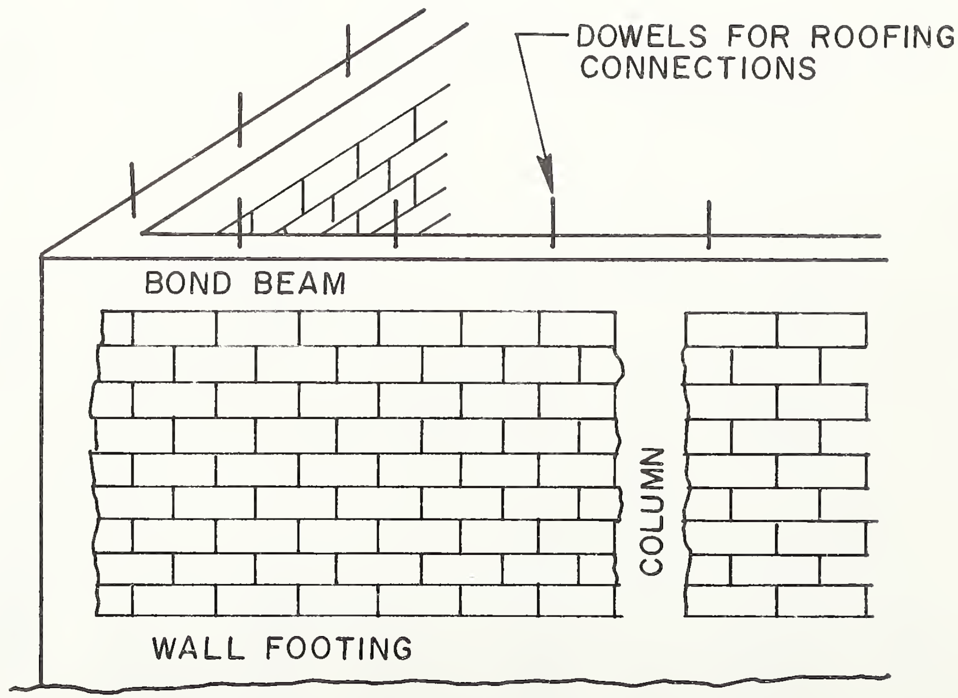


Figure 2.2 Infill wall masonry construction.

Figure 2.3 Collapse of one-story building caused by the November 1974 typhoon in the Philippines.

Figure 2.4 Failure of metal anchor plate in building destroyed by the November 1974 typhoon in the Philippines.

Figure 2.5 Roof failure in building caused by the typhoon in November 1974, in the Philippines.

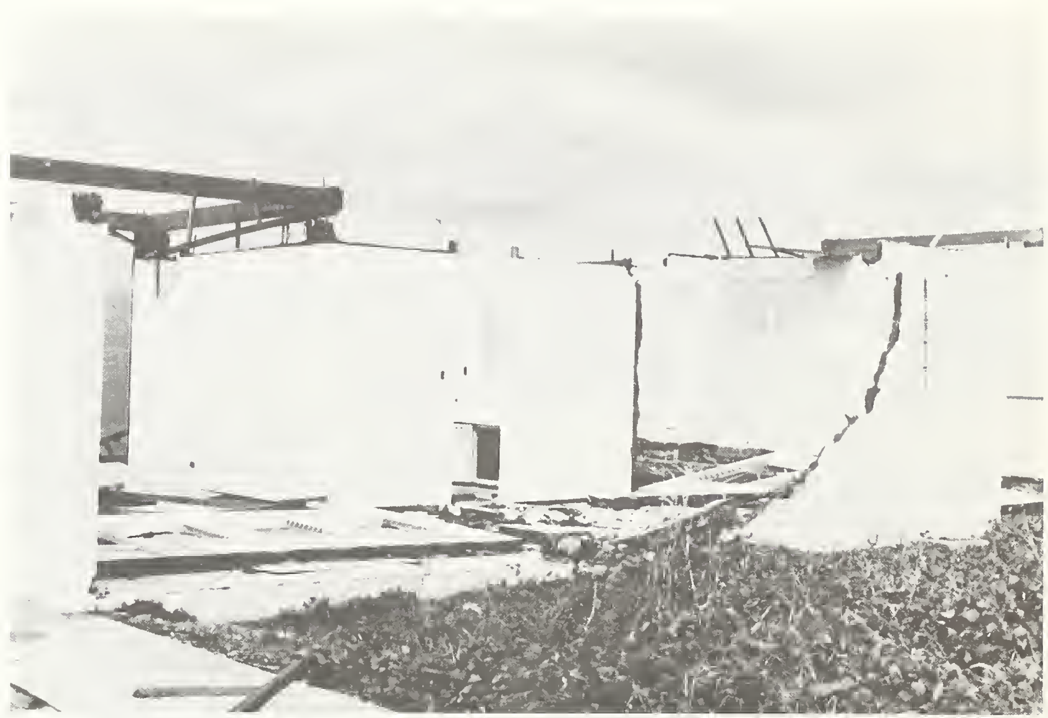


Figure 2.6 Single family houses damaged or destroyed by the typhoon in November 1970, in Central Luzon, the Philippines.

Figure 2.7 Single family house showing collapse of roof and exterior wall during the Philippines typhoon in November, 1970.

Figure 2.8 Interior damage of single family house caused by the November 1970 typhoon in the Philippines.

Figure 2.9 Residential building in Darwin, Australia, destroyed by the December, 1974 cyclone.

Figure 2.10 Building of cavity wall construction in Darwin, Australia, partially destroyed by the December, 1974 cyclone.

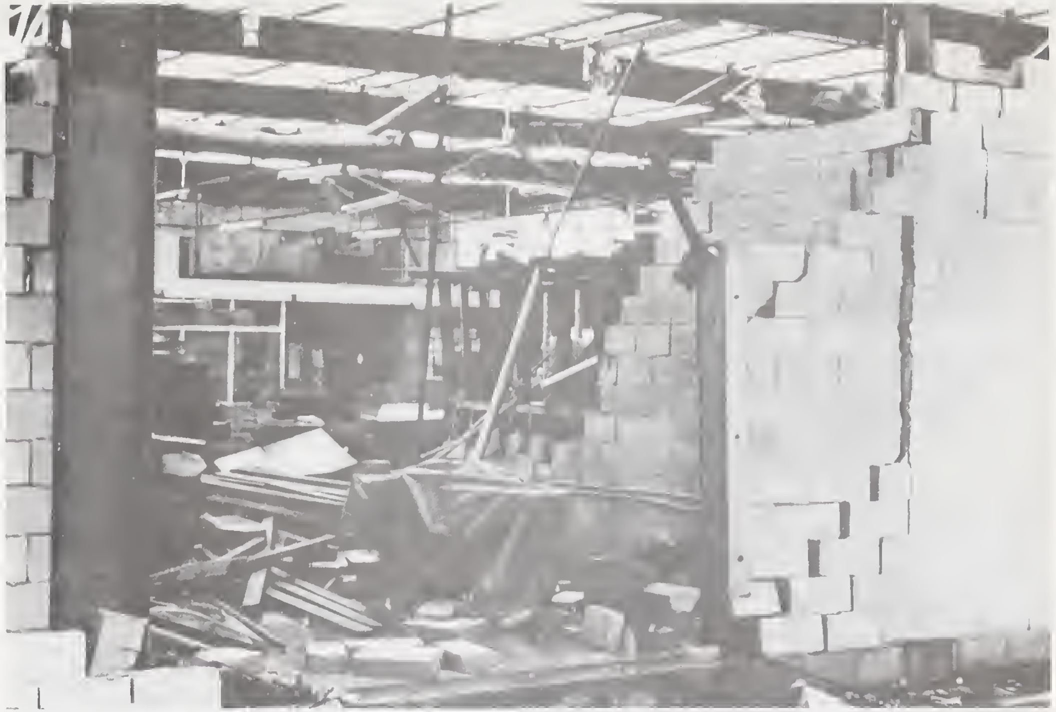


Figure 2.11 Building in Darwin, Australia showing partial collapse of roof and masonry infill walls caused by the December, 1974 cyclone.

Figure 2.12 Failure of concrete block masonry wall in building subjected to the December, 1974 cyclone in Darwin, Australia.

Figure 2.13 Single family masonry house under construction in Central Luzon, the Philippines.

Figure 2.14 Stacked bond concrete masonry wall construction for single family occupancy in Central Luzon, the Philippines.

Figure. 2.15 Single family housing development in Central Luzon, the Philippines.

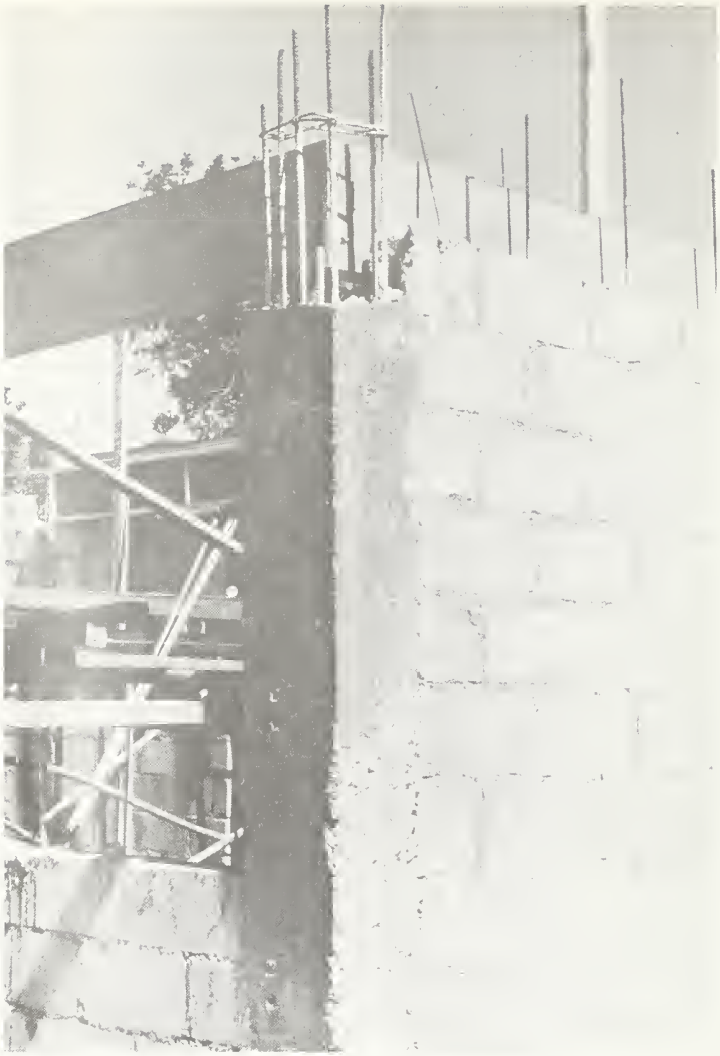


Figure 2.16 Concrete columns with concrete masonry infill walls being constructed for single family dwelling occupancy in Central Luzon, the Philippines.

Figure 2.17 Construction of single family housing unit in Central Luzon, the Philippines, showing concrete masonry filler walls and reinforcement of corner column.

Figure 2.18 Reinforced concrete masonry dwelling unit in Central Luzon, the Philippines.

Figure 2.19 Reinforced concrete masonry walls under construction for housing in Central Luzon, the Philippines.

Figure 2.20 Concrete masonry bearing wall construction with truss type roof for housing in Central Luzon, the Philippines.

Figure 2.21 Single family housing under construction in Central Luzon, the Philippines, showing concrete bond beam detail over openings.

Figure 2.22 CARE sponsored housing project near Dacca, Bangladesh showing cinvaram wall construction with corrugated metal roofing.

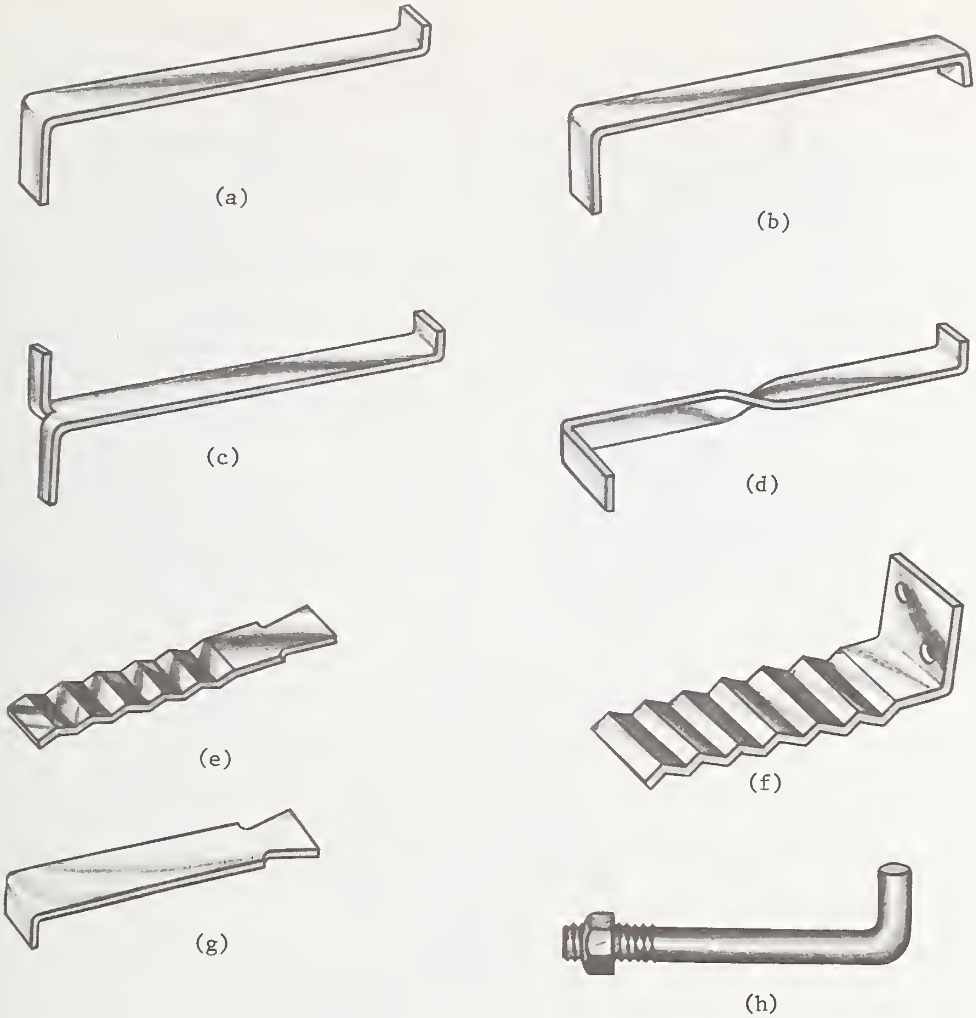


Figure 2.23 *Various metal anchors: (a), (b) tiebars with end hooks; (c) tiebar with hook and split hook; (d) tiebar with 90° twist; (e) corrugated dovetail tie; (f) corrugated tie; (g) dovetail tie with hook; (h) Anchor bolt.*

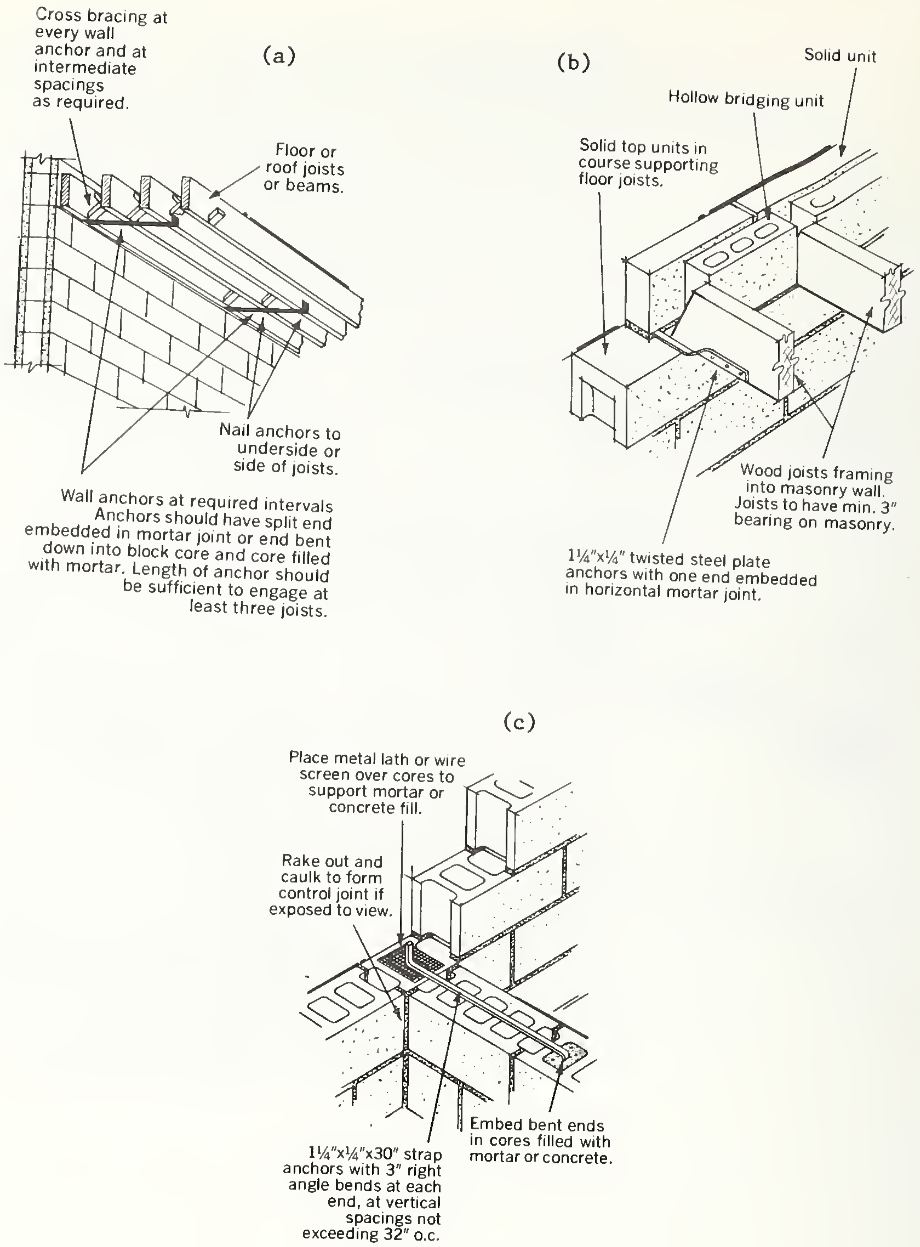
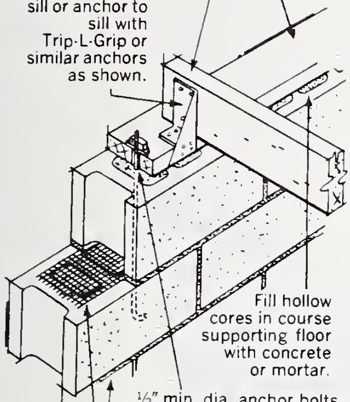
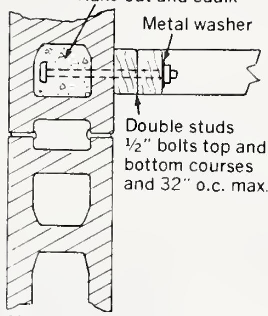


Figure 2.24 Application of metal anchors in masonry construction: (a) tiebar anchor to wood joists; (b) twisted anchor connecting wood joist to concrete masonry bearing wall; (c) tiebar anchor connecting concrete masonry intersecting walls.



(a)



(b)

Figure 2.25 Application of anchor bolt for masonry connection: (a) connection of sill plate to concrete masonry bearing wall; (b) connection of concrete masonry wall to wood stud wall.

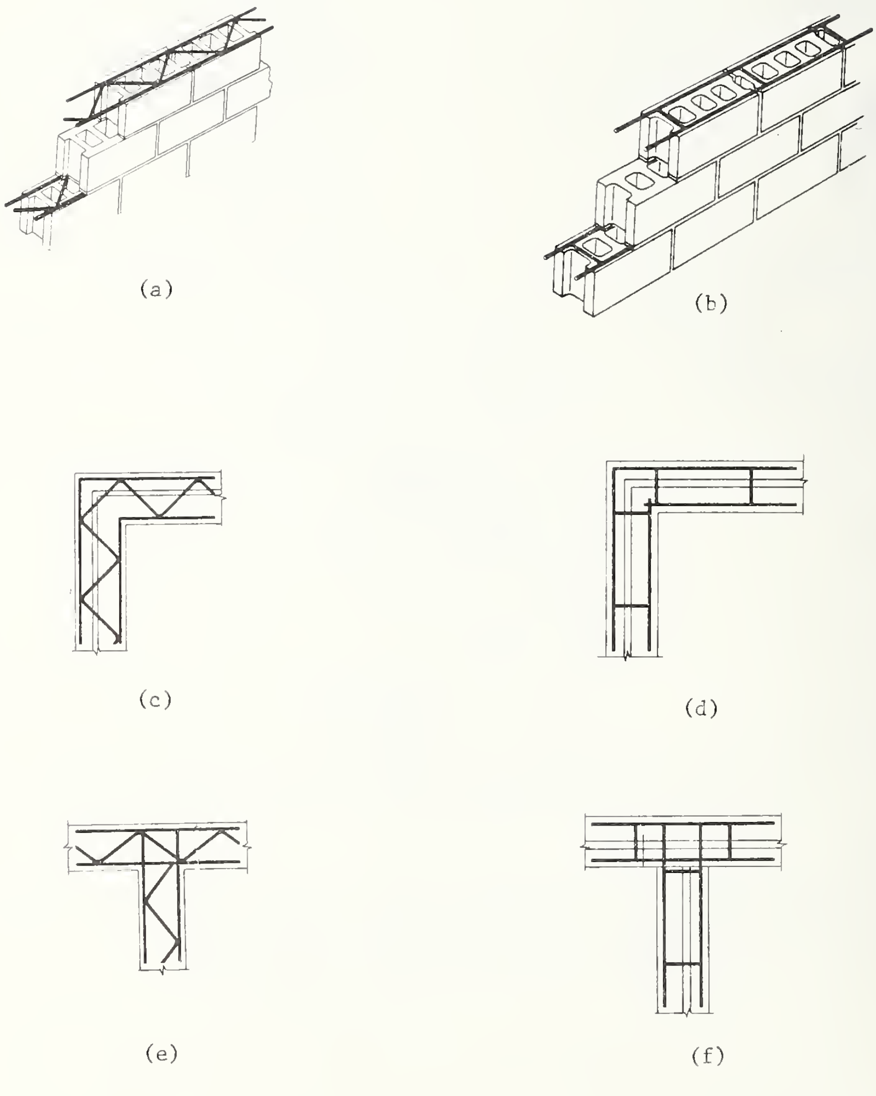


Figure 2.26 Joint reinforcement in masonry walls: (a) truss; (b) ladder; (c) and (d) prefabricated corner section; (e) and (f) prefricated tee section.

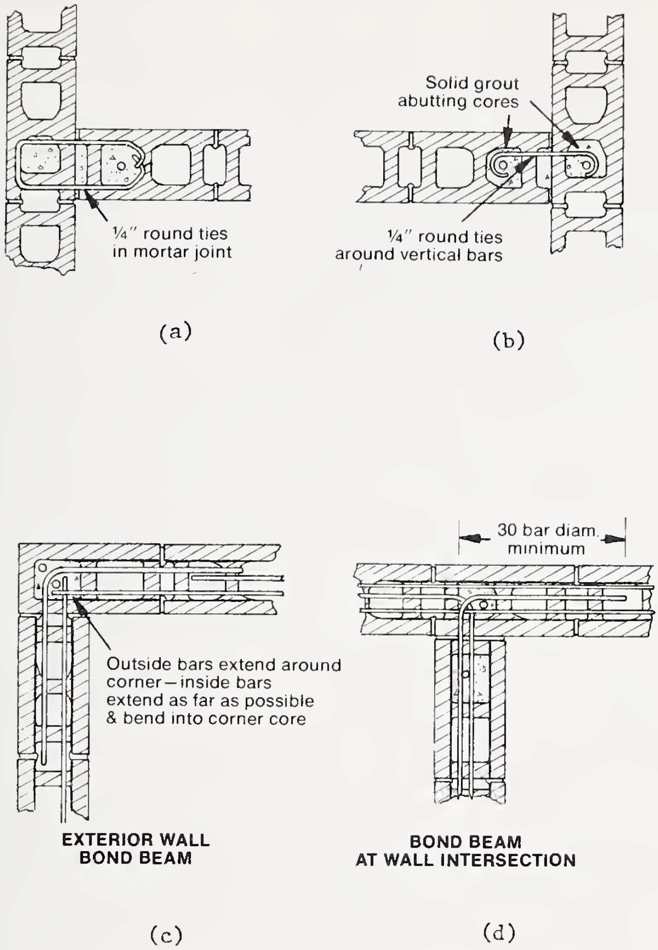


Figure 2.27 *Horizontal reinforcement between intersecting masonry walls: (a) and (b) without bond beams; (c) and (d) with bond beam.*

3. FASTENERS FOR TIMBER CONSTRUCTION IN HIGH WIND AREAS[4/]

by

G.E. Sherwood and T.L. Wilkinson[5/]

3.1 Introduction

Houses and other low-rise buildings in many tropical areas such as Jamaica, Bangladesh, and the Philippines are subject to extreme winds several times each year. Failures that occur in buildings or building elements of wood construction usually occur in the fasteners rather than in the structural members. Buildings that are adequately braced to resist racking forces, and have each element tied together from foundation to roofing, can resist high winds without structural failures. This section describes and provides sources for commercially available timber connectors, existing timber-related building practice in the Philippines, and identification of good and poor timber connector practice. It also presents recommended practice, including connectors that can be fabricated by the indigenous people.

3.2 Available Timber Fasteners

3.2.1 Nails, Screws, Bolts, and Lag Screws

These common mechanical fasteners for wood come in many varieties. A variety of nails is shown in figure 3.1. Some may be used for several purposes while others are intended for special purposes.

In general, nails resist or transmit smaller loads than screws, and screws resist or transmit smaller loads than bolts or lag screws. However, because of their smaller size, more nails can usually be used in a joint. A good source of information of the design of joints with such fasteners is the National Design Sepcification for Stress-Grade Lumber and Its Fastenings by the National Forest Products Association [47].

There are a large number of manufacturers of such fasteners. The best source for obtaining names of manufacturers is the Thomas Register of American Manufacturers and Thomas Register Catalog File [26].

4/ This work was done in cooperation with the National Bureau of Standards, U.S. Department of Commerce, Washington, D.C.

5/ Messrs G.E. Sherwood and T.L. Wilkinson are engineers with the Forest Products Laboratory, Forest Service, U.S. Department of Agriculture, maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

These manufacturers can provide catalogs which describe the fasteners they manufacture along with the intended purpose for each.

3.2.2 Timber Connectors

Timber connectors generally refer to split rings, shear plates, and toothed rings (figures 3.2, 3.3 and 3.4). These are intended primarily for heavy timber (members larger than 4 inches in thickness) construction and usually result in bulky joints. Special tools and skills are needed for properly constructed timber connector joints.

Split rings and toothed rings are used for wood-to-wood joints, and shear plates are used for wood-to-steel joints, and sometimes for wood-to-wood joints. Proper joint design procedures and loads can be found in ref. [47].

Manufacturers of timber connectors as listed in Thomas Register are as follows:

(1) Simpson Company
1472 Doolittle Drive
San Leandro, California 94577

(2) Woodmack Products, Inc.
852 Aldo Avenue
Santa Clara, California 95050

(3) Timber Engineering Company
5530 Wisconsin Avenue
Washington, D.C. 20015

(4) Kees, F.D., Manufacturing Company
21 High Street
Beatrice, Nebraska 68310

(5) Cleveland Steel Specialty Company
14442 Industrial Avenue, South
Cleveland, Ohio 43228

3.2.3 Truss Plates

These fasteners are made of galvanized sheet metal, usually 20 gage, intended primarily for use as gussets for light timber (members 2 inches thick) trusses. The plates may be obtained in many sizes of rectangular shape. Their means of transferring load vary from the use of nails in punched holes, plugs or barbs of different shapes, to teeth of different shapes and lengths. Figure 3.5 shows some typical plates.

Procedures for designing with these plates are presented in Design Specifications for Light Metal Plate Connected Wood Trusses by the Truss Plate Institute [48]. This publication also lists 11 manufacturers which are members of the Truss Plate Institute.

Detailed description of the plates and design loads can be obtained from the manufacturers.

3.2.4 Sheet Metal Fasteners and Other Special Devices

These fasteners include such items as joist and beam hangers, framing anchors, rafter anchors, post anchors, etc., (figure 3.6), which are made of galvanized sheet metal and which require fastening to the framing with nails or screws.

A Good reference for descriptions and specifications of these fasteners is Products in Action by the Timber Engineering Company [49].

Some of the manufacturers of truss plates also make certain types of special fasteners for use in framing applications.

3.3 Philippine Timber-Related Practices

Timber-related building practices in the Philippines can be divided into three general categories:

(1) Pole-type construction in which poles are set into the ground to serve as foundation and extend to the roof (figure 3.7).

(2) Concrete slab, perimeter, or pier foundation of concrete or masonry with wall and roof framing of wood (figure 3.8).

(3) Concrete slab or perimeter foundation supporting masonry or poured concrete walls, and a wood-frame roof (figure 3.9).

3.3.1 Pole Type

This type of construction is well suited to highwind areas because the major structural member, the pole, serves as the connecting link between all other structural members. If the poles are set 4 feet or more into the ground, they serve as anchors for the building. For long life, all poles must be pressure treated for resistance to decay and insect attack.

Roof-framing members are either round or sawn timbers. In remote areas, they may be tied together with strips of bamboo (figure 3.10). This type of connector appears to provide good resistance to wind forces. Nailing is also effective if nails are loaded laterally rather than in direct withdrawal.

Covering materials for this type of construction are often thatch roofs and walls of thatch or bamboo. There appears to be no way to assure anchorage of thatch during high winds (figure 3.11). Wood siding nailed to framing members offers good resistance to wind, but nails should be corrosion resistant.

3.3.2 Wood-Framed Wall and Roof

Wood-framed walls often have a single covering material. It may be applied to the exterior of the building or set between framing members. Anchor bolts are used to tie the wall to the foundation. Where the foundation is concrete block, the anchor bolt should extend through blocks into the footing. If the house is anchored only to the top concrete block, this block may be pulled from the foundation and moved with the house.

Covering material applied on the outside of the framing (fig. 3.12) protects the wall framing and connectors from rain. Walls with the covering set into the framing have a greater potential for trapping water, and thus promoting decay. Anchor bolts on the outside of the wall are particularly susceptible to trapping water (fig. 3.13). They can easily be placed on the inside for protection. The type of sill plate shown in figure 3.13 also traps water. The sill plate should at least be sloped to the outside so water will drain from it, and the joint with panel materials should be caulked.

Roof framing is either nailed to the top of the wall or secured with sheet metal connectors. Good nailing should hold down the roof framing, but sheet metal connectors provide a stronger joint and have less chance of being improperly nailed.

3.3.3 Masonry Wall

One method of tying roof framing to a masonry wall is to pour reinforced-concrete columns at all corners and at intermediate locations on long walls. Reinforcement is tied to the foundation and extends above the columns so that it can be attached to a wood beam which extends completely around the perimeter of the house on top of the masonry wall. Trusses are sometimes anchored to this beam by metal straps nailed to both members. The metal strap has a 90° twist at its center which weakens it and allows the nails to be pulled out when anything but a direct uplift force is exerted on the strap (fig. 14).

A sheet metal connector that can be nailed to both sides of the rafter and beam would prevent the type of failure caused by rotation in the single, heavy strap.

3.3.4 Roof Framing

Framing for the roof of any of the types of structures involves use of either trusses or a rafter-and-joist system. Trusses are fabricated with metal plate connectors or bolted joints. In some larger structures, split-ring connectors are used. Trusses generally are made from an engineered design and under controlled conditions, so they have less potential for failure than the conventional rafter-and-joist system.

Where rafters are used, some type of collar tie is important to keep the roof from dividing at the peak (fig. 3.15). Ceiling joists, well nailed or bolted to rafters, prevent the roof from spreading outward (fig. 3.16).

Purlins are connected to rafters or trusses in several ways. Nailed joints are among the most vulnerable because in this application the nail is loaded in direct withdrawal. Short 2 by 2's nailed to the purlin and the rafter (fig.3.16) provide a stronger joint by loading the nails laterally.

3.3.5 Roofing

The major roofing material in the Philippines is corrugated sheet metal. One method of tying roofing to purlins is the use of sheet metal straps (fig. 3.17). One end of the strap is bent at a 90° angle, and that bent portion is riveted to the roofing. The strap is nailed to the side of the purlin and bent under the purlin. The attachment of the strap to only one side of the purlin results in an unsymmetrical load so the strap can be twisted off by wind forces. Two straps riveted to the roofing on both sides of the purlin and lapped under the purlin, would resist forces due to moment in the connector.

Figure 3.18 illustrates the effectiveness of having tiedowns symmetrically loaded. A wire was tied to a nail in the bottom of the purlin, punched through the roofing, wrapped over the purlin, and tied back to the nail. This tie held well enough that the purlin-to-rafter connection failed before the roofing connector. However, roof leakage may be a problem.

3.3.6 Protection From Wood-Destroying Organisms

A key element of good performance of timber connectors is maintenance of the strength properties of the wood. In many cases where failures have occurred, some deterioration of the wood is evident (fig. 3.19). Staining is prevalent around many nails and bolts (fig. 3.20), which reduces decay resistance of the wood. Corrosion of nails also results in loss of cross section which loosens the nails. In such a humid environment, all connectors should be corrosion resistant.

3.3.7 Summary of Good and Poor Practices

Design, construction, and maintenance practices are summarized below:

Good Design Practices

Design the building to act as a unit by connecting all components together and anchoring the whole structure to the foundation. Design joints to resist torsion as well as uplift even where it means using connectors in pairs.

Good Construction Practices

The use of engineered trusses fabricated under good quality control assures structural integrity of the roof framing. Where trusses are not used, collar beams and ceiling joists must be nailed or bolted to the rafters. Sheet metal connectors provide better quality control at joints than nails alone.

Pole framing offers a good way of tying componenets together because all major structural members are connected to the poles. In masonry construction, a reinforcing rod extending from the footing to the roof provides the required continuous tie.

Good Maintenance Practices

All connectors should be corrosion resistant. Locate connectors where they are protected from rain, and avoid exposed joints which trap water.

Poor Design Practices

Loads should not be concentrated in a small number of connectors. Connectors applied to only one side of a member can often be twisted off because they have little resistance to torsional loads.

Poor Construction Practices

Nails loaded in direct withdrawal offer less resistance than laterally loaded nails. Roof framing that is anchored only to the top course of a block wall may blow off taking the blocks with it.

Poor Maintenance Practices

The use of connectors that are not corrosion resistant is poor practice in a humid location. Exposure of connectors to rain provides a place for water to enter the wood and promote decay. Horizontal members exposed as exterior elements form water traps which can lead to decay.

3.4 Timber Fasteners Appropriate for Construction in Developing Areas With High Winds

3.4.1 Pole-Type Construction

Where poles are set in the ground to serve as the main vertical framing, major floor and roof framing securely attached to the poles assures the structural integrity of the building. Round framing members commonly used for indigenous type of construction have been successfully tied to the poles with strips of bamboo (fig. 1.3). Sawn timbers should be bolted to the poles using 3/4-in or larger bolts, depending on the load. If round poles are used with sawn timber framing, notching the pole to provide a wider bearing surface (fig. 3.21) may be necessary, especially where two members meet end-to-end (fig. 3.22).

Siding materials may be boards nailed directly to the framing. Corrosion-resistant nails are particularly important for this application. Indigenous-type construction often employs walls of bamboo or thatch. These coverings have served well in many applications, but are difficult to secure in extreme winds.

3.4.2 Light Wood-Frame Construction

The wood-frame must not only be anchored to the foundation at its base, but must also provide a continuous tie from the foundation to the roof. Anchorage of wall framing to a concrete foundation may be accomplished with hooked bolts embedded 8 to 12 inches in the concrete. A large washer should be used under the nut to spread the load on the wood framing (fig. 3.23). Where the foundation is concrete block, the anchor bolt should extend through the block and be anchored in the concrete footing (fig. 3.24). The exposed end of the anchor bolt should be protected from weather. Were a single covering material is set into framing, the bolt should be placed on the protected side of the covering material (fig. 3.25).

The wall must be tied together as well as anchored. Panel-type covering material nailed to the anchored sill and to the top plate provides this continuous tie. Panel material nailed to framing completely around its perimeter also provides racking resistance in the wall. Where siding does not provide such a tie, sheet metal straps can be used as connectors between plates and vertical framing (fig. 3.26).

Roof framing is effectively tied to walls with sheet metal brackets (fig. 3.27) or wood cleats (fig. 3.28). Where a ceiling joist-and-rafter system is used, sheet metal straps nailed to joists and studs (fig. 3.29) provide a good tiedown for roof framing. In this method, the rafter must be well nailed to the ceiling joists.

3.4.3 Concrete and Masonry Construction

Poured concrete posts at corners and intermediate locations in concrete block walls provide tiedown points for roof framing. Wood plated can be tied down to hooked bolts in the poured concrete posts or walls. This is the same type of connector shown in figure 3.23. Roof framing can then be attached to the anchored plate by sheet-metal brackets or wood cleats as shown in figure 3.27 and 3.28.

3.4.4 Roof Framing

Trusses may be used for roof framing for any of the types of construction that have been discussed. Connectors may be metal plates for light construction or split-rings for heavy construction. Split-rings that are tapered in cross section and wedged into place have the highest load-carrying capacity.

3.4.5 Roofing

Thatch roofs are often used for indigenous construction. The thatch is tied to small poles which are laid on the roof in courses with each course overlapping the one below. Poles are secured by tying them to roof framing with bamboo strips which provide good resistance to wind loads. However, the thatch itself may blow off in extreme winds.

The predominant roofing material is corrugated, galvanized sheet metal. The usual roof system consists of purlins (sometimes referred to as roof joists) spanning between rafters or trusses, and roofing attached to these purlins. The purlins should be tied to rafters with sheet metal brackets (fig. 3.30) or with wood cleats (fig. 3.31). In either case the tiedowns should be attachable to both sides of the purlin and rafter, so they cannot be twisted off by loads that are not perpendicular to the purlins.

Corrugated roofing is best affixed by a fastener that wraps completely around the purlin. Two sheet metal straps lapped under the purlin and riveted to the corrugated roofing on each side of the purlin (fig. 3.32) provide a good connector system that will resist moment loads which cause failure when a strap is used on only one side.

3.5 Fasteners for Fabrication by Indigenous People

Any of the sheet metal straps could be easily fabricated with a minimum of tools. A minimum thickness of 20-gage galvanized sheet metal should be used. A width of 1-1/4 inches and a length of 20 inches would be suitable for many applications (fig. 3.33). It may be necessary to vary this size for specific applications.

Galvanized strap could be fabricated for roofing tiedowns. This strap should be only about 6 inches long, bent at 90° 1 inch from one end, and have a 1/4-in hole punched in the 1-in section (fig. 3.34). These straps should be used only in pairs on opposite sides of a purlin. The ends of the straps should be bent under the purlin with the two straps lapped and nailed to the bottom as well as sides of the purlin.

A multipurpose bracket could be fabricated from 20gage galvanized steel. A suggested size is given in figure 3.35; however, this could be varied for other standard sizes of wood framing. Slits cut in the sheet metal permit forming the bracket for a variety of uses.

Split-ring connectors have been fabricated by cutting 3/4-in wide sections from 3-in steel pipe, and then cutting the ring at an angle. This connector and present commercially produced split-ring connectors are shown in figure 3.36. For maximum strength the ring should be wedged tightly into the circular groove cut in the wood. Present commercial split-rings cut from steel pipe should have good load-carrying capacity even though its capacity would be somewhat less than the tapered ring.

Metal plate connectors for truss joints is another possibility for fabrication by indigenous people. These are usually fabricated from 20-gage galvanized sheet metal. The sheet metal is punched in a way that produces barbs or teeth at right angles to the plate. Plates with barbs punched in the pattern shown in figure 37 generally do not maintain optimum strength after expansion and contraction of the wood with moisture changes over a long period of time. Plates with teeth that penetrate deeper than barbs are less affected by moisture cycling of the wood.

3.6 Summary

Wind-resistant construction for wood-frame buildings in developing countries can be achieved by providing good connectors between all members from foundation to roofing. All connectors should be corrosion resistant and protected from rain where possible. Connectors should be designed to resist being twisted off. Where nails are used, connectors should be a type that load the nails laterally rather than in direct withdrawal.

Sheet metal straps and brackets could easily be fabricated by indigenous people in developing countries. Such connectors could be fabricated using a minimum of tools and equipment.

3.7 A Caution

In present tropical cnstruction, the most frequent failure caused by high winds is the loss of roofs. It should be recognized that improved design which holds the roof securely will ultimately result in the concentration of greater loads in other parts of the building. Details of wall construction and anchorage to the foundation which have been adequate when the roof failure relieved the total load on the building, may not be adequate when the roof remains intact. The building will be subjected to a large overturning moment as well as to uplift load on walls.

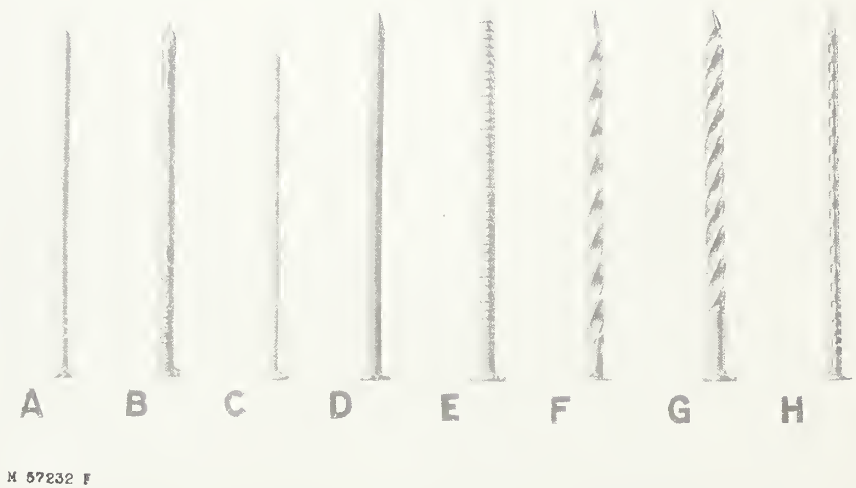


Figure 3.1 *Various types of nails: A, bright, smooth wire nail; B, cement-coated; C, zinc-coated; D, chemically etched; E, annularly threaded; F, helically threaded; G, helically threaded and barbed; and H, barbed.*

Figure 3.2 Joint with split-ring connector showing connector, precut groove, bolt, washer, and nut.

Figure 3.3 Joint with toothed-ring connector.

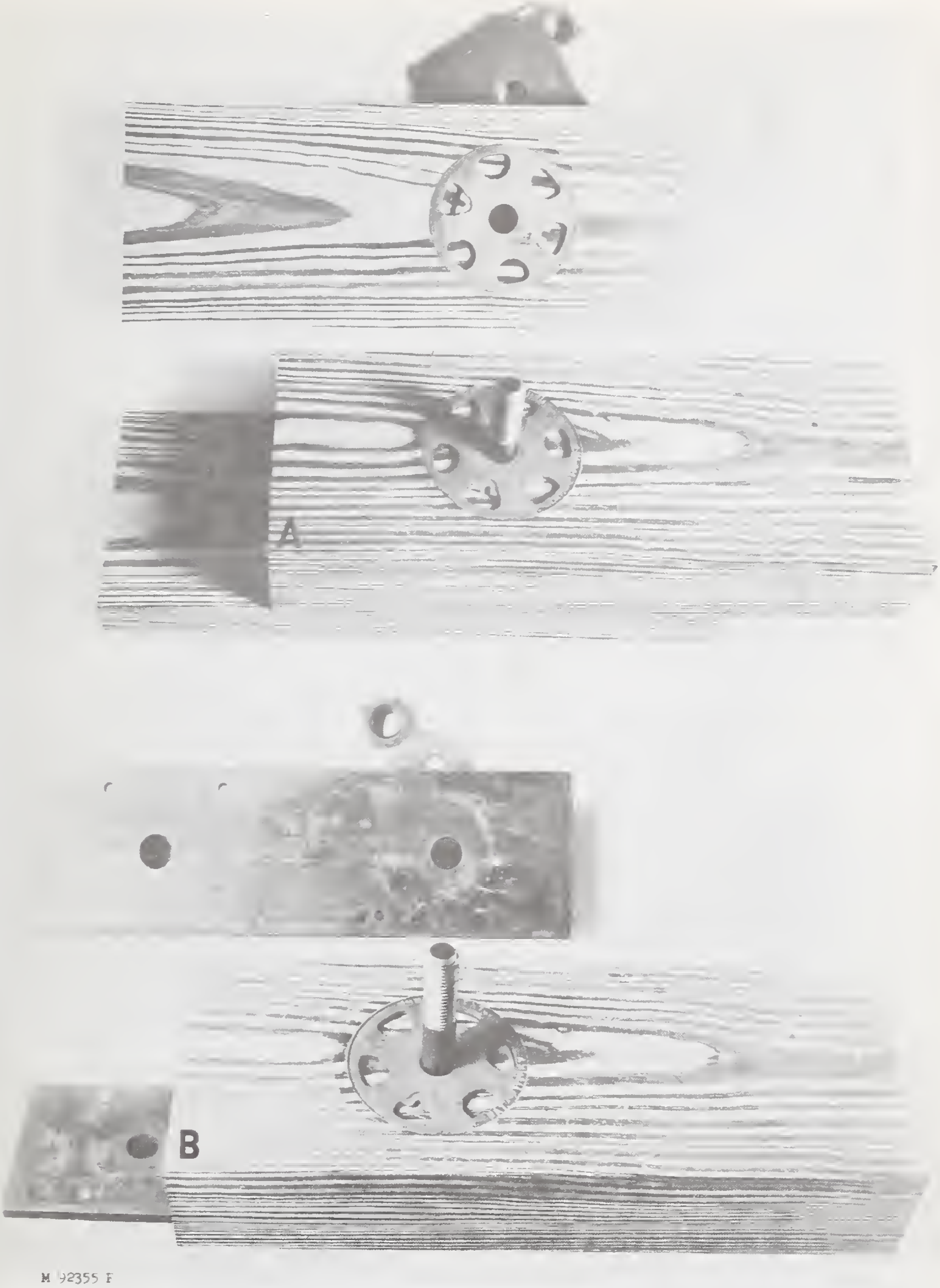


Figure 3.4 Joints with shear-plate connectors with A, wood side plates; and B, steel side plates.

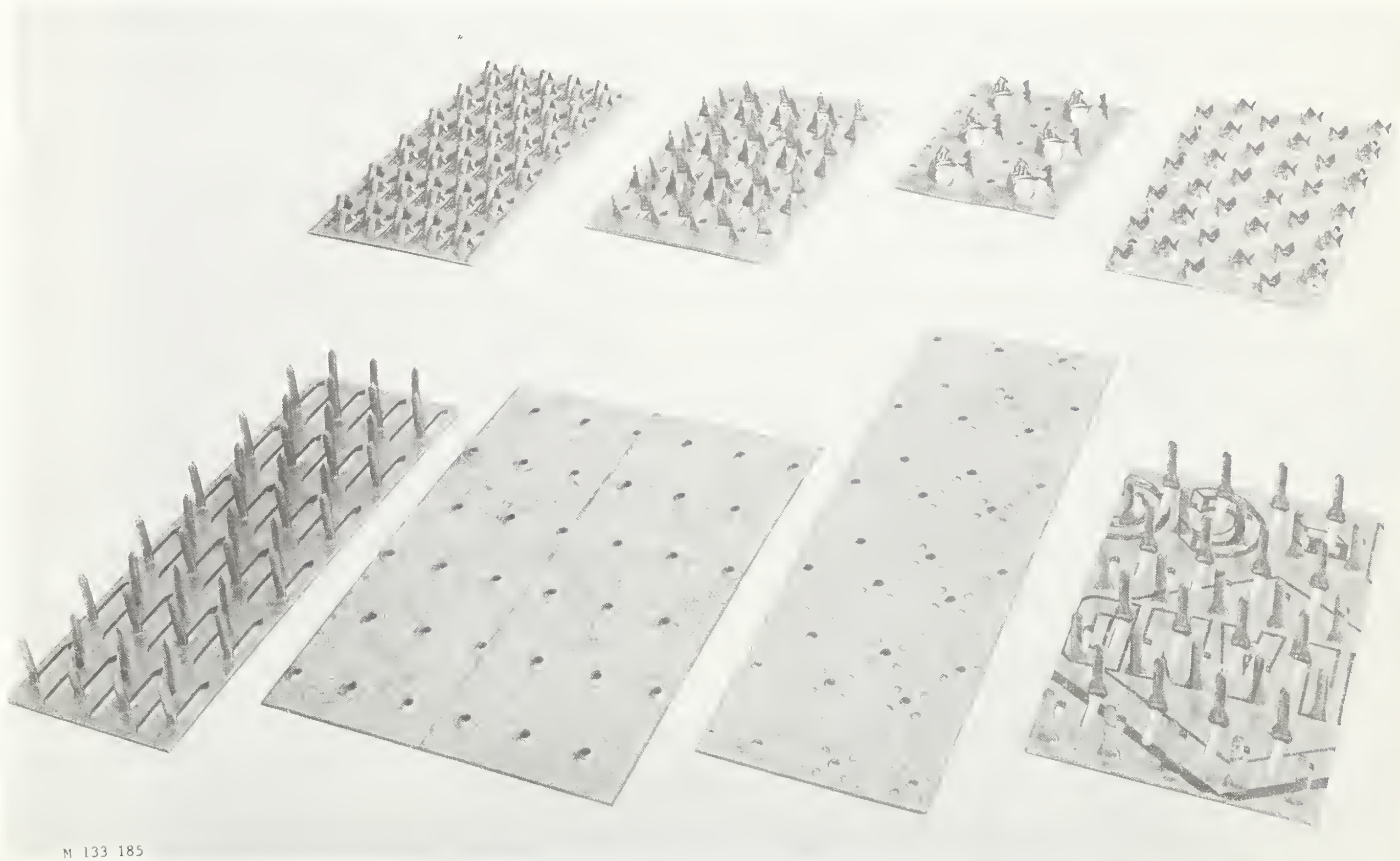


Figure 3.5 Some typical truss plates.

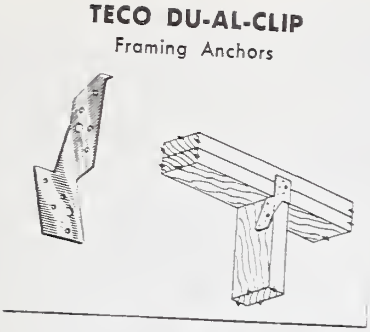


Figure 3.6 Some examples of special fasteners made by the Timber Engineering Company.

Figure 3.7 Pole-type construction.

Figure 3.8 Wood-frame wall and roof.

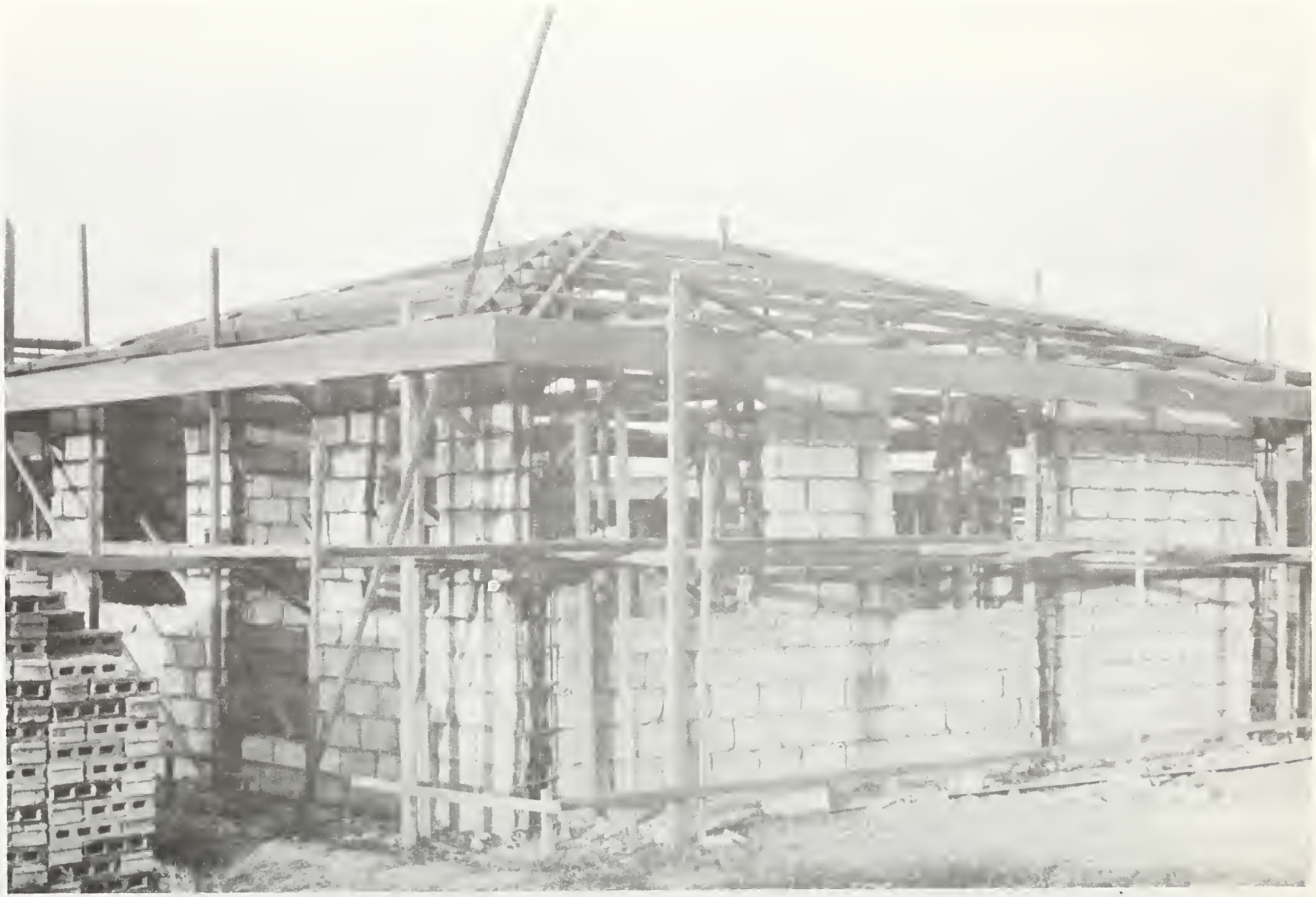


Figure 3.9 Concrete block wall with wood frame roof.

Figure 3.10 Roof framing tied down with strips of bamboo.

Figure 3.11 Thatch roof with thatch partially blown off.

Figure 3.12 Covering material on the outside protects framing and connectors.

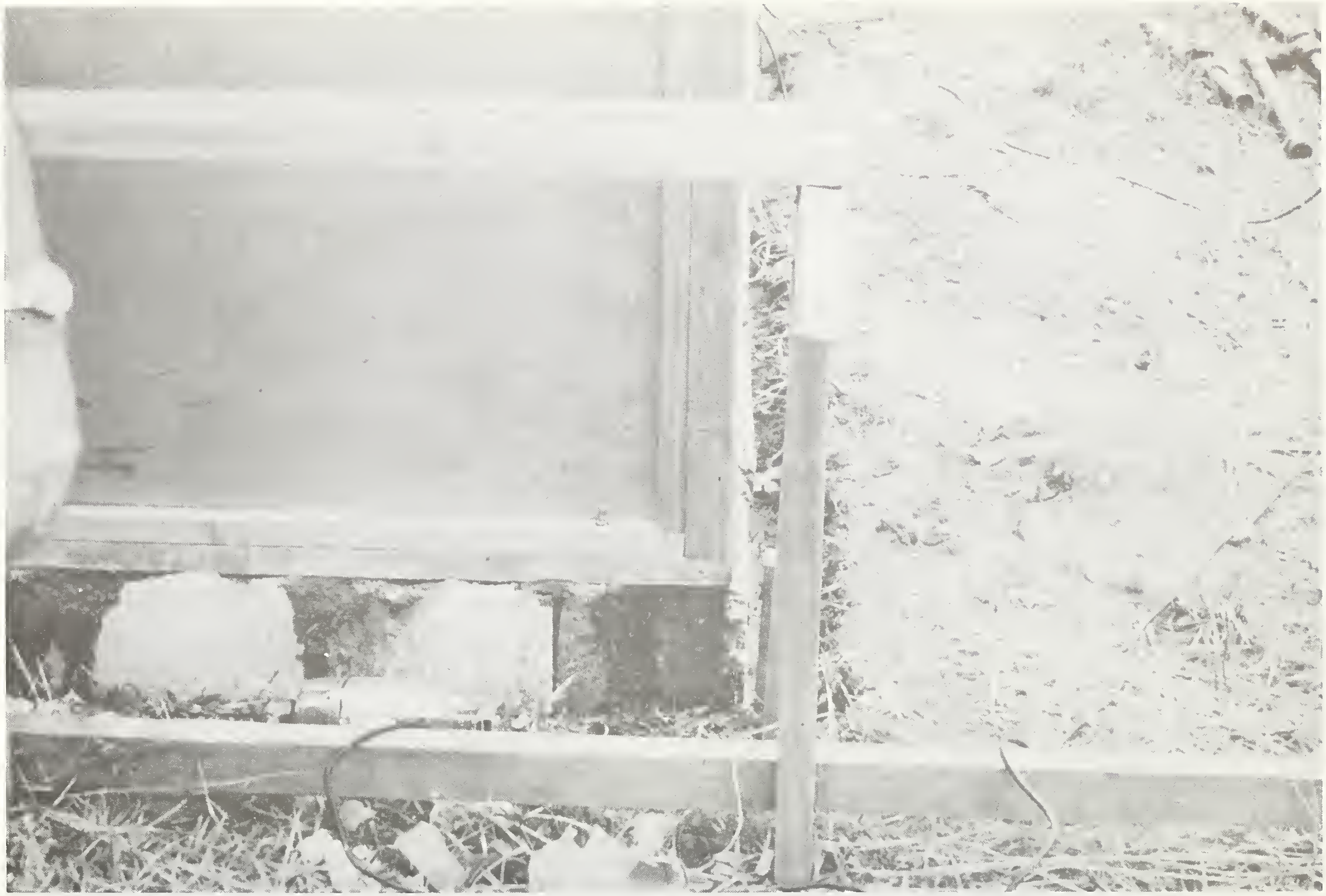


Figure 3.13 Anchor bolt and sill plate exposed to weather present decays hazards.

Figure 3.14 Metal strap on only one side of framing failed to resist bending load.

Figure 3.15 Collar ties hold rafters from pulling apart at the peak.

Figure 3.16 Ceiling joist bolted to rafter resists outward thrust of rafter. Wood cleats tie purlins to rafters.

Figure 3.17 Sheet metal strap nailed to one side of purlin and riveted to corrugated roofing.

Figure 3.18 Although the roof blew off of the structure, the corrugated roofing was effectively tied to purlins by wires completely around the purlins.

Figure 3.19 Joint failure due to decay in wood.

Figure 3.20 Staining from corrosion of bolts and nails.

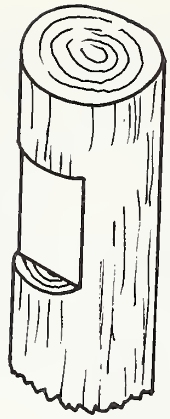


Figure 3.21 Round pole notched for sawn framing member.

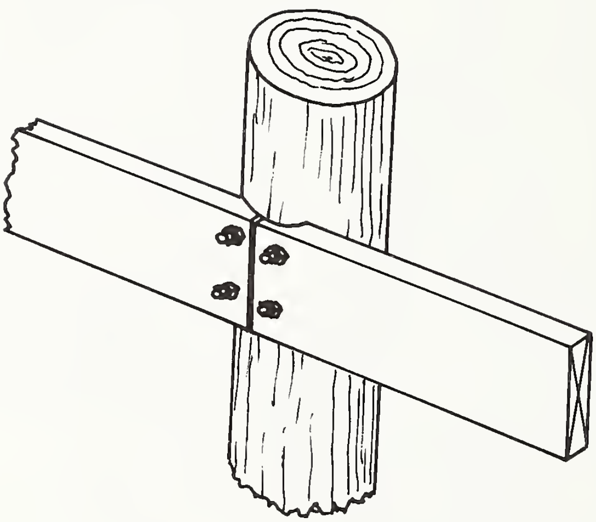


Figure 3.22 Two framing members butted end-to-end over flat notch and bolted to a pole.

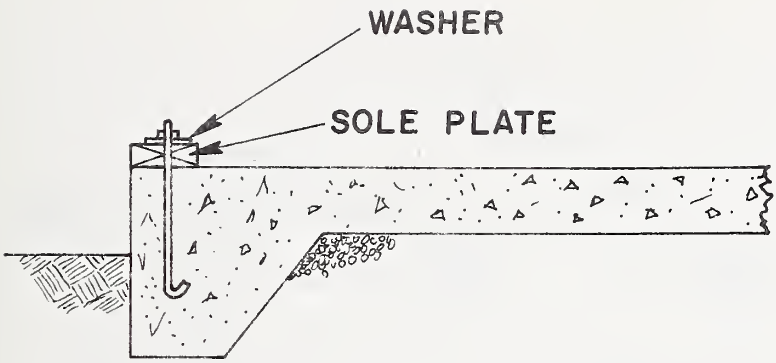


Figure 3.23 Anchor bolt in concrete a minimum of 8 inches. Washer to spread load.

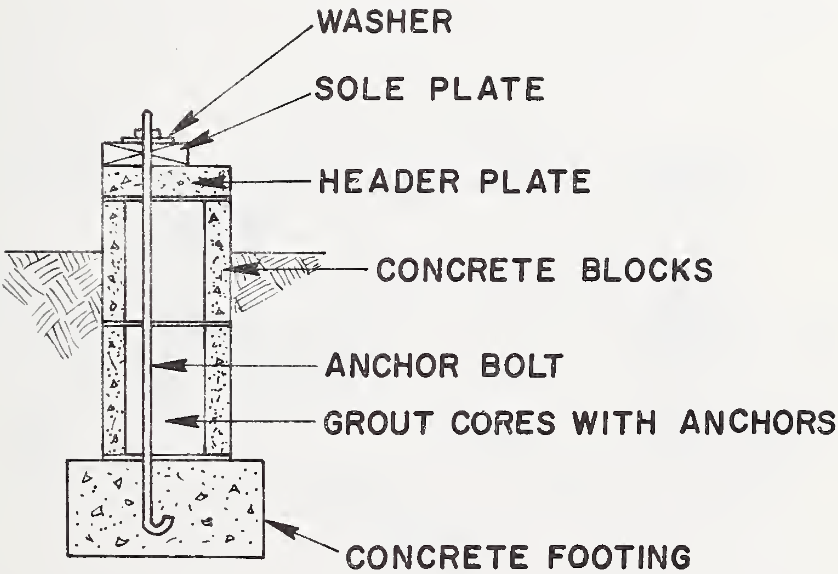


Figure 3.24 Anchor bolt through concrete block foundation into footing.

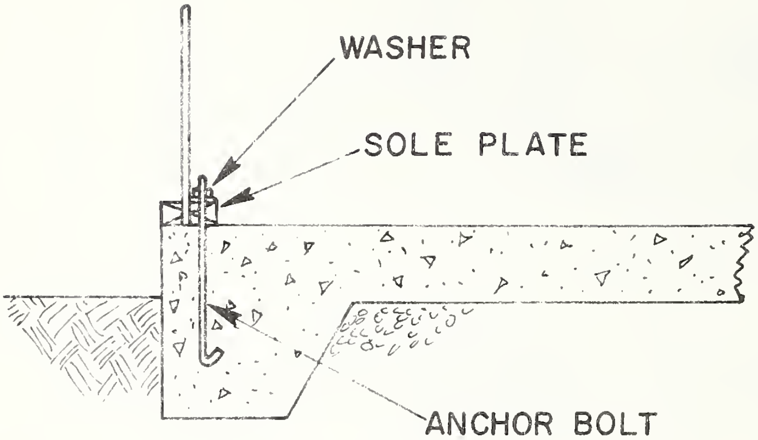


Figure 3.25 Anchor bolt installed on protected side of wall.

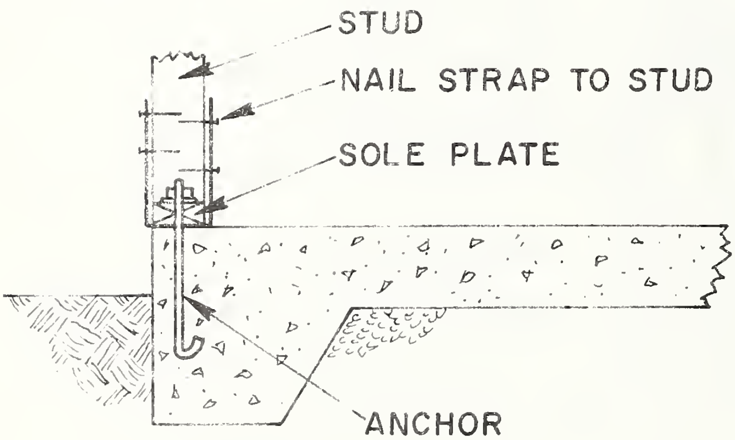


Figure 3.26 Sheet metal strap tying stud to bottom plate.

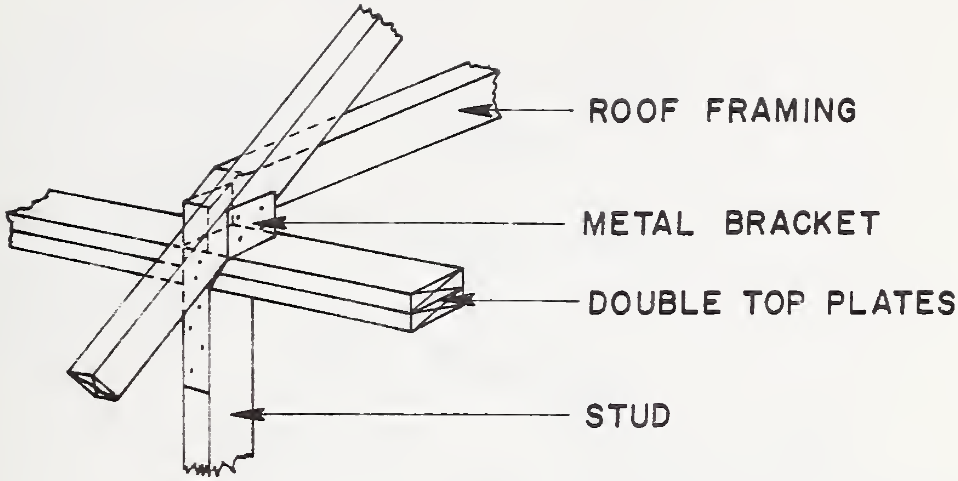


Figure 3.27 Sheet metal bracket for tying roof framing to walls.

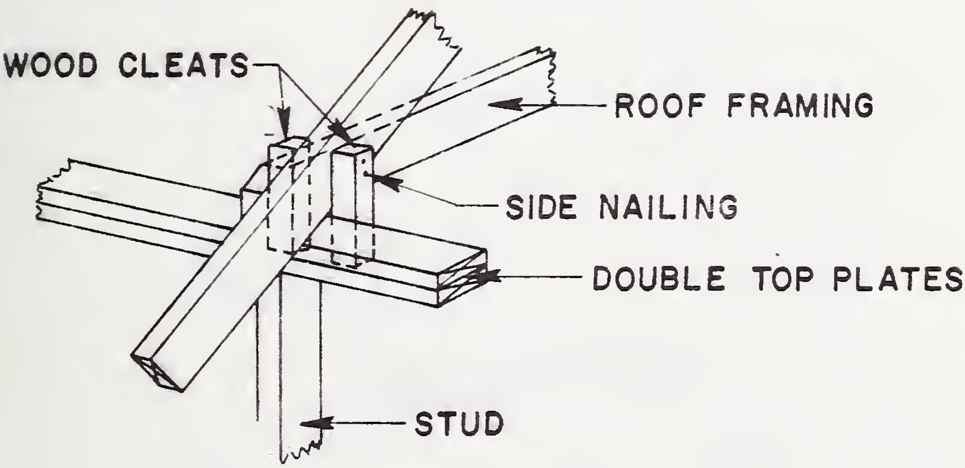


Figure 3.28 Wood cleats nailed to each side of roof framing and to top plates.

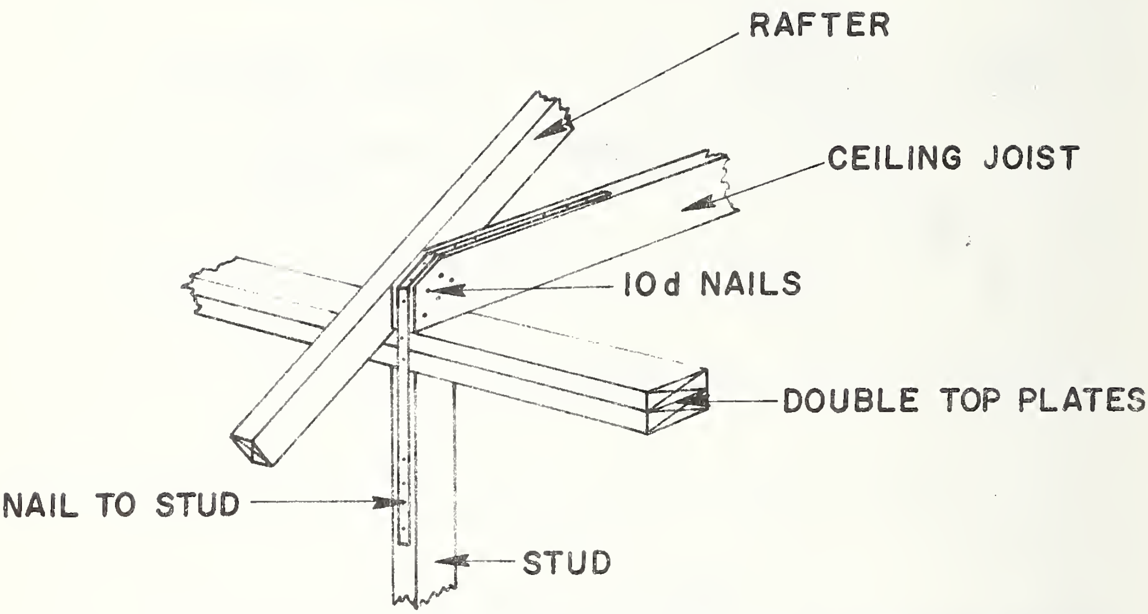


Figure 3.29 Sheet metal strap nailed to ceiling joist and stud to anchor roof framing to wall.

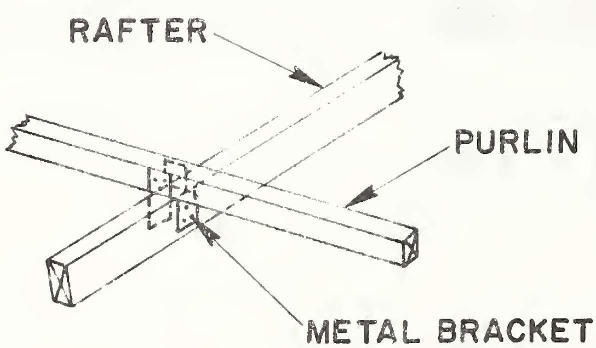


Figure 3.30 Sheet metal bracket used to connect purlin to rafter.

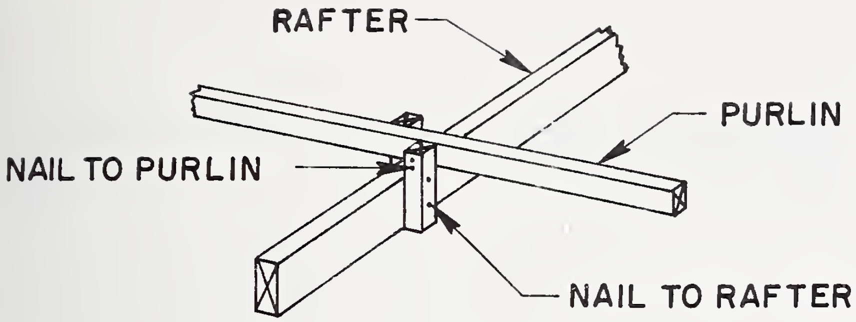


Figure 3.31 Purlins tied to rafters by wood cleats.

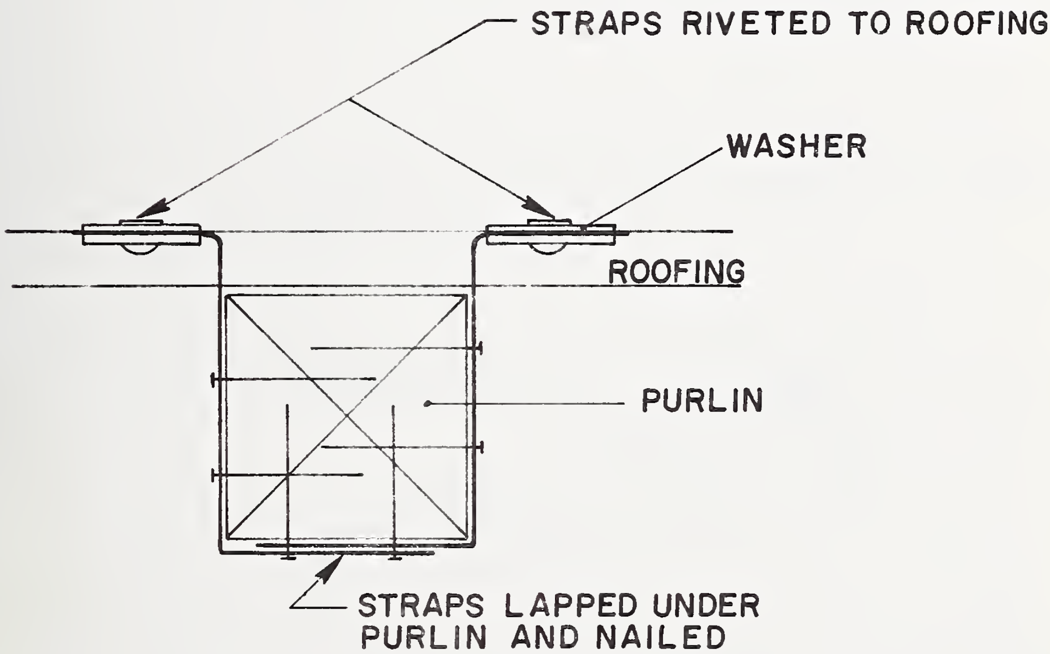


Figure 3.32 Two metal straps riveted to corrugated roofing, lapped under purlin and nailed to purlin.

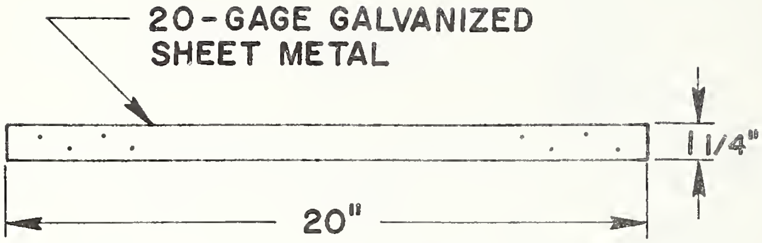


Figure 3.33 Multipurpose strap. Length and width can be varied for specific applications.

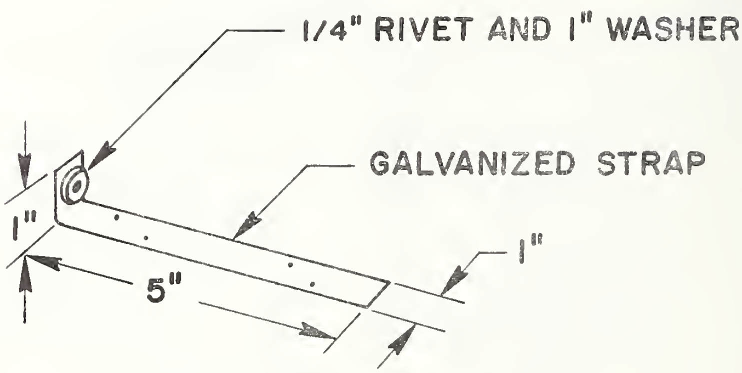


Figure 3.34 Galvanized sheet metal strap with rivet and washer for tying down corrugated roofing.

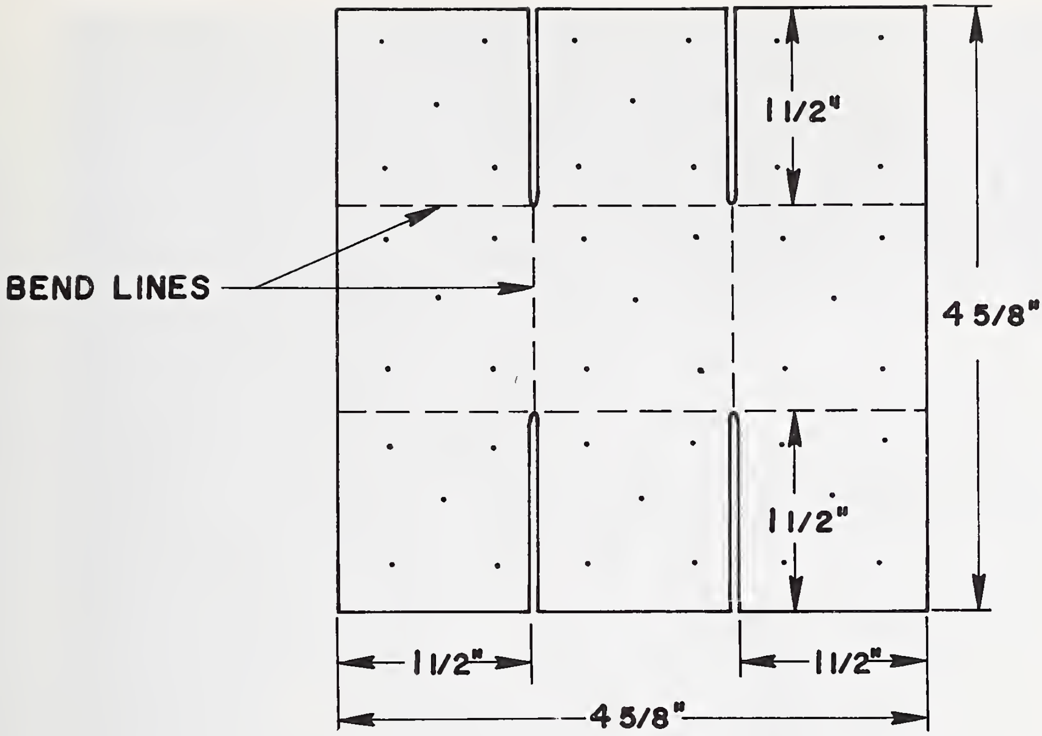


Figure 3.35 Multipurpose bracket fabricated from 20-gage galvanized steel. Bend either direction at bend lines to form desired bracket.

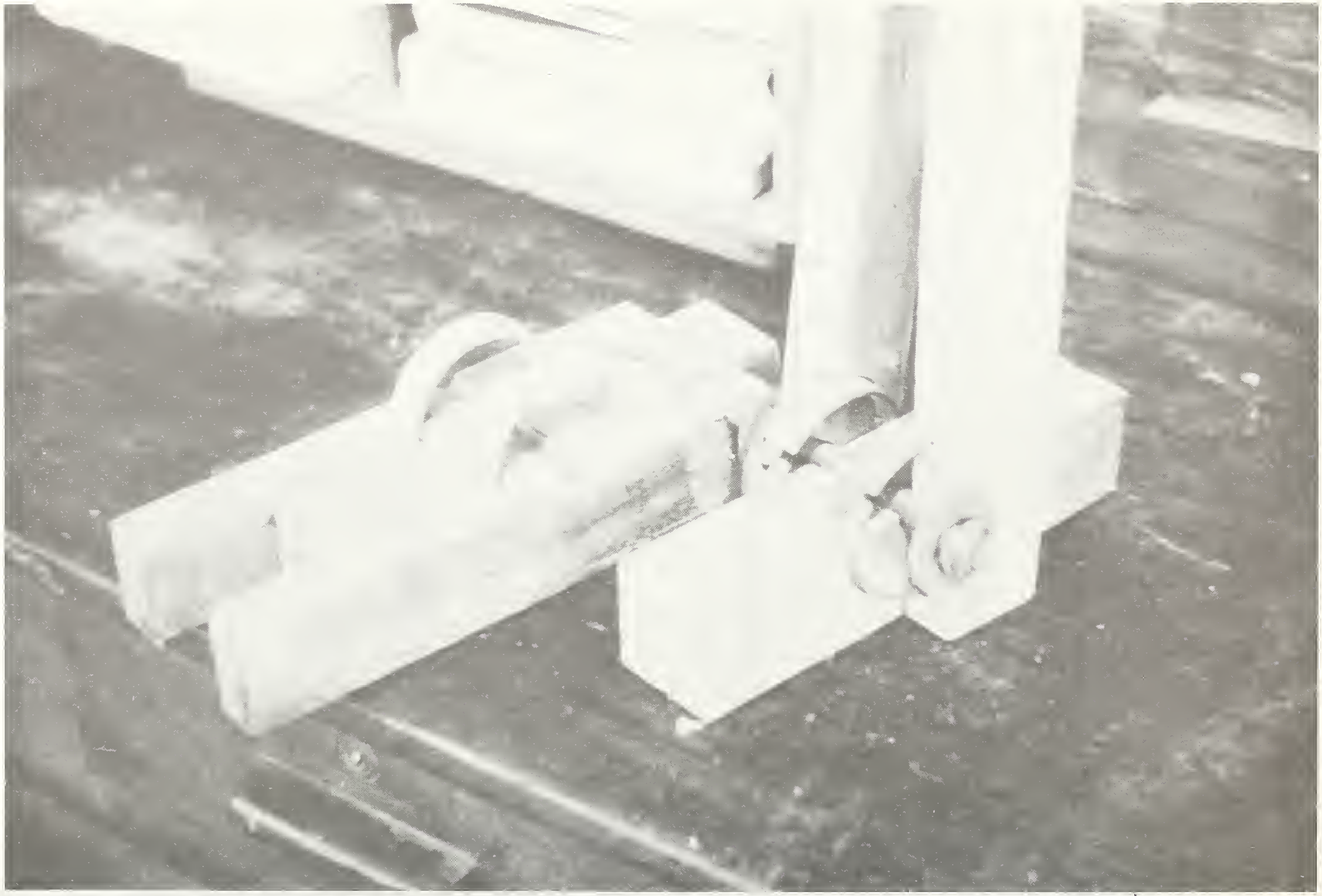


Figure 3.36 Split-ring connector for indigenous fabrication (left), and commercially produced split-ring connector (right).

Figure 3.37 Plate connector with barbs.

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APPENDIX G

The Economics of Building Needs:

A Methodological Guide

THE ECONOMICS OF HOUSING NEEDS:

A METHODOLOGICAL GUIDE

by

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Report Presented at Regional Meeting On Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds

PREFACE

This study was conducted by the Building Economics Section to demonstrate the application of economic analysis to the determination of housing needs. Dr. Harold Marshall and Ms. Rosalie Ruegg of the Building Economics Section and Dr. Carl Muehlhause of the Institute for Applied Technology provided constructive reviews of this paper. Mr. Noel Raufaste, project coordinator of the Center for Building Technology's project to develop design criteria and methodologies for low-rise/low-cost buildings to better resist extreme winds (of which this paper is one input), provided valuable editorial assistance. Those errors which remain are, of course, my responsibility.

ABSTRACT

Housing is probably the single most important consumer good in most economies. Measuring the size of a region's unmet housing need is a first step to planning and implementing improvements in housing conditions. This study analyzes the concept of housing needs in an economic framework. A methodology for estimating and projecting housing needs at the regional level is developed. The methodology attempts to make explicit the income redistribution intent which is the core meaning behind the concept of housing needs.

EXECUTIVE SUMMARY

Determining the size of a region's unmet housing needs is an important first step to planning and enacting public policies and programs which will improve the condition, size and quality of a country's housing inventory. The assessment of current and future housing needs is particularly important in the developing regions of the world where the twin pressures of population growth and urbanization especially aggravate the housing problem.

This study develops a basic methodology for estimating and projecting housing needs. Procedures are developed to compare the costs with the potential income redistribution effects of meeting the housing need shortfall. This methodology has been designed to be flexible and adaptable to situations in which housing and demographic data may be sparse. An extended example is presented which illustrates this methodology.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

The condition, location, size, and quality of the housing inventory are important elements in the set of factors which describes a country's standard of living. This is irrespective of the stage of economic development or the organizational basis of a country's economic system. Housing is probably the single most important consumer good in most economies. Housing expense is often the single largest component of a household's monthly budget. The public attention given housing often centers around the universal complaint that housing costs too much. Other problems, slums and squatter settlements, congestion, crime, and overcrowding become intertwined with and heighten concerns over the adequacy of an area's housing stock. Miserable housing conditions are the most visible manifestation of an area's poverty problem.

Such perceptions, if they are to be translated into realistic and effective public intervention, require accurate assessment and definition of the nature and size of the problems that exist in the housing area. Providing such measurement is the general purpose of studies of a country's or region's housing needs or requirements.

The twin pressures of population growth and urbanization are forcing the developing nations of the world to make careful measure of their present and future housing needs. Such assessments are an imperative input to the efficient allocation of scarce public resources. Public housing programs must compete for the public dollar with other vital social programs.

The purpose of this paper is to clarify some of the issues that are involved in the measurement of housing need and to provide an implementable housing needs estimation and projection methodology. First we shall discuss the economic issues involved in housing needs estimation. Next we shall present in some detail a step-by-step description of the procedures for estimating the current level, and projecting the future level, of housing needs. A detailed example will illustrate the methodology. Finally we shall discuss the modifications to the methodology that are implied by the development of a building technology for low-rise/low-cost buildings to better resist extreme winds.

1.1 The Normative Basis of Needs Estimates

At any particular point in time, a country's or region's housing need is measured by the number or value of additional units that would be required to bring the current inventory up to some pre-defined standard of acceptability. Given this definition, the subjective or normative basis of housing "needs" or "requirements" is clear. What is judged as acceptable housing conditions will vary between countries and between regions of a country. Differences in the minimally accepted standard will be influenced by income, methods of construction, climate, custom, and expectations. Only if the standard of acceptability is clearly defined and the underlying normative basis for it is widely agreed upon, will the meaning of the needs estimate be unambiguous and useful. Often in needs studies the housing standard against which need is measured is not explicitly stated. Housing needs studies usually imply their standard through a process of elimination. For example, often what is done is to examine current housing statistics to identify the number of housing units which are substandard by some physical criteria, and then to count or estimate the number of families that are living in doubled up arrangements. The sum of these components is taken as the magnitude of unfilled housing needs.

The notion of housing need can be clarified and its subjectivity modified by examining the economic meaning behind it. By definition an individual is in need if he or she does not have at his or her disposal an adequate amount of housing stock or housing capital. In order for the policy maker or reader to judge if the need level is reasonable an explicit definition of the housing standard or target level must be stated. A housing need study which only defines situations in which housing need exists and does not specify the minimum socially acceptable level that each consumer should have (i.e., how much should exist) has only fulfilled part of its function.

1.2 Projecting Future Housing Needs

A housing needs study is concerned with more than the assessment of the size of the housing gap at present. It also is concerned with projecting the future position of that gap given certain assumptions about the path of housing production. Furthermore, a housing needs study must identify those sectors in the economy which are to receive the subsidies that are implied in meeting housing needs. These are difficult research tasks.

To make a projection we must perform three tasks which are at the conceptual core of a housing needs study. We need to (1) assess the future standard, which will be influenced by conditions of supply and demand in the future, (2) to determine the gap between the actual per capita quantity and the target per capita quantity, and (3) to project the future size of the population.

In actual practice, it is very difficult, if not impossible, to obtain accurate projections or forecasts of precisely these constructs, given the nature of the existing data. In practice, an analyst will have to rely upon the information that is available. Nevertheless, the concepts of benefits and costs and the use of an economic model are useful in defining the nature of the research task and in guiding the specification of a projection methodology. In the next section a methodology for estimating and projecting housing needs is presented. The economic conceptual model which guided the development of the methodology is discussed in Appendix I.

2. A NEEDS ESTIMATION AND PROJECTION METHODOLOGY

Two general research strategies can be used to determine current and future levels of housing needs. The first may be termed the national approach. In this approach the current and future inadequacies of the housing inventory are analyzed from a national perspective. A standard or target is determined and a country's housing stock is measured against this national standard. Usually a governmental housing or planning agency located in the central government is responsible for this type of research.

The second basic strategy is a decentralized approach to housing needs research. This approach requires that regional housing or planning agencies complete housing needs studies for their respective jurisdictions and that the local current and projected levels of housing needs be summed to obtain the national need.

Let us examine some of the factors supporting the regional or summation research strategy for the determination of housing needs. Many of the same arguments used to indicate the inappropriateness of expecting that some housing standard would be applicable across countries support the view that a single national standard would be inappropriate to apply across the diverse regions within a particular country. Of course, the problems of a single standard have considerably less relevance in a country with a high degree of regional homogeneity. Examples of such countries are rare, however.

The existence of wide regional divergences and variations in culture, weather conditions, levels of income and development, income distribution, methods and costs of construction, degree of urbanization, and expected population growth indicates that a decentralized approach to housing needs determination is appropriate. The regional approach enables these regional divergences to be reflected in the separate regional determinations of the housing standard or target. This approach is also consistent with the economic reality that housing markets are not national markets, but local markets. Regional differences would most easily be reflected in housing standards if the needs projections are the products or determinations of those most familiar with their local housing market conditions.

If a coordinated regional or summation approach is to be feasible several requirements must be met. First, the regional housing needs studies must follow a consistent needs estimation and projection methodology. Also, it is necessary that overall coordination and planning remain in some centralized housing or planning agency since the reconciliation and summation of the regional or local needs studies can only be accomplished at one point. Finally, the separate needs studies should share common factual assumptions about future population projections. Again this requires a centrally located research agency to supply the regional researchers with consistent population and migration projections.

The purpose of this section is to provide one input to the regional or summation housing needs research strategy, i.e., a basic methodology of estimating and forecasting housing needs. The methodology is designed to be flexible. It will accommodate data scarcities and can be implemented by decision makers with minimal background and/or training in social sciences.

2.1 Estimation of Current Needs

Housing needs estimation involves the assessment of the size and nature of current deficiencies in the housing inventory and the projection of the future inadequacies in the inventory. Dichotomizing the research task in this way allows us to keep separate two major issues: (a) how does one calculate the level of housing need at a particular point in time, and (b) what role does projecting population growth and housing growth play in housing needs estimated for future years. We shall first concentrate on the question of the determination of current needs, and look later to the methodological issues involved in the projection of housing needs in the future.

The calculation of current housing needs involves 11 basic research steps. These tasks can be apportioned into 4 major areas of investigation or analysis. (See table 2.1) The first major area of analysis involves the accurate and relevant description of the housing inventory in detailed statistical terms.

TABLE 2.1

BASIC RESEARCH STEPS IN THE CALCULATION OF CURRENT HOUSING NEEDS

I. Description of the Housing Inventory

- Task 1. Construction of a Housing Characteristics Matrix
- Task 2. Construction of a Population Matrix
- Task 3. Construction of a Per Capita (per family) Housing Characteristics Matrix

II. Determining the Housing Standard

- Task 4. Selection of Target Cell from the Per Capita Housing Characteristic Matrix

III. Determining the Needs or Shortfall Matrix

- Task 5. Construction of a Matrix of Relative Housing Values and Rents
- Task 6. Construction of a Quality Deflator Matrix
- Task 7. Cell by Cell Calculation of Housing Needs
- Task 8. Distribution of Housing Needs by Construction Type and by Income Class

IV. Calculating the Cost of Meeting Housing Needs

- Task 9. Definition of Low-Income Housing
- Task 10. Construction Cost of a New Standard House; Total Annual Public Cost Determination
- Task 11. Cost Evaluation of the Redistributive Impact

The availability and accuracy of the data set will determine the overall accuracy and detail that is possible in the final needs calculations. The second area of analysis requires the specification of the housing standard or target. This will be based on inspection of the data matrix arising out of the first major task area. The third major research area involves the conversion of the housing matrix into housing standard equivalents, and the calculation of cell by cell shortfalls of the housing inventory matrix. Finally, the housing need level has to be costed, and this total cost can then be subjected to an analysis of its cost-effectiveness of redistributing income. If the total income redistribution gains of filling housing needs is less (more) than the implied resource costs, then a new, lower (higher) standard can be chosen and the housing needs estimates be reiterated.

2.1.1 Description of the Housing Inventory

2.1.1.1 Task 1: Construction of a housing characteristics matrix

The goal of this task is the construction of a data matrix which has the number of housing units arranged by locational/tenurial/physical characteristics and cross classified by the income class of the occupants' households. This matrix in effect will divide the housing inventory into a set of mutually exclusive submarkets.

The characteristics of the housing inventory that are of interest will include the location of the housing units (rural or urban), the tenure class of the housing units (owner occupied, renter occupied, or squatter), and the physical attributes of the units (construction type or the soundness of the condition, or the age). Table 2.2 illustrates a possible array and organization of the housing inventory. The degree of detailed subclassification will be determined, for the most part, by the adequacy and detail of the available census data. It would be desirable if data were available to classify the housing inventory in even greater

TABLE 2.2. THE ARRAY OF HOUSING CHARACTERISTICS REQUIRED AS INPUT TO A REGIONAL NEEDS STUDY

The Number of Dwelling Units or Total Number of Rooms

LOCATION	URBAN									RURAL									
TENURE	Owner Occupied			Renter Occupied			Squatter			Owner Occupied			Renter Occupied			Squatter			
CONSTRUCTION TYPE[a]	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	
																			Row Total

[a] S: Strong
M: Mixed
L: Light

detail than indicated by table 2.2. For example, the subcategory of age could be made a subset of the construction type category. Another subset of interest, if data were available, would be by condition of unit, i.e., sound, dilapidating, or deteriorating.

Once the cell totals for an array have been determined, the next step is to distribute the dwelling unit totals in each cell among income classes. It may be that a national census will have the regional dwelling unit data already so classified. If not, a method of distribution is required.[1] Ideally, the data in table 2.2 would be extended into a matrix as seen in table 2.3. Each cell in this matrix will contain a measure of the number of dwelling units or the total number of rooms.

2.1.1.2 Task 2: Construction of a population matrix

The goal of this task is to construct a population matrix which in combination with the housing characteristics matrix of task 1 will enable a cell by cell computation of housing units per capita. The column and row headings of this matrix will be identical to that of table 2.3. However, instead of housing unit data comprising the cellular entries, population data is required.

The construction of the population matrix also may require an estimation or data development procedure. For example, data on the population size of urban renters may be available but not be distributed by income class. In this case it would be reasonable to assume that the

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[1] Let us assume that the analyst only has available an income distribution by families or households which is cross classfied by urban or rural and not by any other housing characteristic. Two alternatives exist in a situation like this. Either the analyst requests and is able to get an unpublished cross-classification from the census bureau, or he or she employs some method of interpolating the totals that are available, among the construction types. Once again there may exist some description in a related area which will allow the construction of reasonable distribution procedures.

TABLE 2.3. HOUSING CHARACTERISTICS MATRIX

The Number of Dwelling Units or Total Number of Rooms

Housing Characteristics / Income class of Occupying Households	LOCATION	URBAN									RURAL									
	TENURE	Owner Occupied			Renter Occupied			Squatter			Owner Occupied			Renter Occupied			Squatter			Sub-totals
	CONSTRUCTION TYPE[a]	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	S	M	L	
10,000 +																				
7 - 10,000																				
5 - 7,000																				
3 - 5,000																				
0 - 3,000																				
Subtotals																				

Total

[a] S: Strong
M: Mixed
L: Light

total or urban renters could be distributed by income classes according to the national distribution of the urban population among income classes. The population of rental income class must then be distributed according to their division among building construction types. Information for determining this distribution by construction types may be available from tangential sources such as reports, surveys, or documents containing estimates of family size by income class. Also data may exist on the extent of "doubling up", two or more families occupying one dwelling unit, which in turn is related to the physical characteristics of dwelling units. These data could be combined using specific assumptions in such a way that the analyst would be able to distribute the population of an income/tenure class among the construction material categories. No set rules for data development are available because each country's data contingencies will dictate the kinds of adjustments which may be required.

2.1.1.3 Task 3: Construction of a per capita (or per family) housing characteristics matrix

This task is a straighforward division of the elements in housing characteristics matrix by the population elements determined in task 2. The result will be a cell by cell (or submarket by submarket) portrayal of housing quantity per capita, h_{ij}/pop_{ij}. It permits comparisons between cells of the amount of housing stock or housing service consumed by each income/housing type submarket of the housing stock.

2.1.2 Determining the Housing Standard

2.1.2.1 Task 4: Selection of a target cell(s) from the per capita housing characteristics matrix

This task is essentially one of judgment. The analyst must designate a target which represents the minimal socially acceptable level of housing consumption per capita. This target, or standard, will be relative to the existing conditions in the current inventory. Thus, initially the analyst can designate one cell in the per capita housing characteristics matrix as depicting or representing the highest standard of housing which should be attained by all household units. Separate standards can be designated for the urban population and rural population.

In effect, the housing needs analyst makes the initial judgment that the housing quality and per capita quantity represented by one cell of the per capita housing characteristics is what should be available for all. It could be, for example, the kind of urban (and rural) owner occupied housing of mixed construction consumed by the middle income class. This particular cell(s) of the per capita housing characteristics matrix is (are) designated as the standard or target cell(s). It becomes the point from which the adequacy or inadequacy of housing conditions in the region, as portrayed in the other cells of the matrix, is measured.

The advantage of this procedure lies in the clear meaning of the standard. Designating, say the housing type and per capita quantity of a particular income class as the standard is unambiguous and allows the reasonableness or unreasonableness of the standard to be perceived by the audience of policy makers. The standard represents an implicit judgment by the housing analysts about the inadequacy of the income distribution. The remaining tasks of a needs study can be viewed as translating such an implicit judgment into explicit terms.

2.1.3 Determining the Needs or Shortfall Matrix

2.1.3.1 Task 5: Construction of a matrix of relative housing values and rents

The entries in housing characteristics matrix represent housing units which vary widely in quality. Housing is a very complex good with many factors determining the quality of one unit relative to another. Thus, the units in the different cells of matrix 1 are in a real sense non-comparable. The purpose of this task and Task 6 is to arrive at a means by which the quantity units of matrix one can be adjusted for quality and thus be susceptible to direct comparison.

The simplest and most sensible measure of variation in quality is recorded in judgments of the market place in its determination of relative price. This means that if quality adjustments are to be made, a matrix of average housing prices is required. This means that a matrix comparable to that described in table 3 must be constructed with housing value (if owner occupied), and rental values (if renter or squatter occupied) as the cell entries.

This is a difficult task and will require expertise and knowledge on the part of the local needs analyst. Because there is wide regional variation in the structure of housing prices, the completion of this task is only feasible at the regional level.

Data may be available on housing prices at the local level. Evidence suggests that such data are difficult to locate. Thus, the housing needs analyst will probably find it necessary to canvass local expert opinion in order to ascertain the actual structure of housing market prices. Of course sample survey techniques are more accurate, but the cost of a special census of current housing prices at the regional level are prohibitive.

2.1.3.2 Task 6: Construction of a quality deflator matrix

The housing price and rental data matrix of task 5 can now be converted into a matrix of relative values -- relative to the value or rent of the price of housing in the standard or target cell. This will result in a cell by cell comparison of the price or rent in any particular cell to that of the price of standard housing. In other words, this task requires that each cell of this matrix of housing prices and rents be divided by the price or rent of the standard or target unit.

In order that the value cells in the owner-occupied columns be comparable to those in the renter and squatter-occupied columns, the housing values in the owner-occupied columns must be converted into service values or prices. Thus, if a owner-occupied unit has a stock value of $15,000, it would be necessary to convert this into a gross rental value of $1,500. This can be done by assuming a gross rent/price ratio of a given magnitude based on the following equation:

(2) $R/P = V_d + V_k + V_v$

where R/P = the annual gross rental receipts divided by owner occupied value,

V_d = the rate of depreciation, maintenance, and repair expenditures,

V_k = the tax rate on housing services, and

V_v = the rate of return on housing services.

The rate of return on housing services will be at least as large as the mortgage rate currently prevailing in the housing finance market.

2.1.3.3 Task 7: Cell by cell calculation of housing needs

Housing needs now can be computed for each cell. This will result in a new matrix, the housing needs matrix. The cell-by-cell computation is relatively straightforward. For each cell we wish to calculate need level, N_{ij}. It will be the product of two terms: the per capita shortfall from the designated standard in housing quantity per capita times the population in that cell. Equation 3 specifies this procedure. The first term on the right-hand side of equation 3 represents the per capita shortfall in cell ij.

(3) $N_{ij} = (S - \frac{h_{ij}}{pop_{ij}} \cdot D_{ij}) \times pop_{ij}$

where S = per capita quantity observed in the standard cell.

h_{ij}/pop_{ij} = per capita quantity in cell ij,

D_{ij} = the deflator value in cell ij,

pop_{ij} = the population of cell ij,

For example, let us assume that the income row i represents the $3,000 to $5,000 income class and the housing characteristic column j is urban rental housing of medium construction. Assume that the standard cell has an observed per capita quantity ratio of 1/5 while that for cell ij is 1/8. Also assume that the rental value deflator D_{ij} is 0.70 (calculated in task 6) and that the cell contains a population of 5,000 (calculated in task 2). This data results in a need estimate of 562.5 units (= [0.20 - (0.125 x 0.7)] 5,000). This means that 562.5 units comparable to standard units would have to be added to the housing stock of cell ij, either by new construction or in the form of rehabilitation of existing units, in order to bring housing in that portion of the housing inventory up to standard. Thus in this cell the 562.5 units of standard quality plus the 437.5 existing units of standard quality (437.5 = 0.7 x 625) add up to a final total of 1,000 standard quality dwelling units. Thus the goal of 0.2 standard units per capita has been attained.

2.1.3.4 Task 8: Distribution of housing needs by construction type and by income class

The matrix approach has the advantage that the distribtuions of housing needs by income class or by urban/rural and building characteristic will automatically result from the summation of the row entries and column entries. Some cells, particularly those in the higher income rows, will probably contain negative entries in the needs matrix. This means that housing in those submarkets surpasses that of the standard.[1] Thus, when summing the rows and columns of the need matrix the negative entries should be set equal to zero, indicating that no housing need exists in those submarkets because the housing quantity per capita exceeds that of the housing standard specified in task 4.

2.1.4 Calculating the Cost of Meeting Housing Needs

2.1.4.1 Task 9: Definition of low-income housing

Defining a low income dwelling unit is equivalent to defining how much the low income part of the population is willing and able to pay for the standard house or dwelling unit which has been defined in task 4. Thus, this task is essentially one of determining that price or rent level which can be afforded by the poorer part of the population.

The income-class, price data of task 5 can be used to accomplish the analysis of the income and housing price relationship. The data of task 5 can be inspected to determine the current average price of housing which is being paid by each income group. If facilities are available, a simple regression of housing prices (or rents) can be estimated as a function of income using the data from task 5. Thus, the estimated relationship

$$(4) \quad P_i = \alpha_o + \alpha_1^{\;Y} + e_i$$

where P_i represent housing prices or rent, Y is the measure of income, and e_i is the residual, can be used to determine what housing price can be afforded with a given particular family income, Y. Once the low-income level of income is defined according to the region's definition of relative poverty, the maximum price of a low income dwelling unit can be determined by substituting the low-income cutoff in the estimated

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[1]A negative entry will arise in equation 3 when $S < \frac{h_{ij}}{pop_{ij}} \times D_{ij}$.

regression and solving for the price or rent level. Any dwelling unit renting for a higher price or whose market value implies a higher inputed rent can not be considered as a low-income house. The differential between the maximum price of housing that the poor can afford and the price of the standard dwelling unit describes the subsidy per dwelling unit that will be necessary to fill the low-income populations' housing needs.

2.1.4.2 Task 10: Construction cost of a new standard house; total annual public cost determination

The result of task 8 is a detailed estimate of the number of new standard housing units required to bring the housing stock up to the socially desirable standard. These estimates are categorized two ways: by income class and by housing type. In order to determine if these housing needs are worth meeting, or, put differently, to determine if the housing standard or target has been set too high, an estimate of the annualized public costs of filling these needs is required.

A housing needs study does not require an elaborate and detailed cost estimation. Only an order of magnitude estimate of cost is necessary. The cost concept involved is the annual public subsidy required to supply standard housing to those who can not afford the cost of standard housing (See task 9). The additional standard/needed units will not be supplied by the building community unless the subsidy is granted since those for whom the housing is intended cannot afford the standard house at its going market price.

The main capital costs that require estimation are the average unit costs of land acquisition and development and the average cost of construction of a new unit which is comparable to the standard or target unit. These total investment costs can then be annualized using an appropriate length of life and an appropriate interest rate. The difference between these annualized costs and the average yearly rentals that the poor can afford represents the annual net resource costs which must be borne by the public sector.

The total size of the annual governmental housing subsidy, the public cost of meeting housing needs, can now be computed. The total public cost can be computed either on a cell-by-cell basis and summed or computed only for each income class and then summed. Within each cell or for each income class, the total cost will be the product of the subsidy per unit times the number of needed units which require subsidization.

2.1.4.3. Task 11: Cost evaluation of the redistributive impact.

The costs discussed above in task 10 have the primary purpose of attempting to raise the real income levels of that portion of the population residing in housing which is less than standard. Augmenting the inventory in those housing submarkets where the need is the greatest will generate real income increases in those submarkets. The real income increases will accrue to those who will occupy the subsidized housing. Also of importance will be the impact on real incomes which will arise because of the price effect that will occur becuase of the significant increase in the size of the housing stock. A fall in the price of housing services should occur because of the increase in supply. This will raise real income levels by reducing rent levels. Thus the primary effects of fullfilling housing needs are to be found in the changes in real income of those at the lower end of the income distribution. The income increases discussed above are in effect transfer payments. This is the case since the lower housing prices while of benefit to those not owning the stock (the renters) are net losses of rental receipts to the holders of the stock. The redistribution from the landlord to the tenant (in owner-occupied units the landlord and tenant are one and the same) is not done costlessly. The costs discussed in task 10 represent the public sectors' administrative or income redistribution implementation costs. In evaluating the reasonableness of statements about housing needs the policy makers of the public sector should be appraised of the cost effectiveness of these implementation costs since alternative methods of achieving the same level of redistribution may be available. Thus the last task of the needs estimation methodology is to assess the size of the potential income redistribution and to identify the gainers and losers in each cell of the housing characteristic matrix.

The amount of the income increase (redistribution) within any particular submarket (or cell in the housing characteristic matrix) will be measured by the gain in consumers' surplus[1] which will arise because of the fall in the price of housing services due to the increase in the size of the inventory needed to bring that submarket up to standard.

Thus if the need level in a particular submarket cell has been computed to be x percent of the existing inventory, one must ask: What effect will an x percent increase in the size of the inventory have on housing prices? Answering such a question presumes knowledge of the price elasticity of demand[2] for housing in that particular submarket. For the moment, assume reliable information about price elasticities is available. The gain in consumers' surplus can be approximated by the change in price, Δp,[3] times the existing number of standard units, h,

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[1]For an explanation of consumers' surplus, see Appendix 1.

[2]Price elasticity of demand is discussed in more detail in Appendix 2.

[3]The price change will be equal to the product of the percentage change in quantity $\Delta q/q$ times the price per unit in that submarket divided by the price elasticity of demand.

plus one-half times Δp times the additions to the inventory ($1/2\Delta p \cdot \Delta h$). The cell-by-cell calculations of consumers' surplus gains will, when summed, yield the income redistribution change that would be associated with attainment of the housing standard and the elimination of housing needs. This change in the income distribution can then be compared to the resource costs or implementation costs which have been calculated in step 10. It may be that the cost effectiveness of redistribution via the fullfillment of housing needs is competitive with other programatic approaches. If the housing needs levels and the income redistribution gains are not cost effective it may be that the housing standard has been set too high. A reiteration of the needs estimate may be called for where a lower standard or target has been specified. The implementation costs will be lower and it may be that cost effectiveness will be increased. A table like Table 2.4 below can be computed as a means of explicitly presenting these considerations to the policy maker.

TABLE 2.4. THE COST EFFECTIVENESS OF MEETING HOUSING NEEDS AS A MEANS OF REDISTRIBUTING INCOME (SAMPLE FORMAT)

(1) STANDARD	(2) HSG NEED ESTIMATE	(3) IMPLEM-ENTATION COSTS	(4) INCOME REDISTRIBUTION AMOUNT	(5) COST-EFFECTIVENESS (5)=(4)/(3)
A				
B				
C				
D				

2.2 Projecting Future Housing Needs

In the context of the needs methodology discussed above, the projection of future housing needs involves applying tasks 1 through 11 to data which represent values that are expected to exist in the future projection year. Thus, the housing need analyst will be required to modify the current needs matrices so they contain projected values. This section discusses ways in which the projections can be feasibly accomplished.

2.2.1 Projecting the Housing Characteristics Matrix

The problem involved in projecting the housing characteristics matrix is in finding a set of factors which when multiplied by the elements in the housing characteristic matrix of the base or current period yields reasonable projections of the corresponding future values. If we let the current housing characteristics matrix be denoted by HC^c, the set of projection factors be denoted by matrix f, and the projected future housing characteristics matrix by HC^f, then the conversion of HC^c to HC^f can be viewed symbolically as the operation of (in matrix notation):

$$(4) \quad \underset{(ixj)}{HC^c} \cdot \underset{(jxj)}{F} = \underset{(ixj)}{HC^f} .$$

Thus, the housing needs analyst must find a reasonable approximation of F. To further simplify the problem let us assume that F can be a diagonal matrix, i.e., one in which the non-diagonal elements take on zero values. If this is the case, then an element of F along the main diagonal will be equal to

$$(5) \qquad f_j = \frac{hc^f_{ij}}{hc^c_{ij}} .$$

that is, that ratio of any element i from column j of the future housing characteristics matrix divided by the corresponding i_{th} element from column j of the current housing characteristics matrix. This is equivalent to assuming that all the elements of a given column of the current matrix will grow at the same rate. In other words we are assuming that urban housing of a given tenure and building characteristic type will increase at the same rate across all income classes. This is not as restrictive an assumption as it may first appear since it is likely that a particular kind of housing, say owner-occupied of strong construction, or squatter-occupied of light construction, will be concentrated in a few income classes. This assumption will considerably ease the problem of projection. Without such an assumption, the housing needs analysts would be required to make separate projection of each cell of the current housing characteristics matrix.

The j^{th} diagonal element of the growth factor matrix will be based on the net rate of growth:

(6) $$F_j = (1 + g_j - d_j)^n \quad ,$$

where

g_j = the projected annual average rate of gross additions to the housing stock of housing type j,

d_j = the projected annual average rate of depreciation from the housing stock of housing type j, and

n = the length of the period in years over which the projection is to be made.

Thus, the projection problem is essentially one of determining for each housing type (for each of the columns of the housing characteristics matrix) reasonable estimates of the net growth rate. The net growth rate is the sum of two rates as seen above. The rate of gross additions of housing type j can be based on past experience. Annual data on new construction by building type, location, and tenure class can serve as the basis for calculating g_j. If a trend is observable in a time series of g_j, the value of g_j can be modified to reflect projections of that trend. Annual data on losses from the inventory by housing type may also be available; if not, alternative assumptions about the deterioration rate can be substituted. For example, different lengths of life can be assumed which are based on the kind of construction material used in the dwelling unit. Straight-line depreciation can be assumed and the depreciation rate can be calculated as one over the average length of life of units of a given construction type. Alternatively, an estimate of the projected rate of net additions ($na_j = g_j - d_j$) can be included. This can be based on comparisons of the size of the inventory of housing of type j as revealed in the decennial census for 1970 and the census for 1960.

2.2.2 Projecting the Population Matrix

As was the case in the discussion above, the problem is again one of finding a set of factors by which the base period population matrix can be multiplied to yield estimates of future population. A workable approach to determining such factors even where data is extremely limited is to multiply all the cell entries in the base period population matrix by a factor, G,

$$G = (1 + p + nmr)^n \tag{7}$$

where

p = the rate of natural increase in the population

nmr = the net migration rate of the region

n = the length of the period in years over which the projection is to be made.

Most central governments develop estimates of the projected rate of natural increase by region. Similarly, they may project nmr by region.

The population projections can be refined. As was the case in the housing matrix discussed above, a diagonal population growth factor matrix, PG, can be constructed. For example, the population growth factor matrix could assume that all cellular entries will grow at the same rate of natural increase but that the migration rate within a region will be positive in the urban sectors and negative in the rural sectors. Further subdivisions are possible. For example, within the urban sector, the migration rate can be adjusted to reflect differences by tenure class. Specifically, a higher rate can be assumed for squatter occupied housing than for owner occupied or renter occupied housing. These rates of migration can be based on recent historical experience and adjusted according to the conditions that are expected to prevail over the projection period. Special studies may exist which can allow the analyst to justify the rates of growth that are entered in the diagonal matrix. The employment of a diagonal growth factor projection matrix implicitly assumes that the distribution of income will remain unchanged between the current and future periods.

2.2.3 Combining the Projected Matrices

The above two projection tasks can now be combined and a per capita housing characteristics matrix can be constructed for a future period. This step brings us through the analogous task 3 as outlined in section 2.1.1.3. From this point, there are only slight deviations required from the remaining calculations outlined for current needs. The procedure for selecting a target cell is identical to task 4. Even the matrix of relative housing values and rents is best left unchanged from that calculated for current housing needs. This does not mean that no price changes are expected to occur. Inflation may in fact exert a large influence on all housing prices. Nevertheless, since our interest is in real relative prices, the assumption that the matrix of relative housing prices and rents task 5 applies to the future period avoids the construction and estimation of simultaneous housing price determination models. The housing analyst can then proceed with tasks 6 thru 11, and obtain estimates of housing needs for a future period.

3. AN ILLUSTRATION OF THE NEEDS ESTIMATION METHODOLOGY

The purpose of this section is to illustrate the basic logic of the needs estimation methodology developed in section 2 of this paper. A numerical example -- strictly hypothetical and highly simplified -- has been developed so as to illustrate the iterative nature of the needs estimation methodology. This section can not be used as a guide for the data development and forecasting problems that the needs analyst will encounter. However, if the analyst follows this example through, he or she will come to grips with the overall strategy of the recommended methodology and will be in a better position to develop a data acquisition and forecasting strategy consistent with the goals of this methodology.

Table 3.1 categorizes the renter occupied housing stock of a hypothetical urban area into 15 submarkets based on structural characteristics and on the income class of the dwelling units' household occupants. Since housing needs will presumably be the most pressing in the lower half of the income distribution, the matrix has a highly aggregated income class 5 -- wherein 50 percent of the renter occupied housing is located. As can be seen in this illustrative matrix, 20 percent of the housing stock is of light construction with 86 percent of these building units falling into income classes 1 through 4.

Table 3.2 contains hypothetical data on the number of people living in housing of a corresponding construction type and income class. Income class 5, which contains 38 percent of the population, consumes 50 percent of the housing services produced by the housing stock. The entries in table 3.1 are then divided by the entries in table 3.2 to obtain estimates of housing stock per capita for each of the housing inventory subcategories. (See table 3.3.) The inverses of the cellular entries in this matrix reveal the population per housing unit within

TABLE 3.1

AN ILLUSTRATIVE HOUSING CHARACTERISTICS MATRIX FOR A HYPOTHETICAL URBAN REGION -- RENTER OCCUPIED HOUSING

Dwelling Units Per Housing Category

Income Class	Strong (00's)	Mixed (00's)	Light (00's)	Total
Class 1	9	4	21	34
Class 2	23	12	15	50
Class 3	21	11	27	59
Class 4	38	20	9	67
Class 5	131	67	12	210
Total	222	114	84	420

TABLE 3.2

AN ILLUSTRATIVE POPULATION CHARACTERISTICS MATRIX FOR A HYPOTHETICAL URBAN REGION -- RENTER OCCUPIED HOUSING

Population Per Housing Category

Income Class	Strong (00's)	Mixed (00's)	Light (00's)	Total	Percent
Class 1	78.94	35.71	190.91	305.56	12.5
Class 2	179.69	97.56	125.00	402.25	16.4
Class 3	151.07	84.62	203.01	438.70	17.1
Class 4	193.88	119.76	57.69	371.33	15.1
Class 5	536.89	335.00	62.50	939.11	38.1
Total	1140.47	672.65	639.11	2452.23	
Percent	46.5	27.4	26.1		

TABLE 3.3

AN ILLUSTRATIVE HOUSING QUANTITY PER CAPITA MATRIX FOR A HYPOTHETICAL URBAN REGION -- RENTER OCCUPIED HOUSING

Housing Stock Per Capita

Income Class	Strong	Mixed	Light
Class 1	.114	.112	.110
Class 2	.128	.123	.120
Class 3	.139	.130	.133
Class 4	.196	.167	.156
Class 5	.244	.200	.192

each subcategory of the inventory. For example, housing of light construction which is occupied by households in income class 1 contains an average of 9.1 persons per unit (1/0.11 = 9.1) whereas housing of strong construction occupied by persons in households which fall in income class 5 contains 4.1 persons per unit (1/0.244 = 4.1). Thus there is considerable variation among the different sectors of the housing stock in degree of crowding.

After the construction of the per capita housing matrix, the analyst can either arbitrarily or judgmentally designate one of the cells as the target or standard cell. The analyst asserts that, say, for example, the kind of housing and degree of crowding typified by those units which are occupied by households in income class 4 and which is constructed of materials of mixed qualities should be the standard level to which all the population should have access. (This judgment may or may not be supported by the rest of the analysis. Thus at this point the analyst is simply setting a standard as a hypothesis.)

Table 3.4 contains hypothetical value data in dollars for the mean yearly rental value of housing in each of the subcategories. The cell in row 4 column 2 is the designated standard or target cell. Dividing all the entries in table 3.4 by the rent per unit of the standard cell yields table 3.5 -- the matrix of relative housing prices.

The matrix of relative prices represents a set of deflators to apply to the stock per capita quantities contained in table 3.2. Using relative prices as deflators in effect is assuming that the amount of housing services rendered by a unit is measured by the number of target or standard equivalents contained in that unit. For example, if the standard unit has an annual rental value of $1,000, and if another unit is valued at $500, then the second unit is equivalent to 0.5 standard units. Thus multiplying the units per capita in each cell by the corresponding relative value yields a standardized stock per capita figure. These figures are then subtracted from the standard or target stock per capita which is given by row 4 column 2 of table 3.3 in order to determine the cell by cell shortfall of stock per capita. (See equation 3 in section 2.) Table 3.6 contains such shortfall estimates in per capita terms.

To convert the stock per capita shortfall or housing needs estimates into absolute numbers, the positive entries of table 3.6 are multiplied by the corresponding population estimates of table 3.2. Thus table 3.7 contains the first iteration of a cell-by-cell calculation of needs estimates.

This is the critical point of the analysis. The needs estimates must now be evaluated as to whether or not they are worth meeting. If not we must lower the standard or target.

Information on the cost of constructing a standard equivalent is required. Here we shall assume that the standard or target unit can be

TABLE 3.4

AN ILLUSTRATIVE MATRIX OF HOUSING PRICES FOR A HYPOTHETICAL URBAN REGION -- RENTER OCCUPIED HOUSING

Matrix of Annual Rental Values

Income Class	Strong	Mixed	Light
Class 1	830	510	350
Class 2	960	830	500
Class 3	1,120	970	680
Class 4	1,240	1,000	900
Class 5	1,630	1,180	920

TABLE 3.5

AN ILLUSTRATIVE MATRIX OF RELATIVE HOUSING PRICES FOR A HYPOTHETICAL URBAN REGION -- RENTER OCCUPIED HOUSING

Matrix of Relative Prices

Income Class	Strong	Mixed	Light
Class 1	0.83	0.51	0.35
Class 2	0.96	0.83	0.50
Class 3	1.12	0.97	0.68
Class 4	1.24	1.00	0.90
Class 5	1.63	1.18	0.92

TABLE 3.6

AN ILLUSTRATIVE MATRIX OF THE SHORTFALL IN HOUSING STOCK PER CAPITA ADJUSTED BY RELATIVE PRICE WHEN COMPARED TO THE DESIGNATED STANDARD OR TARGET

Shortfall in Housing Stock Per Capita

Income Class	Strong	Mixed	Light
Class 1	0.072	0.110	0.128
Class 2	0.044	0.065	0.107
Class 3	0.011	0.041	0.077
Class 4	--	--	0.027
Class 5	--	--	--

TABLE 3.7

AN ILLUSTRATIVE MATRIX OF HOUSING NEEDS FOR A HYPOTHETICAL URBAN REGION -- RENTER OCCUPIED HOUSING

Matrix of Housing Needs

Income Class	Strong (00's)	Mixed (00's)	Light (00's)	Total	Percent of Existing Units
Class 1	5.7	3.9	24.4	34.0	100.0
Class 2	7.9	6.3	13.3	27.5	55.0
Class 3	1.7	3.5	15.6	20.8	35.3
Class 4	--	--	1.6	1.6	2.4
Class 5	--	--	--	--	--
Total	15.3	13.7	54.9	83.9	20.0
Percent of Existing Units	6.9	12.0	65.4		

produced for $10,000. (The analyst will require a realistic construction cost estimate and can not rely on assumption as is done in this example.) This cost can then be converted to an annualized cost of $1075.[1]

A cell-by-cell calculation of redistribution effects must now ensue. This will require that the analyst make some assumptions about the impact that adding new units to each subcategory will have on the market price within each subcategory. Recall that the main category of impacts to be considered are consumer surplus benefits -- as units are added to the inventory prices will fall on the already existing housing and those who do not experience a housing subsidy directly are made better off because less of their income need be spent on housing. (As price falls more, housing can be consumed within each cell, and housing stock per capita is increasing).

Returning to the problem at hand, let us see what will happen in terms of real income effects going to renters in the row 1 column 3 cell. The need estimate in this cell calls for an extra 2,440 units. Currently this cell contains 2,100 units. The current market price of housing in this cell is $350. If the price elasticity of demand is -1.0 (an x percent change in price will lead to an x percent change in quantity) then increasing quantity by 116 percent (2,440/2,100 = 1.16) would lead to a price decline to zero.[2] Thus consumer surplus gains would equal 2,100 x $350 + 2,440 x 1/2 x $350 = $1.16 million. These benefits

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[1]This calculation assumes a 25 year life, a 10% interest rate and a scrap value of $3,000.

[2]Zero is assumed because negative prices are not meaningful.

would arise if 2,440 units are produced at an annualized cost of $1,075 and given away to the residents of this housing submarket. The annualized cost of implementing the redistribution of $1.16 million will be $2.58 million (2,400 x $1,075). Table 3.8 contains the cell-by-cell computation of redistribution impacts based on a price elasticity of -1.0.

The results in table 3.8 show that the aggregated redistribution effect of meeting the designated target or standard. Table 3.9 contains the estimates, cell-by-cell, of the annualized cost of administration or implementation. Table 3.10 computs the cell-by-cell ratio of redistribution level to administration costs.

For a second iteration we set the standard or target as those housing conditions obtaining in row 3, column 3 (income class 3 of light construction). Table 3.11 recomputes the matrix of housing needs based on this new and lower standard or target. Table 3.12 recomputes the matrix of cell-by-cell redistribution effects and table 3.13 recomputes the matrix of net resource costs. Let us assume that the housing industry can reproduce this lower quality unit for $6,000 because of special scale advantages that are associated with producing such units in large numbers. We shall assume that these units will have a 20 year life, zero scrap value and that the interest rate is 10 percent. Thus the gross annualized cost will be $705 per unit, prior to any rental collections from those occupying the new units. Table 3.13 is based on the net annualized costs per unit. Again we have assumed in tables 3.11 through 3.14 a price elasticity of -1.0.

This second iteration produces a considerably lower need level and an annualized net resource cost approximately seven times lower then the first case. Also the real income gains accruing to the row 1, column 3 cell are only 40 percent lower than those computed under the first

TABLE 3.8

THE REAL INCOME GAINS OF THE OCCUPANTS OF RENTER OCCUPIED HOUSING ARISING FROM FILLING HOUSING NEEDS (REDISTRIBUTION EFFECTS)

(Millions of Dollars)

Income Class	Strong	Mixed	Light	Total
Class 1	0.623	0.296	1.16	2.079
Class 2	0.887	0.659	0.960	2.506
Class 3	0.198	0.393	1.366	1.957
Class 4	--	--	0.157	0.157
Class 5	--	--	--	--
Total	1.708	1.915	3.643	7.266

TABLE 3.9

ANNUALIZED NET RESOURCE COST OF IMPLEMENTING REDISTRIBUTION EFFECTS ASSOCIATED WITH FULLFILLING HOUSING NEEDS

(Millions of Dollars)

Income Class	Strong	Medium	Light	Total
Class 1	.433	.414	2.623	3.470
Class 2	.351	.422	1.354	2.127
Class 3	.007	.144	1.228	1.379
Class 4	--	--	0.038	0.038
Class 5	--	--	--	--
Total	0.791	0.980	5.243	7.014

TABLE 3.10

CELL-BY-CELL RATIO OF REDISTRIBUTION LEVEL TO NET RESOURCE COSTS OF IMPLEMENTATION

Income Class	Strong	Medium	Light	Total
Class 1	1.44	0.71	0.44	0.60
Class 2	2.53	1.56	0.71	1.18
Class 3	28.29	2.73	1.11	1.42
Class 4	--	--	4.13	4.13
Class 5	--	--	--	--
Total	2.16	0.51	0.69	1.04

TABLE 3.11

MATRIX OF HOUSING NEEDS -- SECOND ITERATION

Income Class	Strong (00's)	Medium (00's)	Light (00's)	Total
Class 1	--	1.8	14.7	16.5
Class 2	--	--	5.5	5.5
Class 3	--	--	--	--
Class 4	--	--	--	--
Class 5	--	--	--	--
Totals	0	1.8	20.2	22.0

TABLE 3.12

THE REAL INCOME GAINS OF THE OCCUPANTS OF RENTER OCCUPIED HOUSING ARISING FROM FILLING HOUSING NEEDS - SECOND ITERATION

(Millions of Dollars)

Income Class	Strong	Medium	Light	Total
Class 1	--	0.113	0.695	0.808
Class 2	--	--	0.325	0.325
Class 3	--	--	--	--
Class 4	--	--	--	--
Class 5	--	--	--	--
Total	--	.113	1.010	1.123

TABLE 3.13

ANNUALIZED NET RESOURCE COSTS OF IMPLEMENTING REDISTRIBUTION EFFECTS -- SECOND ITERATION

(Millions of Dollars)

Income Class	Strong	Medium	Light	Total
Class 1	--	.076	.875	.951
Class 2	--	--	.210	.210
Class 3	--	--	--	--
Class 4	--	--	--	--
Class 5	--	--	--	--
Total	--	0.076	1.085	1.161

TABLE 3.14

CELL-BY-CELL RATIO OF REDISTRIBUTION LEVEL TO NET RESOURCE COSTS OF IMPLEMENTATION -- SECOND ITERATION

Income Class	Strong	Medium	Light	Total
Class 1	--	1.48	0.79	0.85
Class 2	--	--	1.55	1.55
Class 3	--	--	--	--
Class 4	--	--	--	--
Class 5	--	--	--	--
Total	--	--	0.93	0.97

set of assumptions. In that cell the ratio of redistribution gains to implementation costs has nearly doubled.

Alternative assumptions about demand elasticities could be employed in further iterations. For example it may be reasonable to assume greater inelasticity in the lower income classes. This will improve the redistribution to resource cost ratios because smaller additions to the stock in those cells will have a greater impact on market price. Thus a lower standard would, with a lower associated annualized cost of implementation, generate larger income gains. As alternative need estimates are generated under different assumptions a table like that of table 2.4 can be generated.

This example illustrates that selecting a standard and computing a level of need will not be an easy matter. Hopefully, even though this example is incomplete it should serve to give the methodology outlined in section 2 a degree of concreteness which will highlight the key problems and issues that are involved in needs estimation.

4. THE IMPACT OF A CHANGE IN BUILDING TECHNOLOGY ON HOUSING NEEDS

In this section we shall explore the effect that improvements in building technology will have on the level of housing needs in the future and we shall discuss ways in which anticipated changes in housing technology can be incorporated into the housing needs estimation methodology.

A good example of anticipated technology change involves building technology research which is related to the impact of high winds on low rise buildings.[1] Extreme winds are a primary contribution to building damage and destruction in some developing countries. For example, in the Philippines between 1948 and 1971 there were 482 typhoons. Similar experiences with high winds are found in Jamaica and Bangladesh.

If building technology develops methods of construction which are relatively low-cost and which result in substantial increases in the ability of low-rise buildings to withstand extreme winds there will be two major economic impacts which could be incorporated into a housing needs estimate.

First, the units which embody the new technology will have longer expected lifetimes than those that do not. This will lower the overall depreciation rate for the existing stock and will result in larger actual stocks at some future date. Coupled with this technological factor is a demand factor. Demand for new construction will also increase. This will be so because the lowering of the depreciation rate will cause a basic shift in the relationship between rental income and housing value. Longer expected lifetimes results in greater rates of return to a housing investment. This will result in greater demand for housing than would have been the case if no technological change had

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[1]Any building technology research that leads to buildings more resistant to natural disasters could be used in this example.

occurred. This means that more units will be purchased over time and that the actual stock of housing anticipated to exist at the future projection date will be larger. The gap between the desired level of housing stock and the actual level will be lower. (These effects will be offset in part if the new technology causes the price of new housing to increase significantly.)

The growth factor matrix must be judgmentally modified if the new technology is to be anticipated in the needs projections. The annual average rate of gross additions will be higher because of the demand affect discussed above and the annual average rate of depreciation will be lower because of the increases in exprected building lifetimes. The actual percentage modifications that need to be made to these two elements will be determined by conditions which differ country by country. The needs analyst could provide alternative forecasts based on high, low, or zero building technology change assumptions.

5. SUMMARY AND RECOMMENDATIONS FOR FURTHER RESEARCH

5.1 Summary

Determining the size of a region's unmet housing needs is an important first step to planning and enacting public policies and programs which will improve the condition, size, and quality of a country's housing inventory. The assessment of current and future housing needs is particularly important in the developing regions of the world where the twin pressures of population growth and urbanization especially aggravate the housing problem.

This study has developed a basic methodology of estimating and projecting housing needs. Procedures have been developed to compare the costs with the potential redistributive impacts of meeting the housing need shortfall. This methodology has been designed to be flexible and adaptable to situations in which housing and demographic data may be sparse. The methodology is consistent with the economic constructs which make the concept of housing needs meaningful.

Finally, this study has shown that in countries where natural disasters such as high winds or earthquakes occur relatively frequently, the development and adoption of new wind or earthquake-resistant building technology will have a mitigating effect on a region's future housing need.

5.2 Recommendations for Further Research

One of the inputs to this paper's housing needs methodology is demand for housing information. Housing needs studies could be considerably improved in terms of accuracy and reliability, if reliable estimates of price elasticities of demand and supply existed at the regional level. Thus, much work could be done on developing and estimating regional models of housing demand and supply. This is particularly critical in those regions of countries where housing problems are the most pressing.

Further work is needed on understanding, first conceptually, and secondly, empirically, the market process in squatter settlements. Both tasks would necessitate special modeling of the squatter settlements as specialized submarkets of the housing inventory. Parallel empirical investigations of the economics of squatter settlements would deepen our understanding of the specific problem areas and work to feed back a sense of priorities into the conceptual work.

Specific empirical research on the housing market impact of the development of new construction methodologies and design criteria could also be undertaken. Although we have some idea as to the direction of the effects that extreme wind research will have, more detailed information on the probable impacts of this technology on both the stock demand for housing and the supply of new housing units would enable those countries affected by high winds to be more fully appraised of the benefits of developing such a new technology.

APPENDIX I

AN ECONOMIC INTERPRETATION OF HOUSING NEEDS

The needs estimation and projection methodology of section 2 has been constructed around a basic conceptual framework. This appendix analyses the economic elements which underlie the notion of housing "need."

In figure 1, the demand curve for housing is labelled as DD. Assume that DD reflects the demand for housing services by a typical family unit. The total amount of housing stock per family in existence, the fixed supply of housing, is represented by the vertical line SS. Assume that each unit of stock renders one unit of housing service. The intersection of the demand for housing services curve and the fixed supply determines the current price per unit of housing (P_E in figure 1).

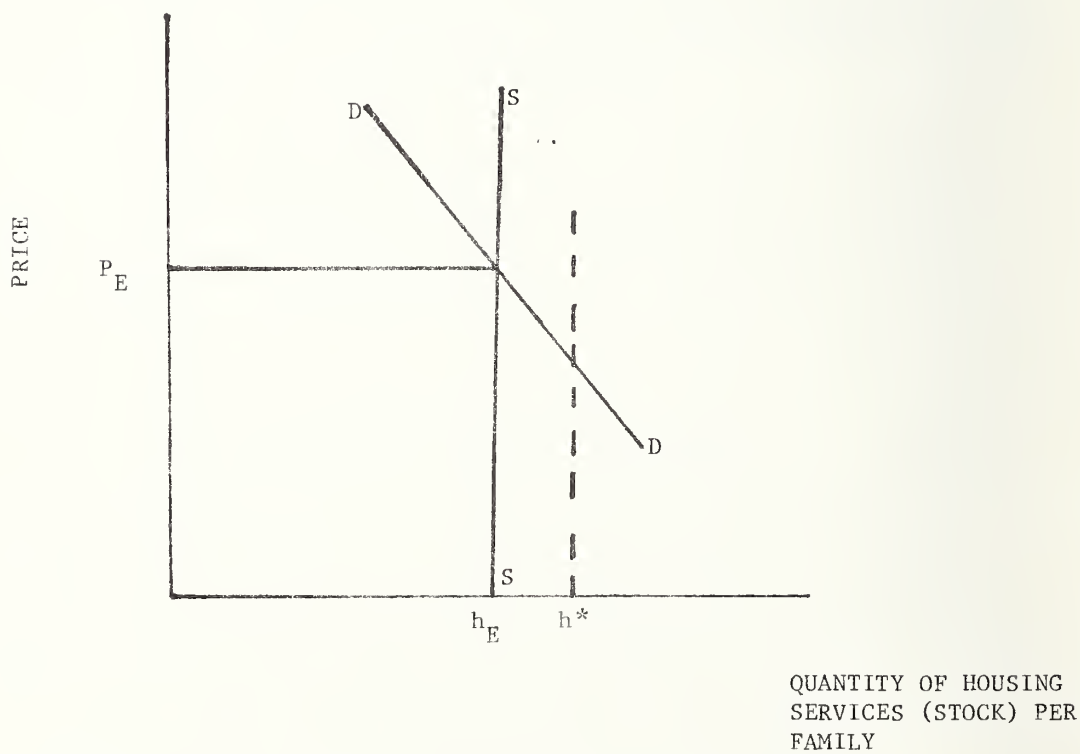

Figure 1. The demand and supply of housing.

Let us assume that quantity of housing per family is measured in square feet of living space. The equilibrium quantity of housing services (stock) per family, h_E, may be less than that which is deemed to be the minimally socially acceptable amount of housing space per family.

Assume for a moment that h* represents the judgment of that amount of housing services per family which is minimally acceptable. The total housing need in this instance will then be $(h^*-h_E) \times N$ (number of families). Of course h* may have been defined to be either larger or smaller than shown on figure 1. What information could be developed which would help guide the determination of where the standard ought to be?

In order to arrive at some conceptual guidelines for determining the standard from which housing need is to be measured, it is necessary to discuss the economics of the housing market. The housing market is composed of two basic markets whose interaction determines housing prices and the amount and kind of new construction. Economists generally describe housing as a stock-flow market.

First there is the stock aspect of the housing market. Consumers can be described as having demand for a quantity of housing services which are associated with a particular size of the housing stock. Such demand will be dependent upon the market price, the level of income, the market rate of interest, and a number of other factors. Figure 1 portrays the interaction of demand with the fixed stock supply. In figure 2, flow demand (dd), the demand for new construction, is derived from the demand for housing stock. At the price P_E in figure 2, given the existing stock of size h_E, there exists zero demand for additional units. (See panel B.) The actual size of the housing stock is in agreement with consumers' preferences. However, at price P_1, consumers would be willing to purchase h_1 units of housing service (stock). Thus, we see

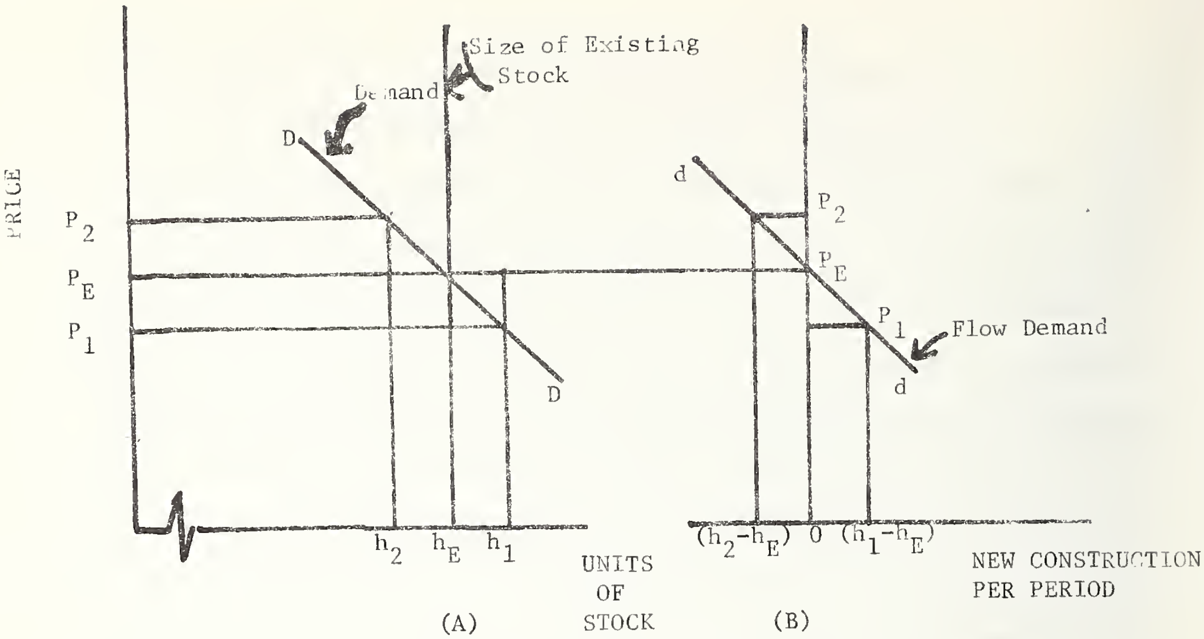

Figure 2. The demand for housing stock and the demand for additions to the stock

in panel B that the demand for new construction at price P_1 will be h_1 minus h_E units. Similarly, if price were P_2, consumers would be faced with too large an inventory of housing stock. At that high a price the flow demand would be negative, h_2 minus h_E and holders of the stock would depreciate the stock by undermaintaining the existing inventory.

The housing construction industry responds to the flow-demand for housing. Since housing construction approximates a competitive market, little reality is sacrificed if we add to the flow side of the market an upward sloping supply curve which describes the number of new housing units that housing producers would be willing to build at each particular service price. (Curve ss in figure 3.)

Figure 3 portrays the stock-flow housing market in equilibrium. The actual size of the housing stock, h_E, is such that at the equilibrium price, P_E, the desired stock is equal to the actual stock and the level of net construction will be zero.

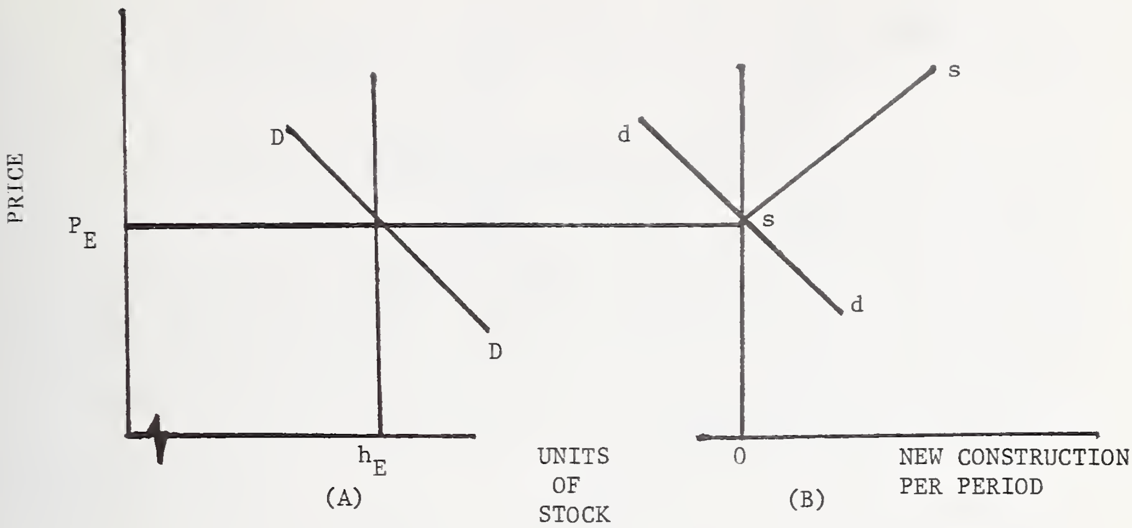

Figure 3. The housing market in equilibrium

If we introduce into this balanced equilibrium world a change in some underlying factor, be it an increase in income, a fall in the rate of interest, or a change in consumer tastes for more housing, which causes demand to increase, the service demand function and flow demand function for housing will both shift up. Graphically, in figure 4, this would be illustrated by a shift up in demand from D_1D_1 to D_2D_2 and in flow demand from d_1d_1 to d_2d_2. P_1 was the previous equilibrium price. It will not be maintained in the face of the increased demand. Price will immediately rise to P_2. The price of housing will fall by the end of the first period to P_n, because of the new construction activity which is generated in the flow market (panel B of figure 4). The intersection of d_2d_2 and the flow supply curve ss determines P_n. At the new end of period price, P_n, the housing industry will be producing Δh units per year. As these units are added to the existing inventory the flow demand schedule will fall because the housing stock of panel A will be growing. The size of the stock after the end of the first period

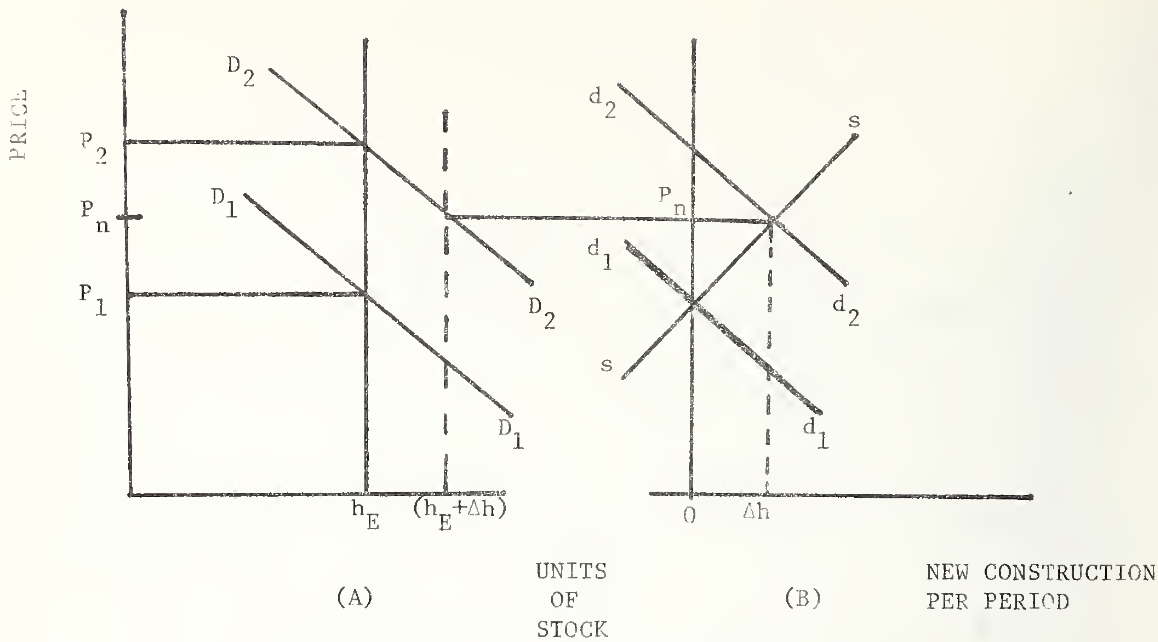

Figure 4. The adjustment of the housing market to an increase in demand

will be $(h_E + \Delta h)$ and the flow demand will be shifting down. Eventually, as the stock continues to grow and flow demand continues to fall the housing market will reattain the long-run equilibrium price of P_1.

The meaning of "housing needs" can now be put in the perspective of a stock-flow housing market analysis. Using such an analysis can shed some light on the issues that are involved in determining the minimally acceptable standard which is set as the target in a housing needs study. The obvious principle behind the establishment of a housing standard is to set a target that is worth filling. Often, in housing needs studies, the standard is set implicitly without considering the cost of attaining it. Determining a housing standard is equivalent to the specification of an amount of income redistribution that ought to take place. Accomplishing a given size of income redistribution will entail real resource costs. Explicitly identifying the size and beneficiaries of the income redistribution which is implied by a specific housing standard and asking how much it will cost in terms of resources will clarify the tradeoffs that are involved when discussing the concept of housing needs.

The following discussion provides an approach for determining the resource costs and income redistribution gains associated with reaching a target level of the housing stock. Before the redistributive nature of housing needs can be clearly seen we must consider the notion of the "benefits" associated with any investment, e.g., housing, which has as its object the reduction of the cost of a product or service. (Primary to the notion that a housing "problem" exists is the impression that housing is too expensive.) In these instances the basic measure of benefits can be thought of as a measure of "consumers' surplus." In a market situation (see figure 5), consumers purchase x_1 units of goods at price P_1. The dollar costs to consumers for these units is given by the

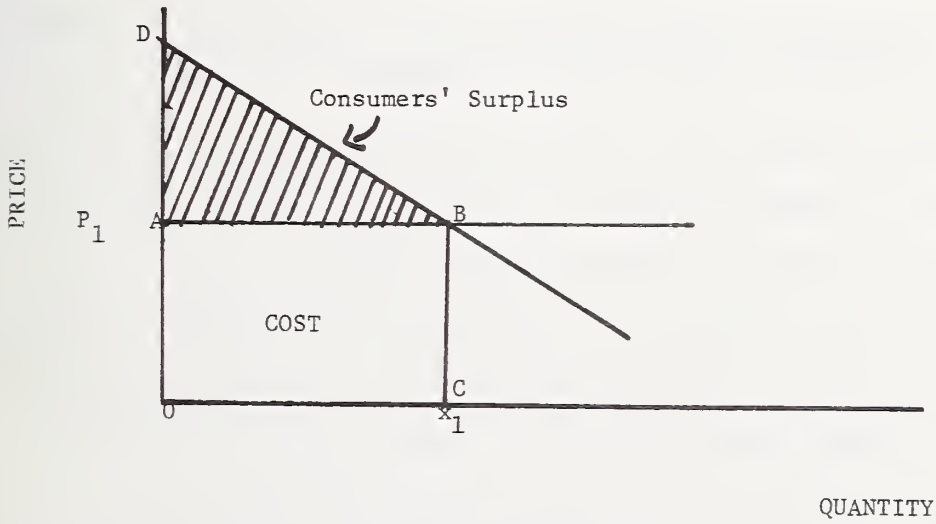

Figure 5. Consumers' Surplus

area OCBA. The total dollar value to consumers of the OC units can be measured by the area under the demand curve, OCBD. Thus, consumers realize a surplus of the amount ABD in their valuation of the x_1 units over their costs. This amount, ABD, is known as consumers' surplus.

The benefits to consumers of a fall in the price of a product due to increased supply can be illustrated in a like manner. In figure 6, if price falls from P_1 to P_2 consumers will realize an addition to their consumers' surplus of the amount DCBA.

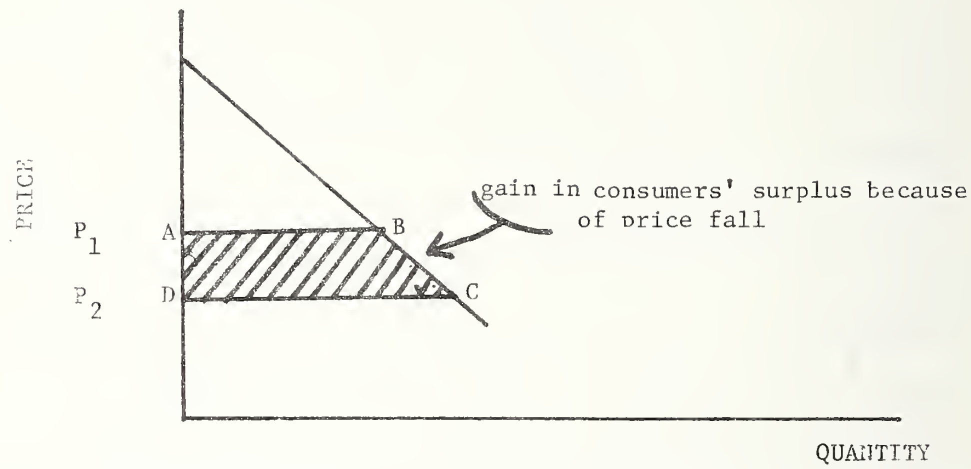

Figure 6. Increase in consumers' surplus due to a fall in market price

Programs which fulfill unmet housing needs are of direct benefit to those which occupy the new, standard, subsidized housing which has been built to satisfy the housing need. In addition to these direct beneficiaries, other groups will reap benefits which arise because of increases in consumers' surplus which will occur because of the impact of the needs fulfillment programs on housing prices.[1]

Returning to the stock-flow framework, the fulfillment of housing needs will result in addition to the stock of housing which will lead to lower housing prices for the rest of the inventory and corresponding

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[1]In addition to the redistributive effects which arise because of changes in consumers' surplus, housing programs may also generate other benefits. Examples of these are increases in sanitation and subsequent reductions in ill-health, reduction of density and subsequent lowering of crime rates, and increases in worker productivity because of the better housing conditions. These by-products of housing programs may or may not exist. In fact, a new housing program could aggravate crime rates, worsen the sanitation problem, and increase densities. Evaluating these other non-market benefits can only be done in the context of a specific housing program. They are not generalizable like the consumers' surplus effects. Thus, the non-market benefits can not be dealt with in this paper.

gains in consumers' surplus. Figure 7 illustrates this process. If we start off in an equilibrium position at price P_E in figure 7, but assert

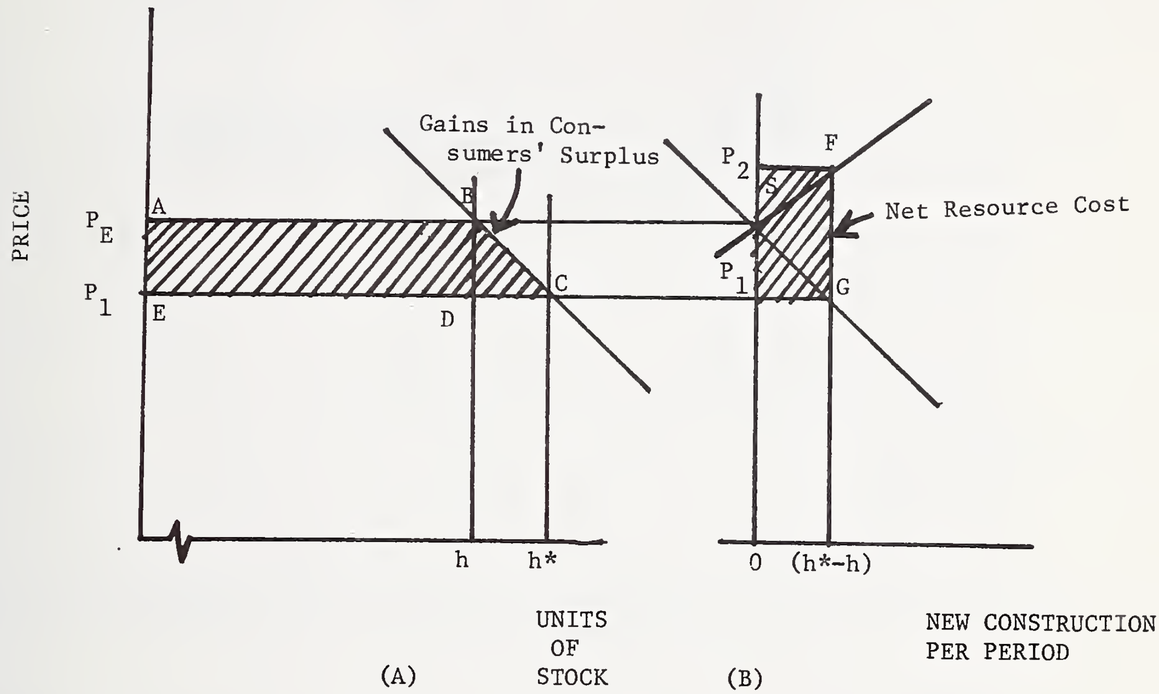

Figure 7. An example of the gains in consumers' surplus being greater than costs -- resulting from a program designed to meet housing needs

that the housing stock is not up to the desired standard of h*, in order to secure h* prices must fall to P_1. Those occupying the existing units will benefit by an amount of EDBA because of the fall in price from P_E to P_1. This dollar amount of gain can be considered to come at the expense of the existing owners of the stock since they will experience an equivalent loss in rental income. Thus one effect of realizing h* will be to redistribute income from one group (landlords) to another group (tenants). Additionally, area DCB will also be confered to those who enter the housing market in response to the fall in price from P_E to P_1.[1]

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[1]Society need not impose the cost of income distribution only upon the landlords. General tax revenues can be used to compensate landlords for their losses.

In figure 7 the shaded area in panel A can be thought of as the amount of income redistribution that is accomplished by attaining h*. But in order to provide the extra (h*-h) units the housing construction industry will require that the housing price be P_2. The total incremental resource cost of the (h*-h) units will be $P_2 \times$ (h*-h). Since consumers will pay P_1, but not P_2, the resource costs which must be met by the public sector will be $(P_2 - P_1) \times$ (h*-h). (See the shaded area in panel B of figure 7.) This subsidy cost per unit times the extra number of units represents the resource costs borne by the public sector of achieving the income redistribution effect of ECBA.

The income redistribution will arise as these extra units are added to the inventory and a fall in price is dispersed across the rest of the occupied inventory. Price will fall to P_1, given the subsidy, and the users of the existing stock, will realize a consumers' surplus gain from the lower prices.

It will not always be the case that the amount of redistribution will be larger than the public cost of achieving that level of redistribution. Consider figure 8, where the subsidy required, P_1HTP_2, is greater than the gain in consumers' surplus, DCBH. In this case, meeting the current housing need of (h*-h) confers much less in the way of redistribution change per dollar of resource cost than depicted in figure 7.

Within the context of this stock-flow model, three factors interact to determine how expensive the income redistribution associated with a particular minimal standard or target (specification of h*) will be. They are: (a) the price elasticity[1] of the stock demand for housing,

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[1]The elasticity of demand is the ratio of the percentage change in quantity demanded divided by the percentage change in prices. The elasticity of supply is the ratio of the percentage change in quantity supplied divided by the percentage change in price.

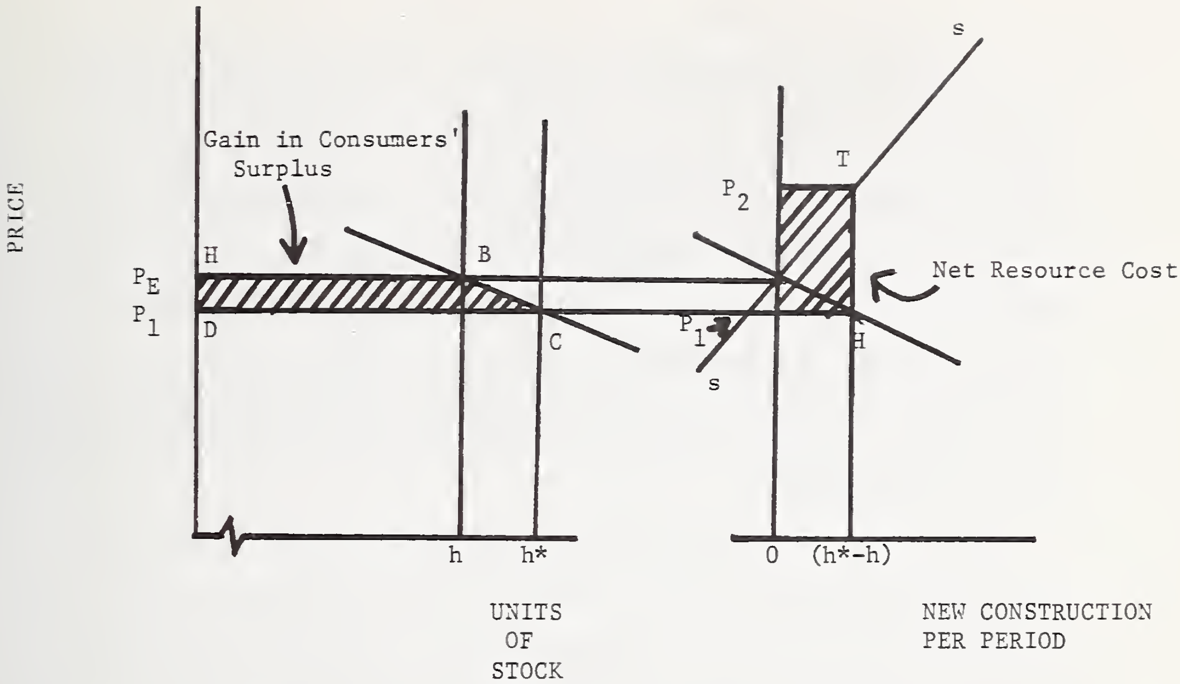

Figure 8. An example of the benefits of fulfilling housing needs being less than the costs of meeting those needs

(b) the price elasticity of the supply of new construction, and (c) the relative size (as a percent of the size of the existing inventory) or the housing needs gap. (See appendix 2 to this paper for a more detailed discussion of these conditions.) These factors can be manipulated to describe one upper limit of the housing standard. The size of the housing gap (h*-h) can be expressed as a fraction of the original size of the housing stock, i.e., as $\beta \times h$ where β is a constant multiplier equal to (h*-h)/h. This gap parameter can be used to describe where a housing standard, h* max. implies net resource costs equal to the amount of income redistributed. In equation (1), h* max. is the size of the stock of housing such that any additions to the stock past h* max will result in a housing needs construction program whose public sector resource costs are greater than the dollar value of its redistribution impact.

(1) $h^*_{max} = h + \beta^* h$

In this model β^* depends on the ratio of the stock demand price elasticity of housing to the price elasticity of new construction supply. If the standard set in a needs study implies a standard where $\beta > \beta^*$, then the housing standard specifies that achieving \$1 of income redistribution entails more than a \$1 net resource cost. If $\beta < \beta^*$, fulfilling housing needs will result in housing programs where the redistribution gains are greater than the net resource costs which must be borne by the public sector.

Although it is the case that housing needs studies are bound to involve normative elements, the discussion above implies that there are economic factors relating to the real resource costs of redistribution which can guide the setting of the housing standards. These factors are rooted in the housing market characteristics of a particular economy. The first economic characteristic of impact is the price elasticity of demand. It will depend upon the underlying tastes and preferences of the consumers in a particular area. It will be influenced by an area's level of income. Of equal importance is the elasticity of supply. It also will depend upon many institutional factors which vary across economies. The degree of competitiveness in the housing industry, the level of production technology employed within a particular country, and the responsiveness of the housing industry to innovation are three underlying factors. Nevertheless the desire for greater equity[1] and a willingness to use the housing market as a tool to increase equity, fundamentally lies in the hands of the public policy decision makers. A housing needs study can be used to specify the real resource costs of

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[1]Greater equity is concerned with the redistribution of income from higher income groups in the population to those at the lower end of the distribution.

achieving greater equity. However, other methods are available to the public sector for income redistribution, e.g., negative income taxes, food subsidy programs, and the non-enforcement of laws against theft. The cost effectiveness in redistributing income housing programs must be compared to these other alternatives.

The income redistribution goals of housing or other welfare-type programs generally are not examples of potential Pareto[1] improvements. Thus care should be taken not to interpret cost-effectiveness computations as ranking redistribution schemes on the basis of efficiency grounds. Whether or not the equity or redistributive effects of such programs are justifiable must be decided, not on economic grounds, but on the views of the policy makers towards the desirability of attaining a more equitiable distribution of income at some cost to real income.

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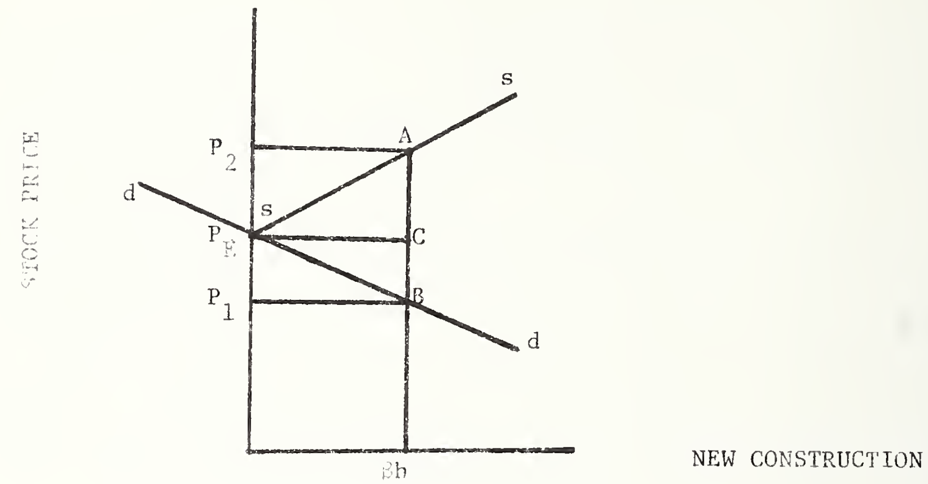
[1]A potential Pareto improvement is one in which an economic re-arrangement can result in the gainers being able to more than compensate the losers. In the case of filling housing needs the gainers (the tenant classes) will not be able to compensate the losers (the landlord classes) and still remain better off.

APPENDIX 2 - Derivation of the Housing Standard

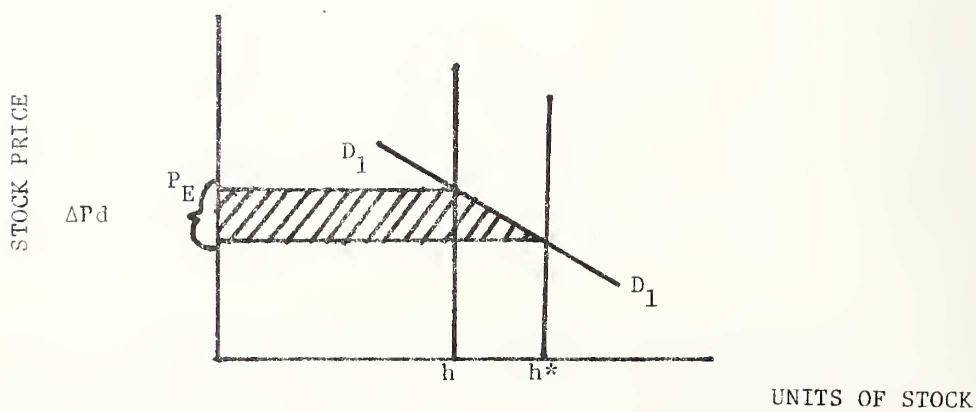
The resource costs borne by the public sector of a housing program designed to meet the gap in housing needs will be distance $\overline{AB}$ in figure 1 times the size of the gap, which will be $\beta \cdot h$. Distance $\overline{AB}$ will be



the sum of the change in price, $\overline{CB}$, that moves along the demand curve, dd, (ΔPd) plus the change in price resulting from moving along supply curve, SS, distance $\overline{CA}$, (ΔP_s). Thus, the subsidy cost, SC will be

(1) $SC = (\Delta Pd + \Delta Ps)\ \beta\ h$

The redistributive effect can be measured as the increment in consumers surplus under the stock demand function of Figure 2.



It will be the change in price ΔPd times h plus (utilizing straight line demand curves) $1/2\ \Delta Pd \times \beta h$. Thus the benefits, B, will equal.

(2) $B = \Delta Pdh + 1/2\ \Delta Pd\ ph$

Setting redistribution effects equal to implementation costs, we can proceed to solve for the value of β which can be used to determine the housing standard at which implementation costs are matched by income redistribution effects.

(3) $(\Delta Pd + \Delta Ps)\ \beta h = \Delta Pdh + 1/2\ \Delta Pd\beta h$

Rewriting (3),

(4) $2\ \Delta Pd\beta h + 2\Delta Ps\ \beta h = 2\ \Delta Pdh + \Delta Pd\beta h$,

Subtracting $\Delta Pd\beta h$ from both sides and dividing by $h \cdot \Delta Pd$ yields

(5) $\beta + 2\beta\ \Delta\ Ps/_{\Delta Pd} = 2$,

since $\Delta Pd = \beta h \cdot \frac{P_E \cdot 1}{Ed \cdot h}$ and $\Delta Ps = \beta h \cdot \frac{P_E \cdot 1}{Es \cdot h}$,

(where Ed is the price elasticity of demand and Es is price elasticity of supply) then Equation (5) can be rewritten

(6) $1/2 + \frac{Ed}{Es} = 1/\beta$,

which can be rewritten to solve for β

(7) $\beta = 1/2\ \frac{Ed}{Es} - 1$.

Interpreting equation 7 yields the following conclusions:

° the greater the size of the gap between the standard and the actual size of the inventory, the less likely it will be that the housing needs are worth filling,

° knowledge of the degree of price elasticity of stock demand and flow supply is an important input in the determination of housing needs,

° a combination of very elastic demand and very inelastic supply will combine to make housing needs not worth filling, and

° a combination of inelastic demand and elastic supply combine to make the filling of housing needs socially profitable.

APPENDIX H

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 developing nations characterized by high wind conditions.

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

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Report Presented at Regional Meeting on Development of Design Criteria and Methodology for Low-Rise/Low-Cost Buildings to Better Resist Extreme Winds

Report

This 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.

The information is based on a review of over 30 printed resources (listed on pages 47 - 50). In addition, the following individuals kindly contributed useful information and suggestions:

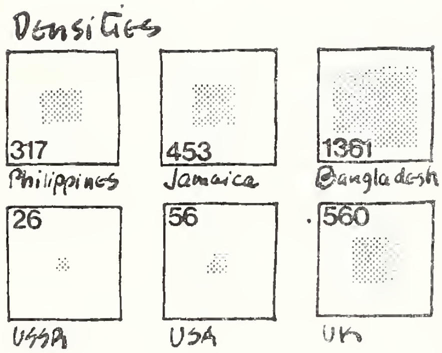
John Edmondson, Paul Campbell (International Cooperative Housing Development Association); Wallace Campbell (Foundation for Cooperative Housing); Ignacio Armillas, Giovanni Carissimo, Evner Ergun, Alberto Gonzales-Gandolfi, Rafael Mora-Rubio, Mario Piche and Ludwig Van Essche (UN Center for Housing, Building and Planning).

Stephen A. Kliment
June 27, 1975

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

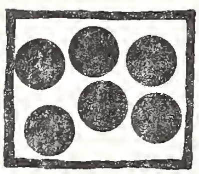
N.A. Not available
▲ 42% of all urban dwellings have one room only, compared to 24.9 for rural (Ref.4) ▲▲Ref. 4 puts it at 2.7, but this appears to ignore emigration.

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.

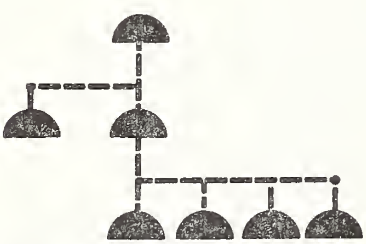
- There are other ramifications to these population patterns. The economics in all three countries are highly labor intensive, so that children are in the Philippines, for example, seen as an economic asset. Family planning efforts designed to bring population more in line with food and other resources 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 overcrowding 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

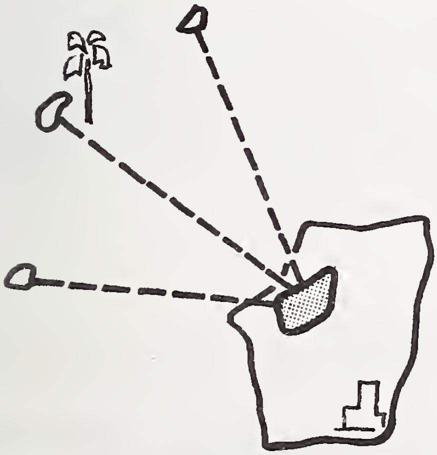
- There are these other factors: shortage of funds, markets not large enough to stimulate economics of scale in prefabricated construction, undeveloped transportation and distribution systems, a shortage of skilled labor and, by and large, low standards of workmanship.

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.

Round shapes ignored needs and traditions of occupants

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 of any kind 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 towns serve as reception centers for migrants, and help them adapt to urban life.

●● "Uncontrolled settlements"

"Uncontrolled settlements", a term which covers "bustees", squatter towns, and "transitional communities", have come in for sharp comment as to their socio-economic merit in developing countries. Following is a summary of arguments for and against this complex phenomenon:

● Contributions to a sound urbanization process: (Ref. 15)

1. They provide migrants with housing at rents they can afford

2. They serve as a reception center for migrants, helping them to adapt to urban life

3. Within their own society they are a source of jobs in small-scale and marginal enterprises

4. They provide accommodation at a reasonable distance from sources of jobs in the adjoining town or city.

5. The communal organizations provide support during unemployment and other difficult times (a study by a Presidential Council on the Squatters of Manila, the Philippines, found, in a squatter community of 2,625 families, 29 organizations, with 65% of family heads interviewed belonging to at least one organization -- Ref. 16).

6. They encourage (and reward) small-scale private enterprise in the field of squatter housing.

7. In many cases, they provide their own security system of a caliber that Government would find very costly to furnish.

● Limitation

Some planning professionals question the merits of uncontrolled settlements, due to the public health, educational, family health care, circulation and other problems which these settlements find hard to solve. The absence of "sites and services" aggravates these conditions.

● Six fallacies

Several fallacies of thought have arisen around the squatter town problem:

1. <u>"The more you improve squatter settlements, the more migrants you attract."</u>

   <u>Response</u>: Social and economic stimuli will continue to attract immigrants to urban areas no matter what the living conditions.

2. "Improvements in rural areas can significantly reduce urbanization." (Ref. 17)

o Response: "Without urbanization and industrialization, there is little prospect of rural development. The real question is: 'how is it possible to prevent the exchange of rural poverty for urban misery?'"

3. "Population control measures can substantially effect urbanization in this century." (Ref. 17)

o Response: "...The average age of migrants to urban areas generally falls between 20 and 30 ... Therefore, most of those who will migrate between now and the end of this century are already born. An immediate and decisive decline in the birthrate would not affect the migrant population until the 1990's ..."

4. "Decentralization of urban growth will reduce problems of urbanization." (Ref. 17)

o Response: "Large scale capital investment in a number of rural areas designated as growth centers, may tend to attract imigrants to relatively small towns which, at least in the short and medium term, would (lack) the financial and staff resources for providing community services, and otherwise dealing with a rapidly growing population."

5. "Squatter settlements are home largely for rural and uneducated groups."

The vocational breakdown of squatter communities varies widely

o Response: Squatter settlements vary widely. Residents of some are close to their rural backgrounds. In others, there is a notable proportion of professionals, such as engineers and doctors.

6. "Nearly all squatter town inhabitants are multi-member families."

○Response: Ref. 18 indicates that the ratio of single person families is high (in Bangladesh: 15% in Dacca to as high as 29% in the more industrialized Chittagong). This is seen as an undesirable trend from a sociological viewpoint.

●●Sites and services

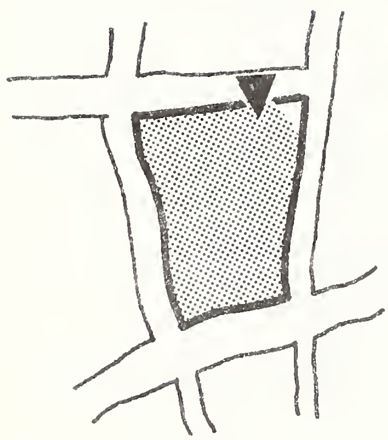
A policy that is becoming more and more accepted is to focus on improving squatter settlements. This is done by providing so called "site and services". Land, water supply, electric power and waste disposal are provided. Better structures come along with appropriate help as the settlement becomes more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

"Sites and services" implicitly recognizes that squatter settlements can be viable economically, and that their main problem is to keep to a minimum their sanitary, educational and other negative aspects.

●Types of "sites and services"

Following are four forms of "sites and services" (Ref. 19):

1. Subdivide land alone -- only an unimproved building lot is provided
2. Subdivide land and instal basic public utilities and some community facilities
3. Subdivide land with a full complement of public utilities and community facilities
4. Install a combination of public utilities and community facilities in existing residential areas



temporary structures inside walls of down-town block owned by government are leased to transient migrants

An interesting variation on the above are the so-called "poles" of India. An entire down-town block owned by the Government is leased to a private individual or company, which then rents space to transient occupants. The block is entered only through a guarded gate, with rent collected weekedly. Temporary structures inside the walls serve newly arrived migrants who are close to day work and temporary job sources, and have the opportunity of acquiring more permanent jobs and housing.

● Hierarchy of public utility services

As the "sites and services" concept evolves, a hierarchy has emerged among the public utility services a government may provide.

In the top category are water supply and waste removal, since lack of purity in the one and improper location and design of the other are the primary causes of disease and mortality in squatter settlements.

Waste and water lines, with sanitary core if possible, are a minimum standard

Water and waste lines, if possible linked to a sanitary core, constitute a minimum standard.

Into the second category fall such utilities as electricity and public lighting, sidewalks and paved roads, gas and telephones.

Public utilities make up one of three components of the "sites and services" concept. The other two are community facilities (or access to them) and the land itself.

● The importance of land

From a public health standpoint, proper water and sanitary systems are supreme. From a social standpoint, the security of land is supreme. Most families, given technical assistance, will find a way to erect a dwelling, so long as they can count on security of land.

To bring down the cost of land to the occupant, a variety of arrangements is possible. An approach tried in Jamaica offers a 40 year leasehold on land at a modest rental; this is renewable for 40 years more. The lessee is responsible for erecting housing and paying for utilities. The only subsidy is in the form of technical assistance.

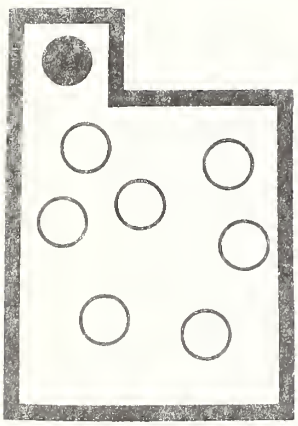
● User requirements

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.



Need for personal space and privacy in crowded houses is one issue that requires further research

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:

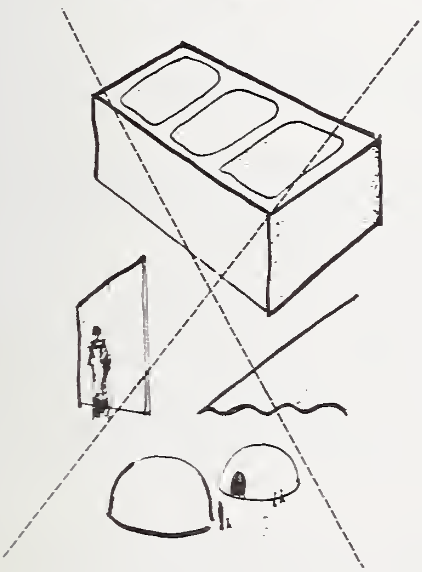
- Health standards in existing environments.
- Need for personal space and privacy in overcrowded housing.
- Social activities in the neighborhood and community.
- Activities of specific groups such as children.

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.

New construction materials are rejected, at least at the start



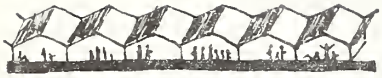
The opposite has been the experience in Peru. Peru is not a part of this report, but is a useful object of study nevertheless. New construction materials always run into a strong initial period of rejection, and only a few have survived this reaction and kept a place in the market (Ref. 1). Examples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

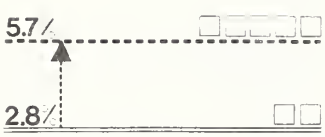
Consumer interest was found to be low because prefabricated houses cost only a little less than brick and concrete houses and a good deal more than adobe houses; they looked too uniform; and the public did not really appreciate the savings inherent in the shorter construction time.

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 "bayanihan") is widely accepted in the building of dwellings. It is discussed in greater detail later in this report.

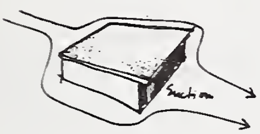
Housing characteristics

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

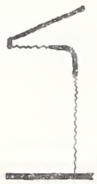


Windstorm resistance can be notably improved by various simple measures. These include horizontal bracing of certain types of roofs over houses made of adobe masonry and other small unit construction; a more rational disposition of openings in bearing walls; reinforcement of critical areas of a building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

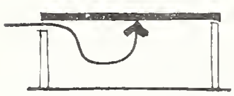
Large overhangs invite problems

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.

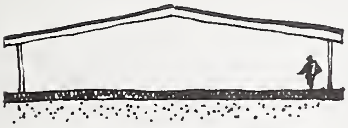


Openings can cause dangerous internal pressures

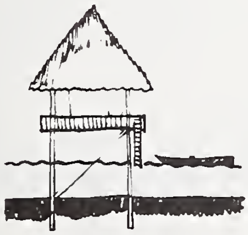
Unfortunately, the internal pressures developed in buildings with openings are usually not considered in design. Roof failures have been caused by wind which penetrated the structure and pressed up on the roof from beneath.

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.

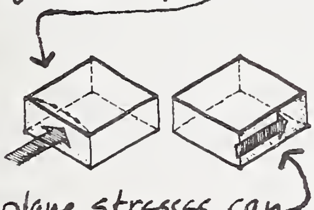


Mat footings spread loads over a greater area



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

Out-of-plane pressures can cause failure through bending



In-plane stresses can cause failure of wall through shear

Construction technique

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

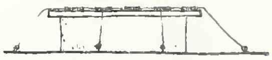
- Foundations: Load transmission to soil becomes less critical since low-rise dwellings of one or two stories do not generate a high dead load. Where flooding is not common, rectangular footings of plain or reinforced concrete or gravel are used.

  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.

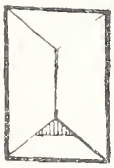
- Walls: Walls are either structural or non-structural. When non-structural, they merely serve as an in-fill for a frame and their constribution to the overall structural resistance of a building to wind pressure should be minimal.

  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.

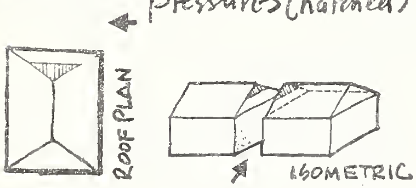
  Wind stresses on walls are either out-of-plane bending or in-plane stresses. Out-of-plane pressures (when wind acts directly at right angles to a wall) cause deflection and eventually failure. Tornadoes common in Bangladesh have pressure drops so strong and sudden as to cause an actual explosive action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

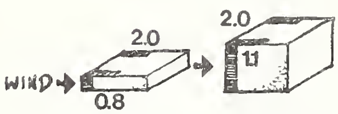


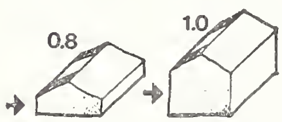
Builders sometimes use an ingenious network of cocoanut matting and cables to anchor roof down.



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.

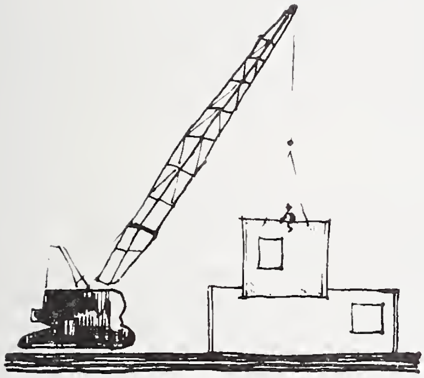
Indirect effects occur when wind loads are transferred to lateral walls, causing stresses. If this mix of pressures on the roof is strong enough, the capacity of the connections will be exceeded and the roof will be lifted off. This brings additional danger since every roof has a structural role as a 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 industralized housing must not conflict with individual uses, traditional preferences and outlook.

In the Philippines, few companies make prefabricated components; included are private firms producing 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.

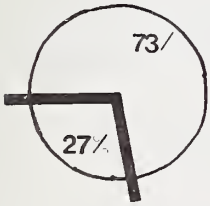


In Bangladesh, reinforced concrete shell roofs in a shape of a hyperbolic paraboloid have been used, using one inch pre-cast reinforced concrete elements, with concrete connections made on site.

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

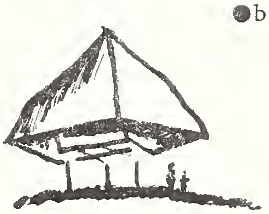
In Bangladee cities, only a small proportion of housing is considered permanent or semi-permanent



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 "barangay" 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.

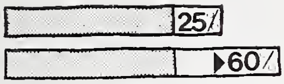
Ranking cities in the Philippines have between 10 and 45 percent of their populations in slums or in squatter areas; the national average is 5 to 6 percent. Filipino squatters are not said to be shiftless people, but well motivated and resourceful.

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.

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.



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

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.

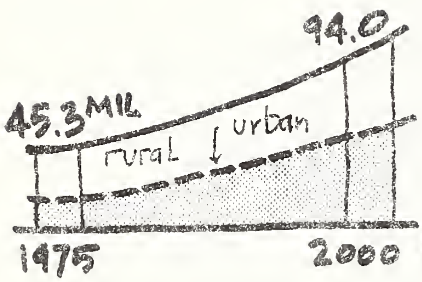
Yet the Filipino economy as measured by its GNP has risen at an average annual rate of 6.6 percent from 1968 to 1973. Average per capita income ($130 in 1970) also rose, and is expected to double in the next 10 to 15 years.

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. Roxas 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.



Population will more than double in one generation. By 2000, half the population will be urban

Population trends

Table 3 shows the results for the Philippines of a world-wide survey conducted by the United Nations to identify population trends. The information is updated through June 1974; population figures are broken down by urban and rural, and indicate rates of increase. Figures for 5-year periods from 1975 to 2000 are given.

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

TABLE 3. Population trends in the Philippines, Jamaica and Bangladesh 1975 - 2000

	Population (in thousands)			Percent	Annual Rate of Increase Preceding 5 Years			
	Urban	Rural	Total	Urban	Urban	Rural	Total	Urban Rural Difference
a. PHILIPPINES								
1975	15837	29468	45305	34.96	4.51	2.70	3.32	1.81
1980	19936	33594	53530	37.24	4.60	2.62	3.34	1.98
1985	25106	37990	63096	39.79	4.61	2.46	3.29	2.15
1990	31272	42132	73404	42.60	4.39	2.07	3.03	2.32
1995	38369	45633	84002	45.68	4.09	1.60	2.70	2.49
2000	46068	47956	94024	49.00	3.66	0.99	2.25	2.66
b. JAMAICA								
1975	830	1199	2029	40.89	3.51	0.22	1.50	3.29
1980	973	1199	2172	44.79	3.19	-0.00	1.36	3.19
1985	1126	1190	2316	48.64	2.93	-0.16	1.28	3.09
1990	1291	1173	2464	52.38	2.72	-0.27	1.24	2.99
1995	1460	1149	2609	55.97	2.47	-0.43	1.14	2.90
2000	1619	1107	2726	59.39	2.06	-0.74	0.88	2.80
c. BANGLADESH								
1975	5296	73616	78912	6.71	4.87	2.78	2.92	2.09
1980	6850	85243	92093	7.44	5.14	2.93	3.09	2.21
1985	8919	98788	107707	8.28	5.28	2.95	3.13	2.33
1990	11657	114235	125892	9.26	5.36	2.91	3.12	2.45
1995	15131	130402	145533	10.40	5.22	2.65	2.90	2.57
2000	19395	146117	165512	11.72	4.97	2.28	2.57	2.69

Courtesy United Nations

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.

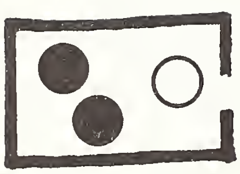
A useful if not totally representative picture emerges from a survey of housing conditions in the Delacree Pen district of Kingston (Ref. 8). Delacree Pen is the site of an urban renewal project. The survey disclosed among other things that:

- 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.

A notable feature of a Delacree Park urban housing project (located in the Delacree Pen District) is its character as a housing cooperative. Such a cooperative, established with government, World Bank or other subsidies, is a useful vehicle for erecting housing, in the construction and maintenance of which the occupants have a strong social and economic stake.

Eventually some 350 units will be built in Delacree, in the form of wind-resistant 2-story garden apartments arranged in clusters of six. The program has been well-received -- both in its social and its economic context (90 units have been built to date).

One difficulty has been adherence to occupancy standards -- a common problem in developing countries. Delacree Park units, which have a living room and 2 bedrooms, may house up to six people, according to government standards of two to a room. In practice, families sometimes have as many as 7 children; consequently the government, knowing it cannot afford to subsidize such supplemental spaces, will permit its occupancy standard to be exceeded by up to 50%.



Occupancy of 50% over standard is sometimes condoned

By and large, cooperatives are now an accepted method for erecting housing in Jamaica. The Jamaican Ministry of Housing has created a Division of Cooperatives and Condominia to coordinate this effort.

Table 4: 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

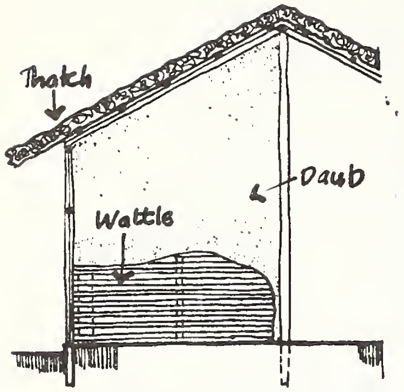
Part 2: DWELLINGS CLASSIFIED BY TYPE

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

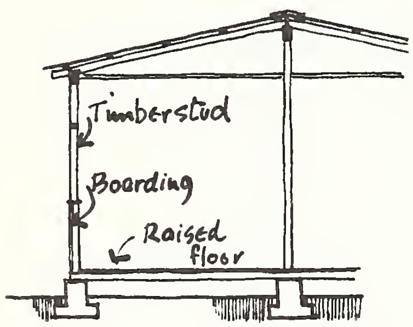
Part 3: PERCENTAGE DISTRIBUTION OF DWELLINGS BY NUMBER OF ROOMS

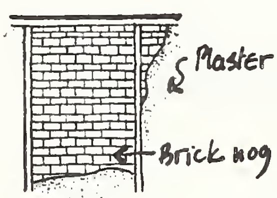
No. of Rooms	Total	Urban	Rural
1	32.7	42.3	24.9
2	26.3	19.6	31.7
3	16.1	11.7	19.7
4	8.5	7.5	9.3
5	5.3	5.9	4.9
6	2.8	3.3	2.4
7	2.6	3.4	1.9
8 or more	5.8	6.3	5.3
Total	100.0	100.0	100.0

● Housing characteristics
(See also Table 4)



Traditional low-cost houses





Detail

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).

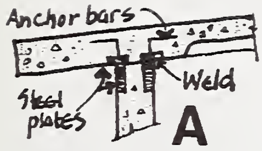
○1. Wattle and daub (4%): Until the 1930's rural owners built most low-cost houses in this fashion. The framework of wooden posts and beams, with sticks interwoven horizontally between the posts, was the wattle. This was daubed inside and out with mud from available clay, to create solid walls. The roofs were pitched and made of a thatch made from bundles of dried leaves and tied in place.

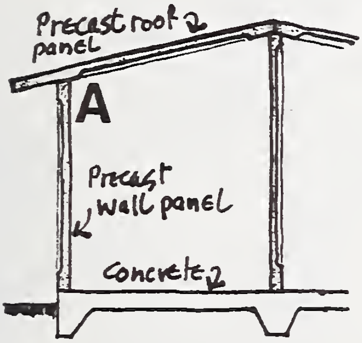
○2. Timber stud and horizontal boarding (36.9%): Roofs were pitched, made of timber rafters covered with corrugated iron sheets or wooden shingles.

○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

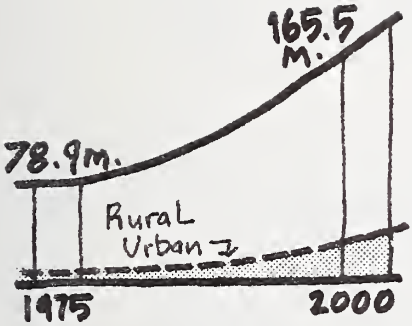
Despite the frequency of hurricanes in the Caribbean, direct hits on Jamaica are few when compared with the number of tropical storms which pass within 150 miles of the island (Ref. 4).

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.

Total population will rise slightly. Rural population will actually decline

- Population trends

Table 3 shows the results for Jamaica of a world-wide survey conducted by the United Nations to identify population trends. The information is updated through June 1974. Population figures are broken down by urban and rural, and indicate rates of increase. Figures for 5-year periods from 1975 to 2000 are given.



Population will more than double in one generation

Bangladesh

- Socio-economic aspects
- Population trends

Table 3 shows the results for Bangladesh of a world-wide survey conducted by the United Nations in an effort to identify shifting population patterns. The information is updated through June 1974. Population figures are boken down by urban and rural, and indicate rates of increase. Figures for 5-year periods from 1975 to 2000 are given.

Bangladesh, a nation with one of the highest population densities in the world, is also troubled by these additional dilemmas:

- Steady population growth has forced families to live on land that is increasingly substandard and subject to wind-induced flooding.
- Periodic flooding of low-lying land further increases density -- from about 1400 per sq. mile to a temporary 40,000 per sq. mile in coastal storm regions, as families flee to land left dry.
- The partition of 1947 left the higher land, with its supply of solid construction materials such as stone and timber, on the Indian side of the boundary, while the Bangali population on the treeless alluvial plain was left with few resources for protection.

Measured by gross domestic product, Bangladesh is 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 imminent. 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.

- Attitudes to disaster

A report prepared after the disastrous November 1970 cyclone (Ref. 22) reveals an interesting set of attitudes. 57 families of various economic levels in the community of Galachipa were surveyed. Dr. Aminul Islam who compared attitudes after the May 1965 and November 1970 storms, found that:

many families must reach safe shelter by boat

- After 1965 no family wanted to move, though many families rebuilt their houses using higher plinths and stronger posts

- After 1970 only 5 families wanted to move; 56 still lived on the site of their old home

- 38 families were still living more than 1 mile from a "pucca" (well-built) structure that could shelter them in a storm

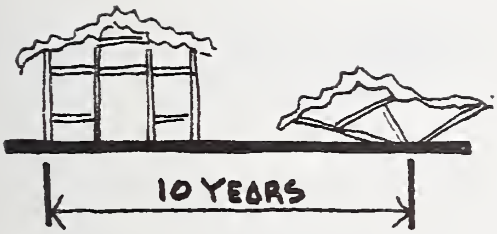
- 14 were living over 3 miles from a pucca structure

- 19 families needed a boat to reach a pucca structure

O Only 24 families would spend their money first on housing. The others' priorities: 1) food 2) cattle

The majority said that if they had the money they would build one small pucca house, rather than several kutchas (or low quality houses) or corrugated iron (CI) houses.

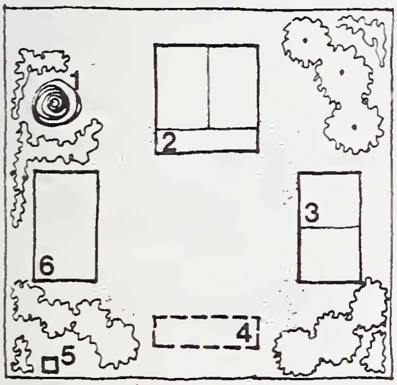
In sum, the survey found the families fatalistic and pessimistic over protection measures.



● Rural housing must be seen as part of agricultural system

Bangali villagers see housing as part of their agricultural system, rather than as a building discipline as in the West. Thus, house building and repair is seasonal, like other farm activities. It helps relieve unemployment. Villagers will grow building materials for houses on their own land. A tree, for example, will serve as a fruit-bearer, windbreaker and fuel, until needed as a building material.

Similarly, a man's jute and the earth itself serve him both for agriculture and for building.



Family compound

1. Haystack
2. Sleeping
3. Storage, kitchen
4. Workshed
5. Latrine
6. Cowshed

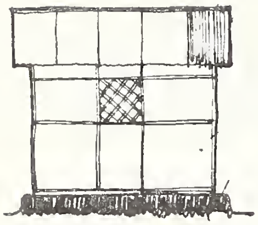
Due to the climate, the bamboo "kutcha" house (described below) itself decays over a 10-year cycle, if not destroyed by a storm before then.

Any program for housing that ignores these rural attitudes risks failure.

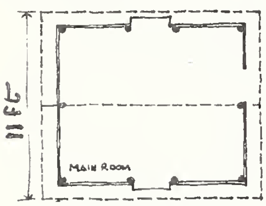
● Housing patterns

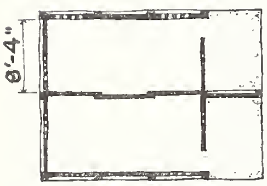
O Rural: The rural population is divided into land owners and landless laborers. One out of five villagers is landless. The average land owning villager has 1.5 acres and usually rents another acre from well-to-do villagers. Houses tend to be scattered throughout the village.

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

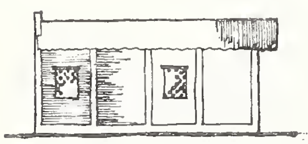


Typical rural house with bamboo posts, fencing and corrugated iron roof.





Typical low-cost house with brick walls



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.

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.

● What happens to the houses

In the 1970 storm, it was the wind that caused initial housing destruction; the storm surge accounted for people and animal casualties.

○ Here is how the materials fared (Ref. 22):

Material	Condition
Thatch	Destroyed or lost
Bamboo matting	Usually destroyed or lost
Wood or bamboo supports	Broken, recovered, reusable
CI sheet	Damaged, in part reusable
5 in. brick	Destroyed. If preserved, hard to reuse
10 in brick	Intact if concrete roof

A small Buddhist community builds sturdier houses, but partial losses after a storm often cost more than it costs to replace a kutcha house.

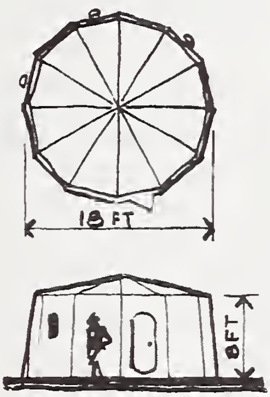
Middle and upper income rural families use Cl sheet and wood. These resist wind and water if well-built. If not, owners can retrieve their materials and rebuild, unless the materials are scattered by flood waters.

- Other types of housing

O 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.

Simple machine makes blocks made from soil and cement

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.

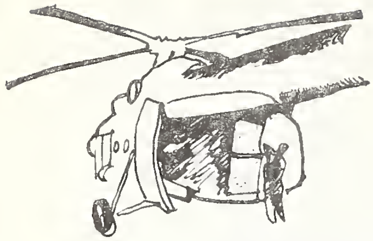


Pie-shaped CARE house (Prototype 1) was sturdy, but shape caused some problems

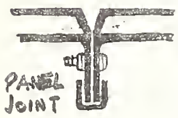
Several variations of material and configuration have been formulated for laboratory testing, prototype construction and wind testing of full-scale units.

Four prototypes have been developed so far. These are:

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

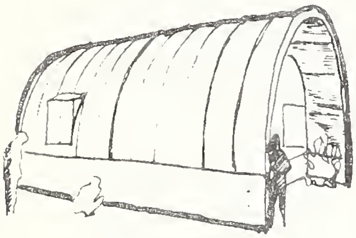


faulted the house for its roundish dome-like shape. This made partitioning difficult and made it unsuitable for low-income families -- especially the 80 percent Muslim families with their tradition of isolating women in one part of the house.



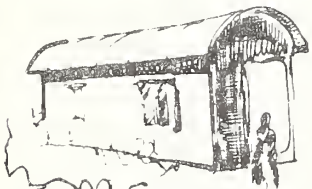
CARE Prototype 2 has small, light components, is more traditional shape

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 shapes.



3. A structure using the above materials but geared for use in larger, non-residential buildings.

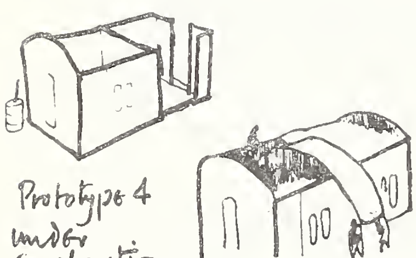
4. A structure designed to substitute the jute/plastic material for the traditional thatch or corrugated metal roof and its customary wood or bamboo support rafters. The new roof of this prototype was designed to fit over either traditional or new walls.



Prototype 4 is designed to be used with more of traditional elements

These four prototypes can be anchored directly to the soil or to standard perimeter footing foundations.

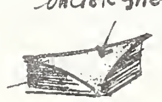
Many of these prototypes have been used for other than residential purposes, and as such have been very popular. These uses have included a medical operating theater, dispensary and office. From a socio-economic view, this is seen as a useful lesson, in that citizens of Bangladesh can get to know the structures in a service role without having to accept them suddenly into their personal lives as homes.



Prototype 4 under construction

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).

Concrete shell



is anchored to brick base

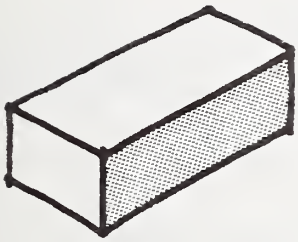
O Reinforced concrete shell roofs of hyperbolic paraboloid shape have been used for industrial and suburban housing. The roof is anchored to the supporting brick walls by means of half inch mild steel bars at the corners.

●● 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.

● The Delta Housing Program

Beginning in 1972, a rural cooperative housing scheme got underway in the Delta area, a coastal strip of 4000 sq. miles with 4,270,000 inhabitants. Its main features have been:



Hand-pressed blocks are made of soil and 10% to 12% cement. Corrugated iron roof sheets are anchored to walls with tie-rods

- Erection of 7500 10 ft X 20 ft soil-cement block houses on burnt-brick foundations to withstand severe flooding and substantial cyclonic winds.

- A cooperative plan under which farmers and fishermen undertake to repay 50% of the cost of the house out of agricultural income to their local cooperative society. These societies are linked into a complex cooperative system known as the Integrated Rural Development Program (IRDP). (The other 50% of cost is subsidized).

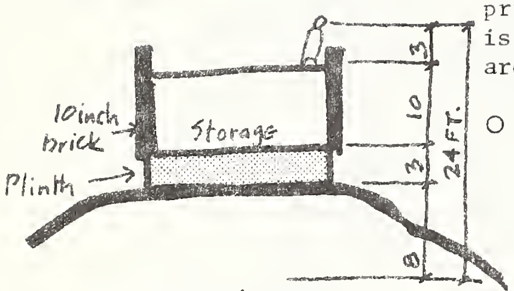
- One aim is to reduce the villager's concern about the annual fate of his house, and thus to attend more to long range agricultural planning and development; and, further, to reduce his (and the government's) repair expenditures after every cyclone season.

  The program, its successes and limitations are described in more detail in Ref. 23

● Siting

Creation of either artificial barriers or embankments in low-lying areas (so as to either shield houses or raise them above mean high flood levels) has been proposed as part of any new wind and flood protection program.

It was found, for example, that Dutch "polder" type barriers have protected many houses in recent storms. Even when the water breached the barriers and caused flooding, it did not destroy the houses.



Semi-private "pucca" shelter is raised above storm surge level

By and large, raised embankments or platforms are thought a better approach. A semi-private shelter system based on this concept is discussed in Ref. 22. Its main features are:

- Build a platform 8 ft above mean high tide level. Over it, erect a small (60 sq. ft.) "pucca" quality shelter house (10 in. brick) with a flat roof (behind a parapet) 13 ft. above this platform (includes a 3 ft. plinth).

- Now a man, woman or child standing on such a roof platform would be at least 24 ft above mean high tide level, and this is said to be protection against even the worst onslaught of a storm surge.

- Each 'bari' or community would be responsible for building and maintaining such a shelter, the interior of which could serve as storage.

- Nucleus housing

Widening the concept of "nucleus" housing has been proposed. A basic, small, wind-secure house (such as the soil-cement CARE house) could serve as a starting point for adding space horizontally or vertically to the taste of the owner or tenant. Open, bamboo-and-thatch lean-to additions have, indeed, been created in some localities. In others, soil-cement blocks have been plastered to better resist wind, floods and temperature extremes. Occasionally, a second and even a third story are added.

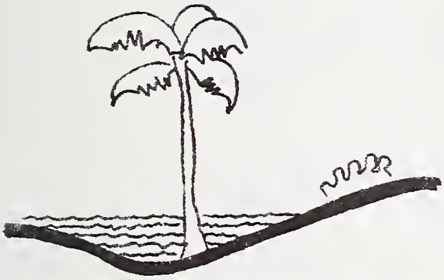
Wind secure house with individualized lean-to

● Materials

Since villagers are inclined by their socio-economic priorities to put food and cattle ownership before housing, a plan is proposed in Ref. 22 to ensure building materials delivery. Its main features are:

- Government subsidies should be in the form of materials not funds.

- The government should set-up local technical assistance units which would help with organized harvesting of wood; introduce mechanized milling to ensure tighter fit; show how to cultivate plants that are sources of building materials (such as the Nipa palm which is semi-aquatic and does not displace food growing and grazing land); and provide seedlings.



Nipa palm is semi-aquatic. It does not dis-place food growing land and can be made into a building material

- Clay is plentful in Bangladesh, and there is a 1000-year old tradition of burnt brick construction. Crushed, it can replace the imported cement in concrete. It is useful as a foundation and, in enough thickness, (10 in) better resists extreme winds.

- The making and use of cement-soil block has been discussed elsewhere in this report and in the base report.

● Wind and flood 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.

● Storm surge

The storm surge that accompanies cyclones **in** coastal Bangladesh usually moves inland at about storm speed (5-25 mph). Its mean depth over a particular site is determined by 5 variables, two of which are man-variable (Ref. 22):

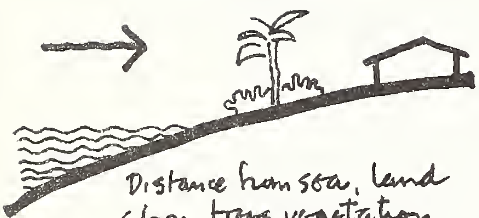
1. Severity of storm (this determines height of water <u>over</u> normal sea level)

2. Level of daily sea tide at time storm strikes

3. Land configuration and wind direction (these reinforce or impede rise of water)

4. Elevation of site (natural plus build-up)

5. Distance from sea or major inlet (land, trees and other vegetation resist flow).



Distance from sea, land slope, trees, vegetation break down force of storm surge

The last two items are man-variable, and should be linked to nature-variables in site planning, design and construction policy.

● Storm warning systems

The huge death rate of the November 1970 cyclone was due in part to a new warning system unfamiliar to the coastal villagers.

Since then, the new "danger -- great danger" warning scale has been supplemented with a preparedness system under which 10 volunteers per "bari", each equipped with signals, lights, etc., are linked by radio to Red Cross central HQ in Dacca, which receives and disseminates the latest storm information.

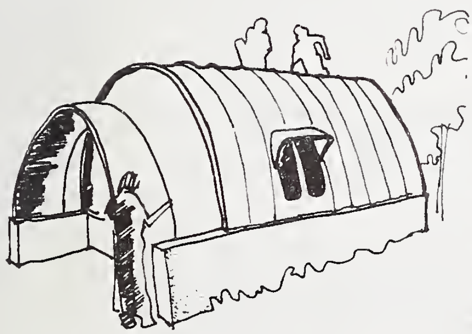
There are also specially trained local relief teams. (Ref. 24)

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.

References

Many of the following studies and reports contain additional references, varying from two or three to as many as seventy five.

(1) "Design, Siting and Construction of Low-Cost Housing and Community Buildings to Better Withstand Earthquakes and Windstorms," William F. Reps and Emil Simiu, editors. National Bureau of Standards, US Department of Commerce, 1974. 133 pp., ill.

(2) "Socio-Economic and Architectural Considerations in Housing," by Geronimo V. Manahan and Josefina M. Ramos, Building Research Service, University of the Philippines. 1973. 11 pp. Report prepared for International Workshop on Development of Design Criteria and Methodology for Low-Rise Low-Cost Buildings to better Resist Extreme Winds, held in Manila 14-17 November 1973.

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(4) "Low-Cost Housing and Extreme Wind-Related Problems in Jamaica", by A. D. Adams, consulting engineer. 1973. 25 pp., ill. A two-part report prepared for the National Bureau of Standards.

(5) "Economic Survey", by National Planning Agency, Jamaica. 1972.

(6) "The Geography of Jamaica," by Jamaica Information Service. 1972. Unpaged.

(7) "The People of Jamaica," by Jamaica Information Service. 1972.

(8) "Survey of Housing Conditions in Delacree Pen." Continuous Social and Demographic Survey Unit, Jamaica. 1969.

(9) "First Report on Low-Rise, Low-Cost Housing and Extreme Wind-Related Problems in Bangladesh," by Dr. Jamilur R. Chowdhury, Department of Engineering, Bangladesh University of Engineering and Technology. November 1973. 31 pp. ill. Prepared for National Bureau of Standards, US Department of Commerce.

(10) "Housing in the Philippines." Preparatory materials for the Conference on Housing. National Economic and Development Authority, Philippines. 1973.

(11) "Design of Low-Cost Housing and Community Facilities, Vol. 1: Climate and House Design," by Otto Koenigsberger, Carl Mahoney and Martin Evans. United Nations. 1971. 93pp., ill.

(12) "Report of the International Seminar on Low-Cost Construction Resistant to Earthquakes and Hurricanes." United Nations. 1971. 59pp.

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(15) "Housing for the Lowest Income Groups: the Calcutta Experience," by K. C. Rosser, Ekistics Magazine, February 1971.

(16) "Report on Slum and Squatter Problems in Metropolitan Manila", by Presidential Coordinating Council for Housing and Urban Development, Manila, Office of the President, 1968.

(17) "Rehabilitation of Transitional Urban Settlements", UNESCO, Committee on Housing, Building and Planning, Report of the Secretary General, E/C.6/115, 17 August 1971. 39pp + appendices.

(18) "Chittagong Region and Metropolitan Chittagong: Proposals for Development", by B.A.W. Trevallion in collaboration with the Chittagong Development Authority, 1967. 209pp.

(19) "Sites and Services Programs: the Experience and the Potential", by the International Bank for Reconstruction and Development in collaboration with the United Nations. Human Settlements, a publication issued by the Center for Housing, Building and Planning, United Nations. October 1972.

(20) "Urban Area Problems: Housing, Slums and Uncontrolled Settlements, Recreation and Tourism," Human Settlements, January 1972.

(21) "Housing Through Cooperatives and Other Non-profit Associations", Human Settlements, January 1974.

(22) "UN Reconstruction and Relief in Bangladesh Following the 1970 Coastal Storm", end of tour report by Daniel C. Dunham, Team Leader, Relief and Reconstruction Team, UN Development Program, Dacca. 1971. Unpublished.

This excellent report, referred to several times in the text, also includes a bibliography, from which the following items have been drawn:

(a) "Cyclone and Storm Surge Destruction", Report and Recommendation on Cyclone Shelter Construction by D.C. Dunham, USAID . Dacca. June 1965, designs, photos, estimates. 30 pp.

(b) "Human Adjustments to Cyclone Hazards", by Aminul Islam, a case study of Char Jabbar. Dacca. Univ. of Dacca, Dept. of Geography. 1970. 26 pp.

(c) "Survey of 1971 Cyclone - Affected Region of Bangladesh", by Drs. Sommer & Mosley, USAID . 1971, maps, charts, tables. 15 pp.

(d) "Handbook of Construction", Department of Democracy and Local Government (by Peace Corps) Dacca, 1965. Charts and drawings. 106 pp.

(e) "Report on Experimental House Types for Cyclone Affected Areas of E. Pakistan", Pakistan Government Housing, Building and Res. Center, Dacca. 1971, photos, estimates. 20 pp.

(f) "Houses Can Resist Hurricanes", by US Forest Service, Madison, Wisconsin, USF Products Laboratory, 1965. 18 pp.

(g) "Social Grouping in Rural E. Pakistan", by Robert Glasse. SEATO Cholera Research Lab. Dacca. 1965. Tables, bibliography. 8 pp.

(23) "The Delta Housing Program -- Bangladesh 1972-1974 -- An Experiment in Rural Housing", prepared by Frank Sullivan (ICDHA) for UN Commission for Asia and the Far East. 1974. Unpublished. 10 pp.

(24) "Cyclones in Bangladesh", Dacca newspaper article dated 13 November 1973, by Ellen Sattar.

(25) "Improvement of Slums and Uncontrolled Settlements", Report of Interregional Seminar, Medellin, Columbia, 15 February - 1 March 1970. United Nations Publication, Sales No. E71.IV.6. 203 pp. $4.50.

(26) "Bibliography", Bangladesh Academy for Rural Development, Comilla, Bangladesh. 1972. 28 pp.

(27) "Self-help Practices in Housing: Selected Case Studies", UN Dept. of Economic and Social Affairs, No. E73.IV.15. 129 pp. $5.00.

Report reviews 5 case studies from Africa and Latin America. Instructive, especially the case of Cali, Colombia, where families were given materials and technical assistance and sold a developed lot, which had to be repaid in 20 years.

(28) "Hope for Improvement of Slum-Squatter Areas", by Clarence Shubert, Newsbriefs of Foundation for Cooperative Housing, Washington, D.C. Aug.-Sept. 1974.

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(30) "Building Research in Jamaica", a proposal for program and staffing, by Ole Dybbroe. Scientific Research Council, Building Research Unit, Kingston. 1966. 23 pp. + appendices.

Good statement of research needs, both as to materials and their acceptance.

(31) "Housing Construction in Hurricane-prone Areas", by Herbert S. Saffir, PE. Prepared for Interregional Seminar on Low-Cost Construction Resistant to Earthquakes and Hurricanes, Skopje, Yugoslavia. 1971. No. ESA/HBP/AC. 6/2. 71 pp.

A good, simply written treatise, but solutions are geared to more advanced technologies (such as S. Florida) than to those of developing countries. Contains details, examples and design computations. Proposes a 5-point scale for measuring hurricane intensity.

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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 represents the major accomplishments conducted during the third phase (FY75) of a three year project to develop improved design criteria for low-rise buildings in developing countries to better resist extreme winds. The research study sponsored by the Agency for International Development commenced in March 1973. Two other reports were prepared; NBSIR 74-582 FY73 Progress Report (first phase of the research--4 months) and NBSIR 74-567 FY74 Progress Report (second phase of the research--12 months). During FY75, 6 major tasks were completed (instrumentation of fifth and sixth of six test houses to collect full scale field wind data, continuation of technician training at the field sites and at the wind tunnel facility, analyzed of extreme wind data, development of draft improved design criteria reports, participation in regional conferences in Manila and scheduling of regional dissemination of project results conference in Jamaica for November 1975). Research activities will be completed in December 1975. A final report will be published by the end of FY76.

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; codes and standards; housing; hurricanes; low-rise buildings; natural disaster; structural connections; typhoons; wind loads.

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