NBS BUILDING SCIENCE SERIES 56

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

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

Proceedings of a Workshop held at the
Dr. Paulino J. Garcia Memorial Hall
National Science Development Board
Manila, Philippines
November 14-17, 1973

Edited by

Noel J. Raufaste, Jr., and
Richard D. Marshall

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

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U.S. DEPARTMENT OF COMMERCE, Frederick B. Dent, *Secretary*

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, *Director*

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Dedicated
to the memory of
Mrs. Magdalena A. Templa
whose enthusiasm and dedication to the
improvement of technology made this workshop possible.

ABSTRACT

An International Workshop held in Manila, Philippines, on November 14-17, 1973, addressed the state-of-the-art in mitigating building damages from winds. The workshop was jointly sponsored by the United States Agency for International Development (USAID), the Philippine Advisory Committee (formed in conjunction with this research project), and the U. S. National Bureau of Standards (NBS). This report presents the proceedings derived from the workshop. The proceedings present recommendations, the workshop program, five reports, and nine technical articles. The technical articles addressed four primary topics which were used to guide subsequent workshop discussions. The topics addressed were; wind and aerodynamics, structural related technology, socio-economic and architectural considerations, and codes and standards.

The results of the workshop will serve a twofold purpose. The first suggests improved building practices for developing countries. This was accomplished through the development of recommendations designed to upgrade to a minimum acceptable level design criteria for low-rise buildings. The second involves integrating appropriate workshop information into the overall three-year AID sponsored research project to develop improved design criteria for low-rise buildings in developing countries to better resist the effects of extreme winds.

Key words: Codes and standards; Information transfer; Low-rise buildings; Pressure transducers; Socio-economic; Structural design; Technology implementation; Wind effects; Wind loads.

CONTENTS

DEVELOPMENT OF IMPROVED DESIGN CRITERIA FOR LOW-RISE BUILDINGS IN DEVELOPING COUNTRIES TO BETTER RESIST THE EFFECTS OF EXTREME WINDS

(Proceedings of a Workshop)

Edited by

Richard D. Marshall and Noel J. Raufaste, Jr.

INTRODUCTION

The Philippines experienced more than 140[1] tropical storms between 1965 and 1971. These storms cause many hundreds of deaths and many hundreds of millions of dollars of property damage. In 1970, for example, when the Philippines were lashed by four disastrous typhoons and 17 tropical storms, the death toll ran over 1,000. But wind-caused death and destruction are not confined to the Philippines; similar losses are inflicted on the Indian Ocean countries, the Northern Caribbean islands, and the United States.

The problem of extreme winds and their effects on buildings is obviously one of considerable magnitude. It is a problem abetted by a lack of information about acceptable building practices and a lack of knowledge concerning the effects of winds on buildings.

Several conferences, workshops and seminars on extreme winds and their effects on buildings and structures were conducted during the past decade. One national workshop was sponsored by The National Bureau of Standards (NBS). This workshop, conducted in 1972 at Boulder, Colorado, centered on current building practices, reviewed disaster mitigation activities and presented recommendations for improvements.

While significant advances have been made in the assessment of wind loads on buildings, much remains to be done, particularly in the area of low-rise buildings which have not had the research attention that has been accorded tall structures.

The United States Agency for International Development (USAID), being aware of this problem, requested NBS to develop improved design criteria for low-cost/low-rise buildings in developing countries to better withstand the effects of extreme winds. Accordingly, one objective of the project is to assess the state-of-the-art of low-cost building technology. To accomplish this, a workshop was held with those individuals concerned with improving building design criteria (research workers, engineers and design professionals).

This workshop was conducted during November 14-17, 1973, at the Dr. Paulino J. Garcia Memorial Hall, National Science Development Board, Manila. Four current state-of-the-art themes covering climatology and aerodynamics, structural engineering, socio-economic and architectural considerations, and codes and standards were discussed.

The first two workshop days were devoted to presentations of technical papers. During the afternoon of the first day, a visit was scheduled to the field test site at the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) Science Garden in Quezon City where pressure measurements are being conducted on full-scale houses. Nine papers were presented during the technical sessions with time reserved for discussions. The third day was devoted to subcommittee working sessions and the resulting recommendations were presented and discussed on the fourth day.

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1 Research Study of the Socio-Economic Aspects of Low-Cost Housing in the Philippines. Progress Report, Sycip, Gores, Velayo, and Co. CPA, Manila, Philippines, March 1972.

Approximately 140 individuals from five countries attended the workshop. This document, which constitutes the proceedings of the workshop, includes recommendations for improved building practices, the opening ceremonies, and five reports and nine technical articles prepared by the National Bureau of Standards, the Philippine Advisory Committee, delegates from Bangladesh and Jamaica, and the Building Research Establishment (U.K.) are included. The workshop program is attached as Appendix A.

The oral reports and technical papers, both of which were reviewed by the authors subsequent to the workshop, follow the recommendations which stem from the workshop.

WORKSHOP RECOMMENDATIONS

The recommendations contained herein represent the consensus of the International Workshop attendees. They do not, however, constitute any individual endorsement by any one participant or organization.

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

RECOMMENDATION 1 - COMMUNICATION AND EXCHANGE OF INFORMATION

A NATIONAL FOCAL POINT SHOULD BE ESTABLISHED IN DEVELOPING COUNTRIES TO PROMOTE COMMUNICATION BETWEEN METEOROLOGISTS AND CLIMATOLOGISTS, THE DESIGN PROFESSION, REGULATORY OFFICIALS AND BUILDING AUTHORITIES ON MATTERS CONCERNING THE DESIGN OF BUILDINGS TO RESIST WIND FORCES.

The interdisciplinary nature of wind effects on buildings requires close communication and cooperation between individuals in several areas of science and technology. This can best be accomplished through the establishment of a national focal point, such as a wind research center, where the needs of the design profession are identified and the collection of wind data can be directed to meet the needs.

RECOMMENDATION 2 - MANUALS OF ACCEPTED PRACTICE

MANUALS OF ACCEPTED BUILDING PRACTICE SHOULD BE FORMULATED BY COMMITTEES REPRESENTING APPROPRIATE SCIENTIFIC AND PROFESSIONAL ORGANIZATIONS, AND SHOULD INCLUDE STANDARD DETAILS OF CONVENTIONAL BUILDING SYSTEMS.

Manuals of accepted practice should demonstrate and explain in a manner acceptable to both practicing professionals and laymen, the design provisions and details necessary to ensure the satisfactory performance of buildings subjected to anticipated loads. The manuals should contain both textual and pictorial step-by-step instructions for the proper construction of buildings. The version intended for the layman should be formatted so that the reader can understand the instructions and requirements without professional assistance. The manuals should be revised as new information becomes available.

RECOMMENDATION 3 - LAND USE PLANNING

A COMPREHENSIVE PROGRAM ON IMPROVED LAND USE PLANNING SHOULD BE ESTABLISHED TO REDUCE THE DAMAGE POTENTIAL OF EXTREME WINDS AND HEAVY RAINFALL.

An effective system for improving land use planning should be implemented by appropriate, qualified professionals, and should include the participation of government agencies, and private and professional groups involved with building design, construction and financing.

RECOMMENDATION 4 - COLLECTION AND DISSEMINATION OF WIND DATA

METEOROLOGICAL AGENCIES AND RELATED GROUPS SHOULD BE ENCOURAGED TO COLLECT MEAN HOURLY WIND SPEED AND PEAK GUST DATA AND DISSEMINATE THIS INFORMATION TO PRIVATE AND GOVERNMENTAL GROUPS INVOLVED WITH BUILDING DESIGN AND CONSTRUCTION.

Weather observation stations in most countries record wind speeds averaged over a 10-minute period at the hour of observation. For design purposes, wind speeds averaged over a period of 1-hour are more convenient, provided that information on the peak gust within the hour is also known.

RECOMMENDATION 5 - WIND OBSERVATION STATIONS

THE METEOROLOGICAL SERVICES IN DEVELOPING COUNTRIES WHICH REGULARLY EXPERIENCE HURRICANES OR TYPHOONS SHOULD TAKE THE LEAD IN IMPROVING THE DISTRIBUTION, DENSITY AND SITING OF WIND OBSERVATION STATIONS.

Wind observation stations are usually located at airfields to provide for needs of the aviation industry. Consideration should be given to the collection of wind data in urban areas and areas having a potential for development. Selection of future station sites should be aimed at improving the geographic definition of design wind speeds.

RECOMMENDATION 6 - STRUCTURAL LOADING

STRUCTURAL DESIGN FOR WIND LOADS SHOULD TAKE INTO ACCOUNT THE LOCAL WIND CLIMATE AND THE EFFECTS OF SURROUNDING TERRAIN AND NEIGHBORING STRUCTURES ON THE CHARACTERISTICS OF SURFACE WINDS.

The characteristics of surface winds, such as mean speed, variation of speed with height, and intensity of turbulence, can be drastically altered by local surface features and neighboring buildings. Basic design speeds should be adjusted to account for these effects.

RECOMMENDATION 7 - ROOFING AND CLADDING LOADS

THE DESIGN OF ROOFING AND CLADDING ELEMENTS SHOULD TAKE INTO CONSIDERATION THE EFFECT OF LOCAL PRESSURE FLUCTUATIONS NEAR THE CORNERS OF WALLS, ALONG THE EDGES OF ROOFS AND UNDER EAVES.

The intensity of localized pressure fluctuations can far exceed the mean pressures used to design the overall structure. If not properly accounted for, these fluctuations can cause local failures which rapidly lead to complete failure of the structure.

RECOMMENDATION 8 - UNUSUAL BUILDING SHAPES

BUILDINGS HAVING UNUSUAL SHAPES AND STRUCTURAL CHARACTERISTICS THAT ARE NOT COVERED BY RECOGNIZED CODES OF PRACTICE SHOULD BE SUBJECTED TO APPROPRIATE WIND TUNNEL MODEL STUDIES.

It is neither practical nor possible to cover all possible building shapes when specifying design wind pressures. Because of the complex nature of building aerodynamics, it is not generally possible to predict these pressures by theory or intuition and one must resort to wind tunnel tests in which the building and surface winds are properly modeled.

RECOMMENDATION 9 - MAINTENANCE

BUILDINGS SHOULD BE DESIGNED SO THAT ROUTINE PREVENTATIVE MAINTENANCE CAN BE PERFORMED WITHOUT UNDUE DIFFICULTY.

Buildings and building components exposed to extreme winds are subject to damage or displacement. Buildings should be designed in such a manner that inspectors may check and maintain the building without undue difficulty. Such checks should be performed periodically and prior to the hurricane or typhoon season. Whenever possible, minimum maintenance materials should be used.

RECOMMENDATION 10 - POST DISASTER SURVEYS

PROVISION SHOULD BE MADE FOR CONDUCTING POST DISASTER SURVEYS BY APPROPRIATE GOVERNMENT AND PRIVATE GROUPS.

Post-disaster surveys provide extremely useful information on the adequacy of building code provisions, construction practices and building performance. The engineering community should develop plans and procedures to collect such information, interpret it, and disseminate their findings.

RECOMMENDATION 11 - LICENSING OF PROFESSIONALS

ARCHITECTS AND ENGINEERS ENTRUSTED WITH BUILDING DESIGN AND CONSTRUCTION SUPERVISION SHOULD BE LICENSED BY AN APPROPRIATE PROFESSIONAL LICENSING BOARD.

The licensing board should establish rules and regulations that provide consistent requirements for the licensing of all architects and engineers. These licensed professionals should assure that future buildings be designed to comply with the minimum wind loading requirements. It is essential to the sucessful implementation of improved building practices that architects and engineers be familiar with these requirements.

RECOMMENDATION 12 - STUDENT EDUCATION

THE PROFESSIONAL SOCIETIES SHOULD WORK CLOSELY WITH COLLEGES AND UNIVERSITIES TO DEVELOP COURSES OF STUDY FOR ENGINEERING AND ARCHITECTURAL STUDENTS RELATED TO THE EFFECTS OF WIND ON BUILDINGS.

It is essential that information on improving building designs to better resist extreme winds be made available to architectural and engineering students. This can be accomplished through seminars, workshops and formal courses.

RECOMMENDATION 13 - CONTINUING EDUCATION

PROGRAMS OF CONTINUING EDUCATION SHOULD BE DEVELOPED AND IMPLEMENTED FOR INDIVIDUALS INVOLVED IN THE DESIGN AND CONSTRUCTION OF BUILDINGS.

Continuing education programs can improve the current state-of-knowledge of design professionals, regulatory officials, and builders. Such programs may take the form of workshops, seminars, formal training courses, brochures and technical journals.

RECOMMENDATION 14 - WIND RESEARCH CENTER

A WIND RESEARCH CENTER SHOULD BE ESTABLISHED AND SUPPORTED BY APPROPRIATE ORGANIZATIONS TO STUDY THE EFFECTS OF WINDS ON BUILDINGS.

Since many of the problems associated with the design of buildings to resist wind loads are unique to each country, the establishment of a research capability is essential to keep pace with changing conditions. Such a center would not only carry on research, but would also serve as a link with institutions in developed countries involved in similar work.

APPENDIX A

WORKSHOP PROGRAM

APPENDIX A

INTERNATIONAL WORKSHOP PROGRAM

on the

"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
The Philippine Advisory Committee

November 14 to 17, 1973

at the

Dr. Paulino J. Garcia Memorial Hall
National Science Development Board (NSDB)
Herran, Manila

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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

Mr. WILLIAM WOUDENBERG, Designer, CARE, Inc, Dacca, Bangladesh

WORKSHOP PROGRAM
Wednesday, November 14, 1973

Master of Ceremonies...		Engr. Cesar A. Caliwara Philippine Association of Civil Engineers
8:45	Registration	
9:30	Philippine National Anthem	
9:35	Welcome Remarks	Mr. Thomas C. Niblock, Director, USAID Mission, Manila
9:45	Introductory Remarks	Dean Alfredo L. Juinio U.P. College of Engineering
10:00	Background of Study	Mr. Noel J. Raufaste, Jr. National Bureau of Standards
10:30	Summary of Local Accomplishments	Dr. Ernesto G. Tabujara U.P Research Building Service
10:45	Break	
11:00	Climatology and Wind Related Problems	Dr. Roman L. Kintanar, PAGASA
12:00	Lunch - Courtesy of Marsteel Corporation	
Master of Ceremonies and Marshal		Col. Alberto R. Sanchez, Land and Housing Development Corp.
1:30	Aerodynamics of Structures and Wind Tunnel Modelling	Dr. Richard D. Marshall National Bureau of Standards and Prof. Angel A. Alejandrino National Hydraulic Research Center
2:30	Visit to the Science Garden Center of the PAGASA	
3:30	Introduction to Wind Measuring Equipment	Dr. Richard D. Marshall, National Bureau of Standards
3:45	Visit Experimental House	
5:00	Social Hour - Courtesy of PAGASA	

WORKSHOP PROGRAM

Thursday, November 15, 1973

Master of Ceremonies		Gen. Gaudencio V. Tobias National Housing Corporation
9:00	Some Problems in the Analysis of Lateral Wind Load Resisting Systems	Prof. Jose Ma. de Castro U.P. College of Engineering
9:45	Socio-Economic and Architectural Considerations in Low-Cost Housing	Dr. Josefina M. Ramos and Prof. Geronimo V. Manahan U.P. Building Research Service
10:30	Break	
10:45	Lessons Learned from Post Wind Disaster Investigations	Dr. Edward O. Pfrang, National Bureau of Standards
11:30	Lunch - Courtesy of: Association of Structural Engineers of the Philippines, National Society for Seismology and Earthquake Engineering of the Philippines, Philippine Association of Civil Engineers	
Master of Ceremonies		Engr. Jose P. Orola Government Service Insurance System
1:00	Technical Paper	Dr. Jamilur Choudhury, Bangladesh
2:00	Technical Paper	Mr. Alfrico D. Adams Consulting Engineer, Jamaica
3:00	Break	
3:15	Codes and Standards	Engr. Ambrosio R. Flores Philippine Standards Assn.
4:00	Wind Research in the United Kingdom	Dr. Keith J. Eaton Building Research Establishment
4:45	Conclusion	

WORKSHOP PROGRAM

Friday, November 16, 1973

Workshop Session Coordinators..............................Prof. Angel A. Alejandrino
Mr. Noel J. Raufaste, Jr.

Time		Session	Co-Chairmen	Rapporteur
9:00	Workshop Sessions	A.	Dr. Richard D. Marshall Mr. Catalino P. Arafiles	Dr. Angel A. Alejandrino, NHRC
		B.	Dr. Keith J. Eaton Engr. Andres O. Hizon	Engr. Rosalio A. Mallonga, BPW
		C.	Mr. Noel J. Raufaste Jr. Dean Aurelio T. Juguilon	Col. Manuel R. Rebueno, PHHC
		D.	Dr. Edward O. Pfrang Engr. Octavio A. Kalalo	Engr. Miguel V. Paala, SSS

10:30 Break

12:00 Lunch - Courtesy of

Engr. Cesar A. Caliwara
Engr. Romeo S. Caparros
Engr. Octavio A. Kalalo
Dr. Fiorello R. Estuar
Engr. Lauro M. Cruz
Engr. Angel Lazaro, Jr.

1:30 Continue Workshop Sessions

3:00 Break

4:30 Conclusion

WORKSHOP PROGRAM

Saturday, November 17, 1973

Master of Ceremonies..Arch. Cesar H. Concio
National Building Code Committee

9:00	Presentations and Discussions	Co-Chairmen of Sessions
11:45	Closing Ceremony	Mr. Noel J. Raufaste, Jr. National Bureau of Standards and Dr. Ernesto G. Tabujara, U.P. Building Research Service
12:00	Lunch - Courtesy of Weldon Construction Corporation	
6:00	Coctails - Architectural Centre Club Makati, Rizal	

Courtesy of:

B. F. Homes Incorporated
and
Philippine Shares Corporation

Coffee Breaks - Courtesy of:

California Sales Corporation
Commonwealth Foods
Getz Bros. and Co.
Republic Flour Mills
American International Dairy Co.
Standard Brands of the Philippines

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APPENDIX B

Report Presentations and Technical Papers

WELCOME REMARKS
by
Thomas C. Niblock
Director, U. S. Agency for International Development
Mission, Philippines

Ladies and Gentlemen:

I would like to congratulate the planners who made this conference possible. One of the problems which has faced planners providing foreign assistance is that of assuring that the benefits of such assistance accrue to the poor. Many critics have asserted that one of the major failings of foreign aid is that the benefits go primarily to the rich. They see slums growing, that the poorest farmers have benefitted little from increased agricultural production, etc. Consequently, some Members of Congress and others despair of supporting foreign assistance.

Certainly, one of the problems most difficult in this typhoon-prone country is that of providing wind-resistant shelter at a cost which the average person can afford. What you will be discussing is a very relevant topic not only because it is addressed to a technical problem of the profession, but because the target of this work is the underprivileged group in the community. I think that if this seminar can provide us a significant step forward in improving low-cost housing programs, a tremendous need throughout the developing world, it will have made a significant contribution.

The U.S. Government has had a program for many years which has provided investment guaranty to institutions wishing to invest in housing projects in other countries. Large sums of money are available from U.S. savings institutions, some of which are available for transfer on a loan basis to the developing countries. These funds have assisted in some measure the improvement of housing programs in North America. But the terms and conditions on which these funds have been available are such that they have gone largely to the middle class. If you can make a contribution in improving the technology, types of materials, the designs, or whatever for low-cost housing, there is the potential of funds to finance such housing.

For the first time in 10 years I expect to see passed shortly a new Foreign Assistance Bill. This new bill emphasizes the necessity to find ways and means to have more relevance for the poor people in the world. No longer is it adequate to provide economic assistance without concern as to whom the primary beneficiaries will be within a country. This new bill provides us with an opportunity and with a challenge. We must find ways to exploit the opportunity and to address the challenge. Certainly the subject you have chosen is one of great relevance in light of this new legislation.

It is for this reason that I am particularly anxious to encourage this group and others to deliberate and discuss ways of achieving greater benefits for the poor with the use of foreign assistance. With you here, I am looking forward to a fruitful conference.

INTRODUCTORY REMARKS
by
Alfredo L. Juinio
DEAN, College of Engineering, University of Philippines

Director Niblock, Dr. Tabujara, distinguished guests from overseas, my esteemed colleagues in the profession--and I see my mentors -- ladies and gentlemen: In a way this is like a homecoming. I have been out of step for sometime now and I feel lost. I am glad of this opportunity to be able to be with you once more. Now I am in my own element. First of all, I want to do my job as the Honorary Chairman.

To our guests, especially those from overseas, welcome. I hope you are enjoying your stay here.

I wish to congratulate the organizers of this International Workshop for bringing together engineers, scientists and researchers, who are all very much interested in the study of extreme winds as they relate to the design of buildings.

Mr. Niblock of course has very ably explained to you why this is very important to this country. I refer to the emphasis placed on low-rise/low-cost buildings. After all, it is said that the Philippines suffers from the great frequency of strong winds -- destructive typhoons. With respect to the designing of buildings and houses this Workshop can do a lot in solving this problem which affects a great bulk of our people, more than 95 per cent of our people.

As far as I can recall, this may indeed be the first serious cooperative effort to seek local design criteria, particularly for low-rise, low-cost buildings.

Before this seminar I remember when I was actively teaching that we used textbooks printed overseas. We can see now how the data on wind velocities printed then differ from actual figures. I remember too that in the Greater Manila area the effects of strong winds differ where roofs of rich homes blew up while humble hovels stayed put. We can see from that that we know so little and that we have to extend what we know. That is why we are glad about the approach being done to this project at this time.

The effects of typhoons which visit the country every year easily makes the Philippines a convenient natural laboratory. I remember that two years ago we were hit by about 23 typhoons. Dr. Kintanar, correct me if I am wrong. I think we are being hit by 17 or 19 typhoons of varying degrees every year. This makes the Philippines a fertile ground for research.

In this regard, I am fully aware that our PAGASA, the former Weather Bureau, has collected throughout these years an enormous amount of wind data. I believe, Dr. Kintanar can elaborate on this later.

Unfortunately, in the past we suffered from one common deficiency -- we did not have enough funds to collate these data. And these have not been properly nor adequately correlated with engineering applications so as to be readily useful to engineers, architects, designers and builders. I think we can make further progress if we begin with the data collected by Dr. Kintanar who has collected these over the years.

With the advent of more sophisticated pressure devices and related recording equipment, the much desired correlation among important parameters can now be done quite conveniently. The more one gets exposed to this might and fury of the forces of nature, the more healthy respect he develops for them.

I am reminded of the time when we were flying over Central Luzon. We wanted to see the conditions in Central Luzon during one of those times. But when we saw the situation, the might of the wind and water forces -- we told the pilot: "We place our lives in your hands." We went back. I think that is something we do not appreciate until we realize or see the destructive might of these forces of nature.

Admittedly, there is still no substitute for fullscale tests if done extensively. The enormous amount of wind information already collected will be very useful for building construction or building design. However, this kind of investigation can indeed prove very expensive. It is with this thought in mind that this study plans to include wind tunnel tests to complement actual field results. The project is planned for three years and we wish it can be accelerated. However, we can all be confident that whatever recommendations may come out of the study will be arrived at in accordance with scientific and refined methods.

A fact which must be appreciated is that the Advisory Committee is composed of experts in their own right representing various government and private entities, as well as professional organizations.

Some two years ago when this project was talked about, I was approached to express my feelings about it. I remember that one of the compelling reasons given by the organizers was how we can effectively organize all sectors -- academicians, active contractors, builders, designers, architects, engineers and everybody concerned with buildings.

At this time I am glad to report to you -- I express my feeling -- that this can be done. And this can be done because there is a common interest in all of these people.

Their enthusiasm and support serve to encourage and inspire us all. It vindicates a feeling I have expressed many times before that such cooperative effort is indeed feasible.

We are grateful to our friends from the U.S. National Bureau of Standards and the USAID for making available to us valuable and modern equipment without which this research cannot be as meaningful as it is intended to be.

On our part, we hasten to assure our colleagues that we will contribute whatever skill and knowhow we can muster until we shall have attained our objectives. We pray for and look forward to the success of this undertaking with the sobering thought that we all have so much to learn. Thank you.

BACKGROUND OF STUDY

by
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Thank you, Mr. Caliwara, Dean Juinio, Mr. Niblock, Dr. Tabujara, ladies and gentlemen, good morning. It is a privilege for us to be here and to participate in this Workshop and to work with so many distinguished attendees.

I would like to thank you for being here this morning. I very much appreciate your attendance. I should especially like to welcome the new members of the Philippine Advisory Committee and all nonmembers attending this Workshop this morning and for the ensuing three and a half days. We are proud and happy to have you associated with us, and we promise to do whatever we can to make your attendance at this Workshop a meaningful one.

This morning I would like to summarize with you the direction which we are going and, with some careful focusing and delineation as with the aid of a telephoto lens, give you a glimpse of the activities that lie ahead and what needs to be done. First of all, in order to perhaps develop a little better appreciation of why we are here and what we are doing, let me quickly review with you who we are and present to you a background of the activities associated with this project.

The National Bureau of Standards, located in Washington, D. C., provides technical resources to all federal agencies and to state and local agencies. We also provide support to private industry, universities and the general public through our role as the federal laboratory. We do not develop new products, materials or systems nor do we compare or rank competitive products. We are, however, engaged in developing improved technology, and in our case for building related activities, and in the dissemination of such technology. As such we are actively involved in testing material products, developing standardized test procedures, designing new instrumentation for improved testing, and developing materials and component specifications.

The National Bureau of Standards has recently completed a two-year research project in which many of you participated. This project was sponsored by USAID to provide initial research and analysis on the design, siting and construction of low-cost buildings to better resist earthquakes and windstorms. This project evaluated the potential of applying improved housing technology to mitigate earthquake and extreme wind damages to buildings in developing countries. In addition, we evaluated relevant socio-economic and cultural constraints which could affect current and new technology. This project recommended that additional research in extreme winds has a potential for very high payoffs.

I would like to introduce the project sponsor, Mr. William Littlewood from USAID.

This is one of several projects within the National Bureau of Standards overall program in building practices for disaster mitigation.

The recommendations from the previously mentioned project were based on such factors as: (1) building failures due to extreme winds in the Philippines and other developing countries represent annual losses of many millions of dollars and hundreds and even thousands of lost lives. We all know the after-effects of the 1970 typhoons in the Philippines. This problem requires immediate attention. (2) A more complete data bank exists about extreme winds and their effects on tall buildings; however, little wind data currently exists on low-rise buildings.

Also, there is considerable evidence to indicate that existing codes do not make provision for steady and fluctuating wind pressures along the edges of roofs and walls where separated flows occur. These regions of extremely low pressures, coupled with high uplift pressures under overhanging eaves, constitute an example of one building area in need of improved design criteria. This topic will be discussed by Dr. Marshall. The above are only examples of some of the background leading up to initiating this research.

Thus, the objective of this project is to develop improved design criteria for low-cost/ low-rise (10 meters and under), houses, school buildings community centers to better resist the effects of extreme winds (130-140) knots) in developing countries, and to transfer this information in a form suitable for implementation by most individuals in highwind countries. Because the Philippines experience the highest incidence of high winds, this nation can serve as a natural laboratory for extreme wind research.

Our project was formally started in February of 1973. Early in the project we identified interested organizations and agencies, universities, and other groups from the Philippines, Bangladesh, Jamaica, and third party countries to participate in and direct major project tasks. This was performed during April and May of 1973.

Examples of such participation from the Philippines include the Philippine Atmospheric, Geophysical and Astronomical Services Administration which has donated parcels of land at their sites for the construction of full scale test houses. The University of the Philippines will perform wind tunnel testing and the National Housing Corporation has constructed the first test houses at the PAGASA's site in Quezon City. We will visit this house later in the afternoon.

In addition, we identified Dr. Choudhury from the Bangladesh University of Science and Technology, Dacca, to represent his country and the selected Indian Ocean countries in assisting us with his experiences and expertise in providing us with climatological, socio-economical and structural related data. Mr. William Woudenberg from CARE, Inc., Bangladesh, will also discuss related topics about his low-cost house. Mr. Adams from Douet, Brown, and Adams and Associates, an engineering consulting firm in Kingston, Jamaica, will represent Jamaica and the Northern Caribbean Islands in collecting data and sharing his experiences and expertise with us. Dr. Keith Eaton, Senior Research Officer from Building Research Establishment in the United Kingdom, has gracefully accepted an invitation to be with us.

During the summer months we assembled and tested our first data acquisition system for our test site No. 1. We transported this system to the Philippines during our second visit in September where we instrumented one test house at test site No. 1 in the Greater Manila Area. And as I mentioned before, we will visit this house later on this afternoon.

The curve in Figure 1 represents the mean monthly frequency of tropical storms in the Philippines. This information is from Dr. Kintanar's publication entitled "Tropical Cyclones for 1970." Our thanks go to Dr. Kintanar and his staff for this information. As you can see, this curve oscillates for a period of two and one-half years, the length of our project. It oscillates from an average of about 3.5 storms per month in the late summer to less than one-half storm in late winter. The activities above the horizontal axis represent full scale tests of our buildings. The first of seven houses was instrumented with wind measuring equipment in September and the last is scheduled to take place in June, 1974.

The activities below the horizontal line indicate the schedule for wind tunnel tests. As you see, initial wind tunnel modeling has been performed by the Colorado State University under the direction of the National Bureau of Standards and will be transferred to the University of the Philippines Aerodynamic Laboratory next week by Dr. Marshall. This transfer will permit Professor Alejandrino to commence his wind tunnel testing program using a scale model of 1 to 80 of the actual full scale field test buildings. Such testing will provide a correlation of information collected in the field with that collected in the tunnel. It will provide us with additional knowledge to optimize the physical placement of the pressure transducers (wind measuring equipment) on the full scale test house. The other two horizontal bars represent further refinements in the University of the Philippines wind tunnel testing program.

Figure 2 illustrates the wind measuring equipment on our test house at the Science Garden site. Note the pressure transducers on the roof. There are six on the roof, two mounted on the exterior walls, and one special transducer mounted on an inside wall to measure internal pressures.

The data collected by the pressure transducers are recorded by a 14-channel tape recorder located in an air-conditioned building adjacent to the test house. The data acquisition equipment under normal conditions is operated with commercial power. However it has back-up power through batteries should commercial power fail during a storm.

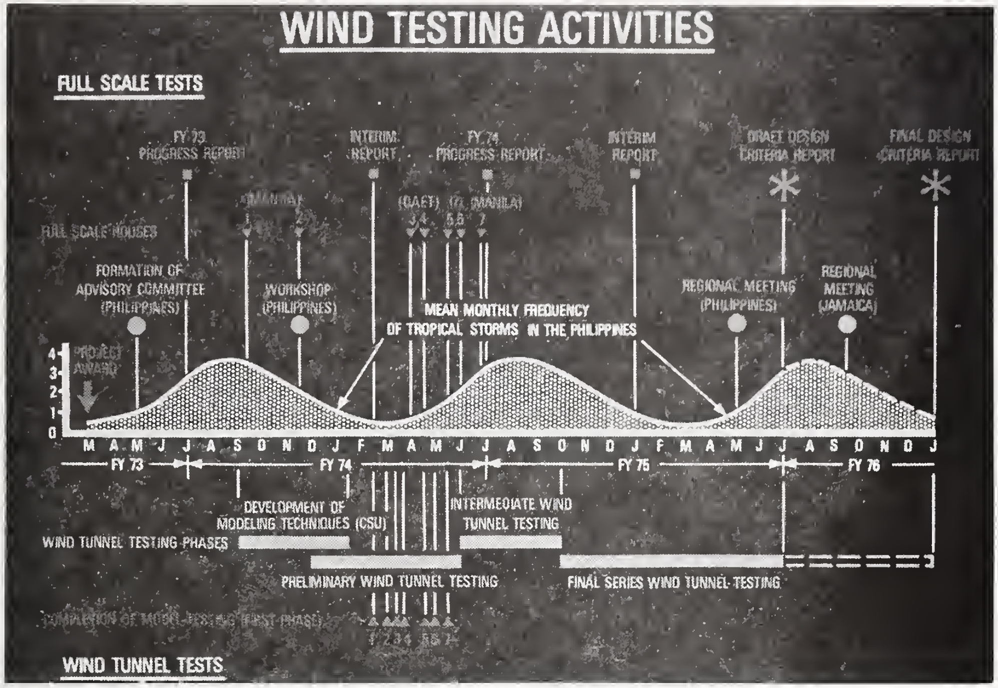

Figure 1. Schedule of NBS Wind Research Project

Figure 2. Test House No. 1, Quezon City Test Site.

In addition to instrumenting a test house in September, we also selected a second of three field test sites to record wind effects on buildings. This site is also owned by the PAGASA which contributed greatly in identifying appropriate locations.

This is a very brief summary of the background of our activities. This leads me to ask why we are here today. This Workshop is the first major step toward coordinating the technical planning and organizing the associated activities to improve design criteria for low-cost/low-rise buildings. What we are all doing today and for two and a half additional days is to learn more about each other professionally, to share with each other information we already know and, more importantly, to jointly identify areas and data gaps which when filled will bear fruit in a relatively barren desert. We want to develop conclusions and recommendations about where we should go from this point in time. Viewed another way, we are assessing the state-of-the-art in mitigating damages to low-cost/low-rise buildings from extreme winds. As you can see from your program, our Workshop is divided into four major categories: the first is Climatology and Wind Related Problems; the second deals with Structural Related Technology; the third involves Socio-Economic Aspects of Low-Cost Buildings with emphasis placed on housing; and the fourth centers around Building Codes and Standards.

These categories are addressed initially by technical papers. On Friday, we will break into four groups, each group representing one of the major subject categories where we will discuss our respective topic and develop conclusions and recommendations based upon each member's background and experiences and from information presented during this meeting. On Saturday morning the conclusions and recommendations will be presented. Later in the year a proceedings report will be prepared from the information assembled during this Workshop. I think at this point you may be wondering what is the end product going to be and who will use it. Well, this is also one of the purposes of our Workshop. Mr. Niblock in his presentation suggested that we not forget the importance of implementation.

The implementation aspect of this project must satisfy the requirements of technical and non-technical users. The first group will be able to understand technical documents.

An example of one such document presenting technical information is our American National Standard A 58.1-Building Code Requirements for Minimum Design Loads in Building and Other Structures. This document is used by those individuals engaged in preparing and administering local building codes. A similar appropriate document will be prepared at the end of this project. But, what about the man-in-the-field? What is he going to use to improve his building construction methods?

The National Bureau of Standards prepared in cooperation with the Ad Hoc Committee on Fuel Conservation, Office of the Special Assistant to the President for Consumer Affairs, a brochure entitled, "7 Ways to Reduce Fuel Consumption in Household Heating Through Energy Conservation." In this brochure we presented in a simple and straightforward manner ways we could reduce fuel consumption. For example, we suggested that if the homeowner insulated his home with the minimum recommended thickness of insulation he could reduce his heating bill by approximately 15 per cent. In addition, the costs associated with installing the insulation could pay for itself due to the reduced heating bill in about ten years. While we are not concerned with insulation in this project, a similar format could be prepared to illustrate for example, improved building connection details to better resist extreme winds.

I hope that what has been presented so far today has given you a little better impression of the overall scope of work and has answered some of your questions. I have addressed myself specifically to the background and general areas associated with our two and a half year research project. Those who follow me will deal more specifically with the topics of our Workshop.

We hope that all of you will be curious during the ensuing days. We also hope that you communicate whenever you feel others may benefit as well as you. As you know, communication is a two-way process and this roomfull of individuals with a broad range of specialized skills is a place where questions must be asked and answers communicated -- your answers to us and ours to you. For the next three and a half days we will be engaged as curious people working together in this meeting place. After the three and a half days are over, we will leave. But if our meeting is a successful one, if we really do communicate with one another, I believe you all will continue to look for answers, arising out of apparent data gaps discussed during the next few days and the newly discovered data gaps popping up after this meeting, asking new questions, looking for new answers and communicating them to the Philippine Advisory Committee and to the staff of the National Bureau of Standards. Thank you.

SUMMARY OF LOCAL ACCOMPLISHMENTS

by

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Dean Juinio, Mr. Raufaste, our guests, colleagues and friends. When the Program Committee requested me to render a summary of local accomplishments, I immediately accepted the assignment because I felt it would be very easy. I was sure that even if I did not say anything, the word "accomplishment" alone was enough to indicate that some things had been done. I will not try to deny that some measure of accomplishment have indeed been done, and I hope you will allow me to enumerate briefly these activities.

The previous speaker, Mr. Noel Raufaste, gave us a comprehensive account of the background of the research from the standpoint of the U.S. National Bureau of Standards, which originally developed the proposal. What Noel failed to mention -- and this he may not be in a position to know -- is that as far as the local point of view is concerned, our involvement actually started at a dormitory cafeteria at Honolulu, Hawaii, almost a year ago. At that time, Mr. Bill Littlewood, Associate Director, Agency for International Development based in Washington, D. C. and Dr. Ed Pfrang, Chief of the Structures, Materials and Life Safety Division of the U.S. National Bureau of Standards suggested to Dean Juinio and myself to have lunch together so that we could discuss a very interesting research proposal. It did not take these two gentlemen long to convince Dean Juinio and me that the project was indeed a laudable one and we knew right then and there that it would draw the interest of our colleagues in the Philippines.

I would like to think that the very first local accomplishment was made when Dean Juinio committed the University of the Philippines Building Research Service to this endeavor -- and to think that such local accomplishment was actually consumated at Honolulu, a foreign country. The four of us who are all here today are very happy to see that the research project we talked about is now on its way to full implementation.

The second milestone in the local effort was the formation of the Advisory Committee which held its organizational meeting on April 27, 1973. We were very glad to bring together experts in their respective fields to compose this body -- and this alone is quite an accomplishment. The response from the Government and the private sectors was spontaneous, and as it turned out, 25 scientists, engineers and researchers representing 11 government entities, four professional organizations and two private groups, made up the total membership of this Advisory Committee.

Since its formation, the Committee has met on several ocassions to come up with important recommendations and decisions as these pertain to local conditions affecting the study. In accordance with a reasonable timetable, the Committee decided on the construction of experimental houses which would be fully instrumented for wind pressure readings. For convenience and expediency, the Science Garden of the PAGASA (formerly Weather Bureau) at Quezon City was selected as the first test site, where we hope to construct three houses for experimentation purposes.

This particular site was preferred because of the gesture of Administrator Roman L. Kintanar when he committed three small parcels of land as well as limited services of PAGASA technicians to double as observers. This move led to a mutual effect in that PAGASA technicians, in turn, assigned at the Science Garden suddenly found themselves with a new home.

I am happy to report that the National Housing Corporation donated the first house, which together with the installation of the measuring and recording apparatus, may be considered the third milestone in this collaborative effort.

You will also be interested to learn that all equipment worked perfectly during the visits of Typhoons Luming and Narsing sometime last month, and this is a tribute to two things: (1) the meticulous checks made on the equipment at the National Bureau of Standards in Washington, D. C., prior to shipping these over, and (2) the excellent know-how and capability of Dr. Richard D. Marshall who almost single-handedly installed all the equipment on the first house. Although General Gaudencio V. Tobias and Colonel Alejandro R. Kabiling of the National Housing Corporation would humbly refuse to confirm that their product is the best low-cost house for one's money, I get it from reliable sources that the direct costs of this donation amounted to some 10,000 pesos.

The fourth milestone is the current construction of the second house located near the first one. This 12,000 peso committment by the Land and Housing Development Corporation, ably represented in the Advisory Committee by Colonel Alberto Sanchez, differs from the first one in that the roof slope has been made steeper, the ridge line oriented at right angles to the ridge line of that of the first house, and we are still hoping to use lightweight concrete -- called porous concrete -- instead of the popular fiberboard for the exterior walls. Unfortunately, the gasoline shortage has caught up with the construction of the house and deliveries of various materials have become most difficult, causing an unforseen delay in its completion. However, we are still optimistic, that we will have the house ready for Dr. Marshall and his assistants immediately after this Workshop is over. We will all have the chance to see for ourselves these phases of the research during the visit to the site scheduled for this afternoon.

The Advisory Committee appreciates the desire of the National Bureau of Standards to supply and make available for our use thousands of dollars worth of equipment and related measuring and recording devices. Details of the formal transfer of the equipment, which are to be donated to the Philippine Government through the Advisory Committee, are being worked out. The PAGASA and the National Hydraulic Research Center have accepted the responsibility to act as custodians for the devices used in full-scale tests and those for the wind tunnel experiments, respectively.

The Advisory Committee has drawn up line-budget proposals for support of this program as our counterpart. Some more details will have to be clarified before we can realize tangible and favorable results, but in the meantime, I am happy to say that the Committee was able to solicit substantial logistical aid from industry, from professional organizations and from concerned individuals. As a matter of fact, the financial assistance given by these quarters is perhaps the greatest accomplishment of the Advisory Committee to date -- for without this help sponsoring this International Workshop would not have been possible. In behalf of the Advisory Committee, other activities of the Advisory Committee for the near future include:

1. Selection of Daet, Camarines Norte as the second test site, with a view of constructing two experimental houses at the PAGASA's weather station there.

2. Consideration of three choices for the third test site. This location will have to be decided shortly after the Workshop.

3. Committment of the construction of four houses at these two additional sites. The People's Homesite and Housing Corporation has announced their donation of two houses at one test site, while the Government Service Insurance System has promised to construct the other two at the third site.

4. Informed the staff of the National Hydraulic Research Center of the start of the preliminary wind tunnel testing which will complement field observations.

5. Alerted possible end-users of the results of this research by agreeing to make available any useful findings even if these have not been formally released.

The above summary reflects the enthusiasm of each and every member of the Advisory Committee. It has been my pleasure to be a part of this undertaking. We now all look forward to a very fruitful research. Thank you.

CLIMATOLOGY AND WIND RELATED PROBLEMS IN THE PHILIPPINES

by
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ABSTRACT

This paper attempts to synthesize climatological information particularly wind data into a form which would be most useful to engineers and designers of building and/or low-cost housing in the Philippines or in similarly situated tropical countries.

The first portion summarizes the climatic controls and resulting wind systems which dominate the country for each particular season of the year. It also gives statistical information on transient systems which give rise to very strong wind speeds experienced in the country. In particular, the frequency distribution of tropical cyclones for various parts of the country have been determined and incorporated in the analysis of extreme wind values.

The main portion of the paper deals with the statistical analysis of extreme maximum wind speeds based on one minute sustained maximum winds observed at a standard anemometer height of 10 meters above the ground. The wind data are extracted from all available records at the Philippine Meteorological Service covering periods ranging from 12 to 21 years.

Employing the statistical theory by Gumbel (1,2) and the fitting technique of Lieblein as discussed by Thom (9), a table was prepared giving the annual maximum wind speeds at certain specified recurrence intervals for 19 representative stations in the Philippines.

Finally, it is suggested that for estimating maximum wind speeds at levels higher than the standard anemometer height of 10 meters, the logarithmic relation of wind speed with height may be employed.

INTRODUCTION

This paper puts together Philippine climatological data particularly wind observations into a form most useful to engineers and designers of buildings. It should be mentioned that this work is done without any joint action between the author and a design-engineer.

A climatological information is a form of information derived from the historical meteorological parameters by some statistical means. Its importance has proved useful in the solution of agricultural, industrial, and management problems in general. In particular, the planning of an engineering design requires such form of information. This type of information, called a climatological design value, will assure with a given probability level that an engineering system will adequately meet a set of prescribed design requirements. The choice of analysis for this type of information is a problem of the climatologist, while the assignment of a probability level and other design requirements are that of the engineer. However, the choice of the meteorological variable and its relationship to the design is a joint problem of both.

Other in design problems, the climatological variable of interest is the wind velocity. The prevailing trajectory of winds helps the designer in determining the proper orientation of the designed structures. For this purpose, a brief discussion on the climatic controls and resulting wind systems which dominate the country is presented. Likewise, the monthly charts of the wind systems' streamlines are shown.

With reference to the strength of the designed structures, the variable of interest is the extreme maximum wind speeds as suggested by several authors (2,3,4,12,15,16). This arises from the fact that if a designed structure can withstand the highest value in a year, it can likewise withstand all other values in a year. The method of analysis used is the statistical theory of extreme values by Gumbel (1). This theory has been widely employed by Gumbel(2) himself, Shellard (3,4) in Great Britain and in the United Kingdom, Kintanar(5) in the Philippines, Okubo(13) in Japan, and Thom(16) in the United States of America. This theory is likewise applicable to hydrometeorological analysis of extreme values. Lirios(7) and Ferraris(8) have used the same theory in the analysis of maximum rainfall amounts in Barbados and in the Philippines, respectively.

The Lieblein technique as described rigorously by Thom(9) is used in fitting the double exponential probability function. This method is quite simple and convenient. It is quite accurate as compared to the other methods discussed by Lowery et al(10). The maximum likelihood method is best and accurate, but the procedure is quite complex and tedious.

The data analyzed consist of one-minute-maximum wind speeds from all available records of the Philippines, Atmospheric, Geophysical, and Astronomical Services Administration. The length of records ranges from a minimum of 12 years to a maximum of 21 years.

Subsequently, maximum wind speeds that are likely to be equalled or exceeded at certain specified recurrence intervals are obtained. However, corrections may be applied to the above results due to other factors such as the frequency of tropical cyclones and the location and height of the design in question. The recurrence of maximum wind speeds are most likely in places where tropical cyclones are most frequent. Thus, a simple linear relationship is used to express maximum wind speeds as function of the tropical cyclone frequency in different places in the Philippines. This idea was set first by Hizon et al (11) but which however is not quite elaborate. On the other hand, the wind profile in the vertical as found out by Orlenko(12) varies exponentially with height depending upon the roughness characteristics of the ground. Hence, the logarithmic method of estimating the maximum wind speeds at some levels above the ground is utilized. The values of the roughness parameter employed for places considered in this study is likewise that of Orlenko(12). The power law used by Hizon et al (11) and Okubo(13) may likewise be applicable but, this method gives no separate values of the roughness characteristics of the ground between towns and cities. In other words, the logarithmic method is more appropriate in this study.

A table of factors in obtaining the maximum wind speeds at different places like towns and cities and at different levels above the ground is presented. The overall results of this study may therefore enable the engineer or designer of buildings to design his structure on the basis of meteorologically calculated risks.

A REVIEW OF PHILIPPINE CLIMATIC CONTROLS

The climate of the Philippines as presented by Flores et al(14) based on the classification of Koppen, Coronas, and Hernandez shows varied types of climates from place to place. The regional variations of climates are attributed to the climatic controls which act in various intensities and in different combinations producing changes in the climatic elements observed in that region. These climatic controls are: wind systems, tropical cyclones, semi-permanent cyclones and anticyclones, ocean currents, thunderstorms, geography and topography, and linear systems. The following is a discussion of each of the above cited climatic controls:

a) Wind Systems Affecting the Philippines

The climate of the Philippines is largely controlled by the wind systems affecting the Philippines as a result of the seasonal differential heating of neighboring continents and oceans. The major types of wind systems that affect the country at different seasons of the year are:

1) The Southwest Monsoon

This air stream is sometimes called the southwesterlies. It originates as Indian Ocean Trades from the Indian Ocean Anticyclone during the Southern Hemisphere Winter. On its journey northward, it is deflected to the right in the Northern Hemisphere as it crosses the equator reaching the country as a Southwesterly air stream. It is of considerable depth, often extending from the earth's surface up to 10 km. The surface trajectory is shown in Figures 6 to 9 based on the 21- year records. This air stream affects the country as early as the month of June. It attains its maximum intensity in August and gradually recedes in the later part of September. In some occasions, it may blow in surges and persists up to the later part of October. Heavy rainfall concentrated along the western coastal areas of the country during the period from June to September is caused by this air mass.

2) The Northeast Monsoon

This air mass is sometimes called the Northers or Winter Monsoon. It originates in the cold intense Asiatic Winter Anticyclone and spirals outward across Japan towards the Northwestern Pacific Ocean. It finally reaches the country as a Northeasterly air stream. It starts affecting the Philippines during the later part of October, attains its maximum intensity in January and gradually recedes in the later part of April. The trajectory of this air stream is shown in Figures 1,2,3,4,10,11, and 12. This air stream is rather shallow extending rarely to 2 1/2 km. The temperature inversion layer of this air stream is moderate at about 1 1/2 km. This air stream is responsible for the relatively cold weather spell and heavy rainfall along eastern coastal regions of the country during the winter season of the year.

3) The North Pacific Trades

This air stream comes from the North Pacific Anticyclone arriving in the Philippines generally from the north and east directions. It blows dominantly during the months of April, May and October (see Figure 5). It usually overlies the Northeast Monsoon air mass over the eastern sections of the country. It is distinctively the warmest air mass that affects the country. Its convective activity may result to the formation of fair weather cumulus and stratocumulus clouds owing to the presence of dry layers above it. At times, showers may result from a towering cumulus developed by this air mass.

4) The South Pacific Trades

This air stream originates from the South Pacific Anticyclone in the Southern Hemisphere. It veers to the right upon crossing the equator and reaches the Philippines as a southwesterly flow during July. It is warm and quite moist at low levels and relatively dry at upper levels. It is difficult to distinguish this air stream from that of the Southwest Monsoon air mass because their characteristics are almost similar. These air streams differ only on the height of their subsidence layers. The south Pacific Trades has its inversion layer at about 1 1/2 kilometers while that of the Southwest Monsoon is at about 4 kilometers high from the surface.

b) Tropical Cyclones

Tropical cyclones influence the behavior of other climate elements to a certain degree. They are responsible for the maximum values of wind speeds, torrential rainfall, and minimal atmospheric pressures observed in different parts of the country. They contribute largely to the rainfall from June to December.

The Philippines is a country considered to have the greatest frequency of tropical cyclones in the world. In general, these cyclones are destructive to life and property. A survey of damages inflicted by these cyclones in the Philippines for a period from 1948 and 1971 showed an annual average of 960 casualties and an estimated yearly loss to property worth 67.8 million pesos. During this period of study a total of 483 tropical cyclones formed-in or entered into the Philippine Area of Responsibility. Out of this number, about 42% touched or crossed the Philippine Archipelago.

The tropical cyclone season in the country generally covers the period from June to December, although the rest of the year is not entirely free from these cyclones. Table 7 shows the monthly and annual frequency of these cyclones. Figure 21 shows the histogram of these cyclones while Figure 13 shows the mean percent frequency in different parts of the country. These cyclones follow widely variable tracks in the vicinity of the Philippines moving at an average speed of 6 meters/second. They usually affect the country from 1 to 7 days depending upon their trajectory characteristics.

c) Other Climatic Controls

1) Semi-Permanent Cyclones and Anticyclones

The climate of the Philippines is controlled to a certain degree by the location and intensity of nearby semi-permanent cyclones and anticyclones. They are responsible for the evolution of air streams and ocean currents affecting the country at different seasons of the year. The large anticyclone centered off Siberia is responsible for the evolution of the Northeast Monsoon while that one located over the Indian Ocean is responsible for the evolution of the Southwest Monsoon air mass.

2) Ocean Currents

The ocean current affecting the country is the North Equatorial current moving westerly across the North Pacific Ocean. This current splits into Northward and Southward branches upon reaching eastern coastal areas of the archipelago. The Northward bound current becomes the Korushio Current while the Southward bound current flows along the east coast of Southern Visayas and Mindanao, recurves to the east and becomes the Equatorical Counter Current. Motions of ocean currents are attributed to the difference in insolation the ocean received and due to the driving effect of winds upon contact with the surface layers. The temperature at the surface of the sea in the vicinity of the country is relatively high. Thus, air passing over the warm sea surface becomes impregnated with water vapor.

3) Thunderstorms

Thunderstorms are relatively small scale and short period disturbances as compared to tropical cyclones. They are usually triggered by the presence of the moist and unstable air streams coupled with orographic lifting. They affect the country practically all months of the year.

4) Geography and Topography

The country is made up of approximately 7000 islands which are grouped into three regions namely: Luzon Region, Visayas Region and Mindanao Region. The islands are mostly oriented north to south and completely surrounded by large bodies of water. Luzon, the largest island, consists of several mountain ranges of more than 500 meters high. The Sierra Madre Mountains are located along the eastern coast of Northern and Central Luzon. The Ilocos Ranges are located along the Western coast of Northern Luzon, while the Cordillera Ranges lie between the Sierra Madre and the Ilocos Ranges. The Zambales Ranges are situated along the western coast of Central Luzon. Most of the bigger islands of the Visayas also have 500 meter elevations or more are situated in western, central and eastern portions of the island. These topographical features may serve as the orographic obstacles to the air streams affecting the country. Figure 22 shows the geographical and main topographical features of the Philippines.

5) Linear Systems

The Philippines is also affected by fronts, the intertropical convergence zone, and easterly waves which are referred to as linear systems. The behavior of each of these systems is as follows:

(a) Fronts

Frontal systems affect the northern portion of the country during the winter season only. They are oriented west-southwest to east-northeast cutting across the island of Luzon during January. The diffused tail ends of these systems move as far south as Mindanao. These fronts are considered as the interfaces between the Northeast Monsoon and the North Pacific Trades. Coupled with topographic effects, they are responsible for the portion of rainfall and cloudiness over the country where they are oriented.

(b) Intertropical Convergence Zone

This zone is also known by such names as intertropical front, equatorial trough, doldrum belt, etc. It is a relatively low pressure zone which serves as the zone of discontinuity between the Northern and Southern Hemisphere air streams. It starts affecting the southern portion of the country during May, oriented generally from east to west and moving northwards. It is at the northern tip of the country during the month of July and well to the South during November. The variations of the position from day to day are quite large and disorganized. Over this zone the weather is quite disturbed consisting of widespread cloudiness, occassional precipitation, and moderate to strong surface winds.

(c) Easterly Waves

These are wavelike perturbations embedded in the easterly current which move from east to west. They affect the country with varying intensities being more frequent during the summer months. These waves are accompanied by cloudiness and precipitation usually along the orographic obstacles on the eastern coastal portions of the country.

ANALYSIS OF THE EXTREME ANNUAL WIND SPEEDS

a) The Theory of Extreme Values

A series of extreme values of wind speeds can be represented by a Fisher-Tippett Type I probability function which is given as:

$$P(x) = \mathrm{Exp}\left(-\mathrm{Exp}-\left(\frac{x-\alpha}{\beta}\right)\right) \qquad \text{.............(1)}$$

where P(x) is the probability that any of the N extremes will be less than x. Taking the double logarithm on both sides of the above equation and expressing P(x) as a function of the recurrence interval, T, which in turn is also expressed as the reciprocal of the probability of non-exceedence, that is,

$$T = \frac{1}{1-P(x)} \qquad \text{.............(2)}$$

Then expressing for x, equation (1) becomes:

$$x = \alpha - \beta \ln\left(\ln \frac{T}{T-1}\right) \qquad \text{.............(3)}$$

where x depends upon the recurrence interval, T and the parameters of the initial distribution α and β . The method of fitting the above function needs only priori value of T and the estimates of the parameters α and β.

b) The Lieblein Fitting Technique

This method of fitting the double exponential theory involves maintaining carefully the original time order series and subgrouping them into a maximum of five or six variables each. These variables in each subgroup are then arranged in order of increasing magnitude such that the whole series will form into a matrix denoted by x_{ij} where i = 1,2,3,.....k, denotes the number of subgroups and j = 1,2,3,....m, denotes the number of variables in each subgroup. Thus, if N = 30, k = 5, and m = 6. This would appear as in Table 1. Each column of x in Table 1 is first summed up to obtain $S_{.j}$. These values are multiplied by the corresponding values of $a_{.j}$ found in Table 2, the Table of Order Statistics Weights. The results will be summed up again horizontally to obtain the row sum $\sum a_{.j}S_{.j}$ as indicated in the table. Next, the $S_{.j}$ are again multiplied by the corresponding values of $b_{.j}$ likewise found in Table 2, and summed up again horizontally to obtain another row sum $\sum b_{.j}S_{.j}$. Thus, the estimates of α and β are as follows:

$$\alpha^* = \frac{1}{k}\sum_{j=1}^{m} a_{.j}S_{.j} \qquad \text{.............(4)}$$

$$\beta^* = \frac{1}{k}\sum_{j=1}^{m} b_{.j}S_{.j} \qquad \text{.............(5)}$$

Equations (4) and (5) are then substituted in equation (3) to get the estimates of x at certain priori values of the recurrence interval, T.

In cases where there are still remainders in the subgrouping of five or six variables each, the remainders will be treated separately. Suppose N = 33 instead of previously 30 variables for the whole series, the last three values of the sample climatological series is then formed into an additional subgroup of m' = 3. These values are likewise arranged in

x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}	
x_{21}	x_{22}	x_{23}	x_{24}	x_{25}	x_{26}	
x_{31}	x_{32}	x_{33}	x_{34}	x_{35}	x_{36}	
x_{41}	x_{42}	x_{43}	x_{44}	x_{45}	x_{46}	
x_{51}	x_{52}	x_{53}	x_{54}	x_{55}	x_{56}	
$s_{\cdot 1}$	$s_{\cdot 2}$	$s_{\cdot 3}$	$s_{\cdot 4}$	$s_{\cdot 5}$	$s_{\cdot 6}$	
$a_{\cdot 1}$	$a_{\cdot 2}$	$a_{\cdot 3}$	$a_{\cdot 4}$	$a_{\cdot 5}$	$a_{\cdot 6}$	
$a_{\cdot 1}s_{\cdot 1}$	$a_{\cdot 2}s_{\cdot 2}$	$a_{\cdot 3}s_{\cdot 3}$	$a_{\cdot 4}s_{\cdot 4}$	$a_{\cdot 5}s_{\cdot 5}$	$a_{\cdot 6}s_{\cdot 6}$	$=\sum a_{\cdot j}s_{\cdot j}$
$s_{\cdot 1}$	$s_{\cdot 2}$	$s_{\cdot 3}$	$s_{\cdot 4}$	$s_{\cdot 5}$	$s_{\cdot 6}$	
$b_{\cdot 1}$	$b_{\cdot 2}$	$b_{\cdot 3}$	$b_{\cdot 4}$	$b_{\cdot 5}$	$b_{\cdot 6}$	
$b_{\cdot 1}s_{\cdot 1}$	$b_{\cdot 2}s_{\cdot 2}$	$b_{\cdot 3}s_{\cdot 3}$	$b_{\cdot 4}s_{\cdot 4}$	$b_{\cdot 5}s_{\cdot 5}$	$b_{\cdot 6}s_{\cdot 6}$	$=\sum b_{\cdot j}s_{\cdot j}$

Table 1

m	$x_{\cdot 1}$	$x_{\cdot 2}$	$x_{\cdot 3}$	$x_{\cdot 4}$	$x_{\cdot 5}$	$x_{\cdot 6}$	
1	-						
2	.91637	.08363					$a_{\cdot j}$
	- .72135	.72135					$b_{\cdot j}$
3	.65632	.25571	.08797				$a_{\cdot j}$
	- .63054	.25582	.37473				$b_{\cdot j}$
4	.51100	.26394	.15368	.07138			$a_{\cdot j}$
	- .55862	.08590	.22392	.24880			$b_{\cdot j}$
5	.41893	.24628	.16761	.10882	.05835		$a_{\cdot j}$
	- .50313	.00653	.13045	.18166	.18448		$b_{\cdot j}$
6	.35545	.25549	.16562	.12105	.08352	.04887	$a_{\cdot j}$
	- .45928	-.03599	.07319	.12673	.14953	.14581	$a_{\cdot j}$

Table 2 - Table of Statistics Weights (after Lieblein)

order of increasing magnitude. Hence, it would appear as in Table 3. Following a similar procedure as in the earlier paragraph, the final estimates of α and β, will be

$$\alpha^{**} = \frac{m}{N}\sum_{j=1}^{m} a_{\cdot j} S_{\cdot j} + \frac{m'}{N}\sum_{j=1}^{m'} a_{\cdot j} S_{\cdot j} \qquad \text{.............(6)}$$

$$\beta^{**} = \frac{m}{N}\sum_{j=1}^{m} b_{\cdot j} S_{\cdot j} + \frac{m'}{N}\sum_{j=1}^{m'} b_{\cdot j} S_{\cdot j} \qquad \text{.............(7)}$$

Equations (6) and (7) are likewise substituted in equation (3) to obtain the quantile values of x.

Table 3

x_{61}	x_{62}	x_{63}	
$a_{\cdot 1}$	$a_{\cdot 2}$	$a_{\cdot 3}$	
$a_{\cdot 1}x_{61}$	$a_{\cdot 2}x_{62}$	$a_{\cdot 3}x_{63}$	$=\sum a_{\cdot j}x_{6j}$
x_{61}	x_{62}	x_{63}	
$b_{\cdot 1}$	$b_{\cdot 2}$	$b_{\cdot 3}$	
$b_{\cdot 1}x_{61}$	$b_{\cdot 2}x_{62}$	$b_{\cdot 3}x_{63}$	$=\sum b_{\cdot j}x_{6j}$

The results of the above procedures as actually applied to all available records of the one-minute-maximum sustained wind speeds are presented in Table 4. The above-cited result yields maximum wind speeds at certain specified recurrence intervals for different places in the Philippines as indicated therein. The effective height of these computed maximum wind speeds is at 10 meters since, records of wind data used in the proceeding analysis are observed at the standard anemometer height of 10 meters above the ground.

Estimates of maximum wind speeds for places in the Philippines other than those indicated in Table 4 can be obtained by interpolation from the isolines of computed maximum wind speeds drawn in as shown on Figures 14 to 19 in the appendix. Isolines of the average maximum wind speeds for places considered in this study are likewise drawn in as shown in Figure 20 for reference purposes. However, these charts should be used with great caution as values interpolated therein may need considerable adjustment from the topography of a place.

c) <u>Correction to the Maximum Wind Estimate Using the Tropical Cyclone Frequency Factor</u>

Maximum sustained wind speeds observed in different parts of the Philippines are mostly caused by tropical cyclones. The frequency of tropical cyclone occurrences varies throughout the archipelago from 40% in Northern Luzon down to slightly near zero percent in Mindanao as shown in Figure 13. In other words, in those areas where tropical cyclone occurrences are more frequent it is more likely that the chance of the recurring maximum wind speeds will be higher. Hence, it appears that a frequency factor from these cyclones for safety of the design may likewise be considered in this type of climatological information.

Perhaps the cost of the design may substantially increase considering that there are still non-meteorological factors to be considered; but this author believes it is reasonable to take into account the tropical cyclone frequency factor. The values of this factor, denoted by ft, for different places in the Philippines are shown in Table 5. These factors are evaluated from Figure 13 which are based on the 24-year period of tropical cyclone frequency study in different places in the Philippines.

Table 4. ANNUAL MAXIMUM WIND SPEEDS (Knots) AT 10 METER LEVEL

STATION	PERIOD	Recurrence Intervals (years) 5	10	15	20	25	50	75	100
1. Vigan	1953-72	56.9	68.5	76.3	81.5	85.3	96.2	100.8	107.5
2. Lucena	1961-72	42.8	50.2	54.3	56.2	58.3	64.2	66.8	70.5
3. Infanta	1960-72	63.6	79.9	88.9	95.8	100.8	115.1	121.6	129.9
4. Casiguran	1964-72	80.7	99.3	109.8	117.3	123.1	139.3	146.6	156.1
5. Legaspi City	1957-72	96.5	119.4	132.2	141.5	148.9	168.9	177.4	189.9
6. Ambulong	1951-72	48.4	58.0	63.4	67.4	70.2	78.8	82.5	87.6
7. Puerto Princesa	1951-72	34.7	42.0	46.3	49.4	51.7	58.0	60.8	64.8
8. Surigao City	1954-72	54.0	63.0	68.0	71.8	74.6	82.6	86.0	90.7
9. Calapan	1961-72	47.3	56.3	61.6	65.5	68.4	76.4	79.9	84.7
10. Baguio City	1951-71	57.0	64.0	68.0	72.0	74.0	60.0	83.0	86.0
11. Cagayan de Oro City	1955-71	16.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
12. Cebu City	1951-71	57.0	70.0	78.0	84.0	88.0	99.0	104.0	112.0
13. Davao City	1951-71	31.0	35.0	38.0	40.0	41.0	44.0	46.0	48.0
14. Iloilo City	1951-71	47.0	51.0	54.0	55.0	57.0	61.0	62.0	65.0
15. Tacloban City	1951-71	53.0	59.0	62.0	65.0	68.0	72.0	74.0	77.0
16. Manila	1951-71	76.1	87.7	94.1	99.0	102.5	112.5	116.9	121.8
17. Pasay City	1951-71	53.0	59.0	62.0	65.0	67.0	73.0	75.0	77.0
18. Zamboanga City	1951-71	37.0	42.0	45.0	47.0	49.0	53.0	55.0	58.0
19. Laoag City	1951-71	62.1	70.3	74.9	78.4	80.8	87.9	91.0	94.4

To obtain the maximum wind speeds where the frequency factor is considered, equation (8) can be used. This is given as

$$U = U_t \ (1 + f_t) \quad \ldots\ldots\ldots\ldots (8)$$

where U is the desired wind speed, U_t is the maximum wind speeds at certain recurrence intervals found in Table 4, and f_t is the frequency factor for tropical cyclones presented in Table 5. The above expression is only a simple estimate using linear relationship between

Places in the Philippines	Frequency Factor, f_t
1. Vigan	0.25
2. Lucena	0.15
3. Infanta	0.15
4. Casiguran	0.35
5. Legaspi City	0.25
6. Ambulong	0.15
7. Puerto Princesa	0.15
8. Surigao City	0.15
9. Calapan	0.15
10. Baguio City	0.15
11. Cagayan de Oro City	0.05
12. Cebu City	0.15
13. Davao City	0.05
14. Iloilo City	0.15
15. Tacloban City	0.25
16. Manila	0.15
17. Pasay City	0.15
18. Quezon City	0.15
19. Zamboanga City	0.05
20. Laoag City	0.35

Table 5 - Tropical Cyclone frequency factor in different places in the Philippines.

the maximum wind speeds and the frequency of tropical cyclones occurrences. But, a more rigorous and more accurate method may be made by the use of regression analysis.

d) Estimates of Maximum Wind Speeds in the Vertical

Designs of tall buildings especially in large towns and cities require climatological information in rationalizing the risk of failure of the design at these places and heights above the ground. Thus, it appears necessary to evaluate the design wind speeds at these areas. It should be mentioned that records of maximum wind speeds in the Philippines higher than the standard anemometer level are nil. The profile of wind velocity in the vertical varies exponentially. Hence, it is possible to estimate the wind speeds in the vertical. Considering the aerodynamic aspects of winds near the ground, the velocity-height relationship formula which is referred to as the logarithmic law provides a means of estimating winds speeds higher than the standard height of 10 meters. This logarithmic law is given as

$$U_Z/U_{10} = \frac{\ln Z/Z_0}{\ln Z_{10}/Z_0} \quad \ldots\ldots\ldots\ldots (9)$$

where: U_Z is the desired wind speed at any height, Z
U_{10} is the wind speed observed at anemometer (10 meters) level
Z is the height at which wind speed is desired
Z_{10} is the height at standard anemometer level (10 meters)
Z_0 is the roughness characteristic of the ground

For large towns and cities, the roughness parameter as found out by Orlenko(12) is 100 centimeters and 200 centimeters respectively. These values are used to evaluate the right side of equation (9). The results are shown in Table 6.

Height above the ground	Towns	Cities
15 meters	1.18	1.25
20 meters	1.30	1.43
25 meters	1.40	1.57
50 meters	1.67	1.94

Table 6 - Computed values of $\ln Z/Z_0 \div \ln Z_{10}/Z_0$

The values presented in Table 6 may be used to estimate the maximum wind speeds at levels and places indicated therein. These values serve as factors to be multiplied to the values of maximum wind speeds shown in Table 4 to obtain the design wind speeds. Suppose a design is desired at 50 meters high in Baguio City and that the lifetime of the design will be up to 50 years, the climatological factor for such design will be based on the maximum wind speeds of 155 knots or roughly 80 meters per second wind speed.

5. Conclusions and Recommendations for Further Studies

This study was based on the well-known methods of statistical analysis for building design purposes as discussed in the earlier paragraph. Therefore, the results obtained can be used operationally in the design of all types of buildings situated in the Philippines, provided the limitations in the use of the data are noted and taken into consideration.

It should be mentioned that the use of simple estimated linear relationship between the maximum wind speeds and that of the tropical cyclone frequency may be sufficiently accurate, but the quantitative analysis or approach by the use of regression technique is highly recommended. It is likewise recommended that the actual profile of strong winds in the vertical and the actual values of local roughness characteristics of the ground be determined for this country.

The future plan of this author is to conduct further research along this line so that problems which may lead to a design not achieved due to some climatological causes may be eased.

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TABLE 7 - MONTHLY AND ANNUAL FREQUENCY OF TROPICAL CYCLONES IN THE PHILIPPINES AREA OF RESPONSIBILITY (1948-1971)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
1948	1	0	0	0	2	0	3	1	3	2	6	5	21
1949	1	0	0	0	0	3	4	2	4	3	4	1	22
1950	0	0	0	0	0	2	3	1	3	2	1	1	13
1951	0	0	0	0	1	1	1	4	2	1	2	1	13
1952	0	0	0	0	1	5	2	4	4	5	3	5	29
1953	0	1	0	0	1	2	0	5	2	2	4	1	18
1954	0	0	1	0	1	0	1	6	2	3	3	1	18
1955	1	1	0	1	0	0	2	3	1	4	1	1	15
1956	0	0	1	2	0	0	5	4	5	3	5	3	28
1957	2	0	0	1	0	2	1	2	3	3	1	0	15
1958	1	0	0	0	0	1	4	3	3	2	4	0	18
1959	0	1	1	0	0	0	1	4	2	4	3	2	18
1960	1	0	0	1	1	2	2	6	1	3	0	2	19
1961	1	1	1	0	1	3	4	4	4	1	1	2	23
1962	0	1	0	0	2	0	5	6	4	1	3	0	22
1963	0	0	0	0	0	4	4	2	3	1	0	2	16
1964	0	0	0	0	3	1	0	6	5	4	3	2	32
1965	2	1	1	0	1	3	4	4	3	1	1	0	21
1966	0	0	0	1	3	1	7	1	3	1	3	2	22
1967	0	1	1	1	1	2	4	5	0	2	3	1	21
1968	0	0	1	0	0	1	3	3	3	2	3	0	16
1969	0	0	0	1	1	0	4	2	3	2	2	0	15
1970	0	1	0	0	0	1	3	4	5	3	3	1	21
1971	1	0	1	2	4	2	5	2	4	4	2	0	27
TOTAL	11	8	8	10	23	36	80	84	72	59	61	31	483
MEAN	0.46	0.33	0.33	0.41	0.96	1.50	3.34	3.50	3.00	2.46	2.54	1.29	20

JANUARY

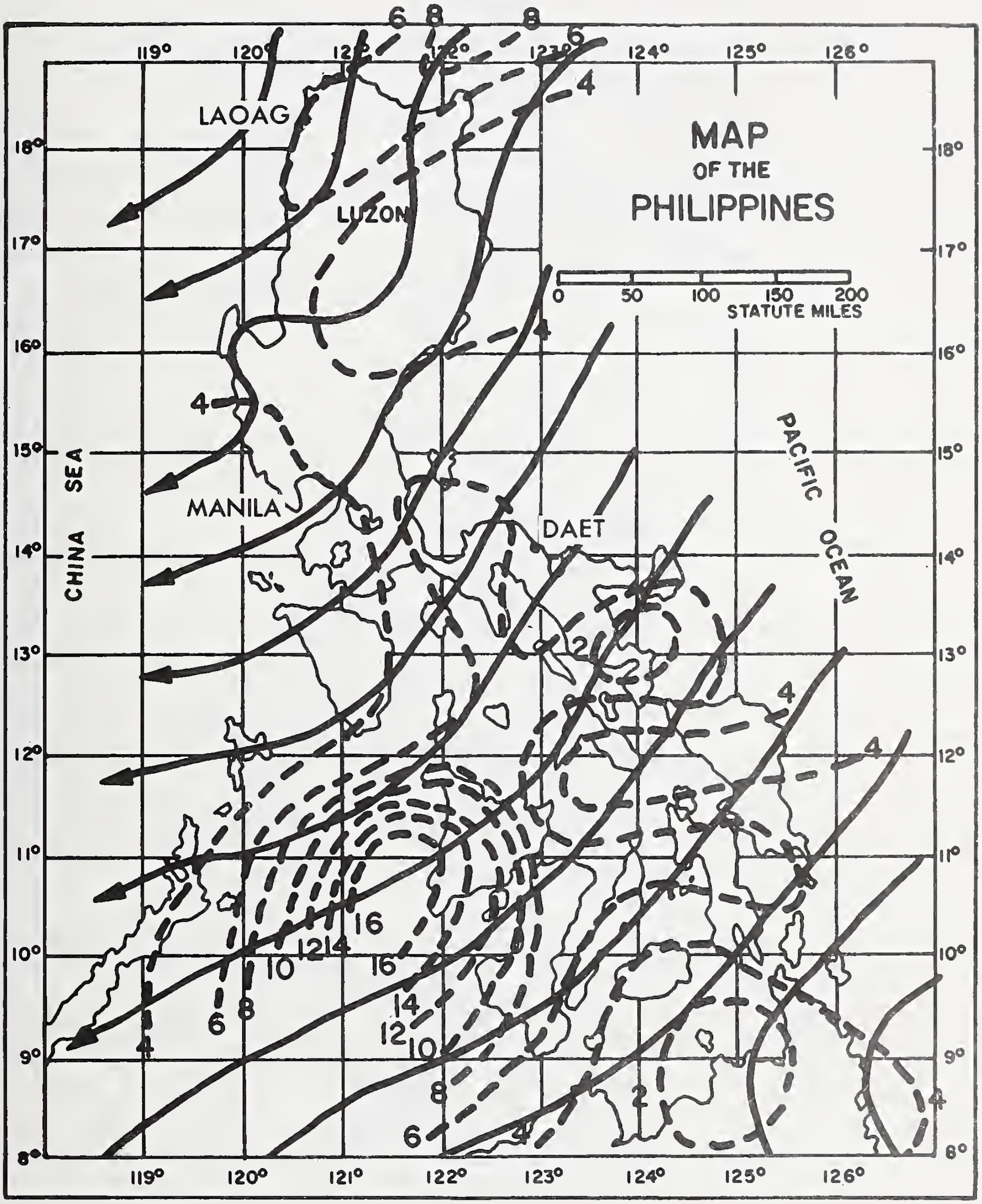

Fig. 1 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

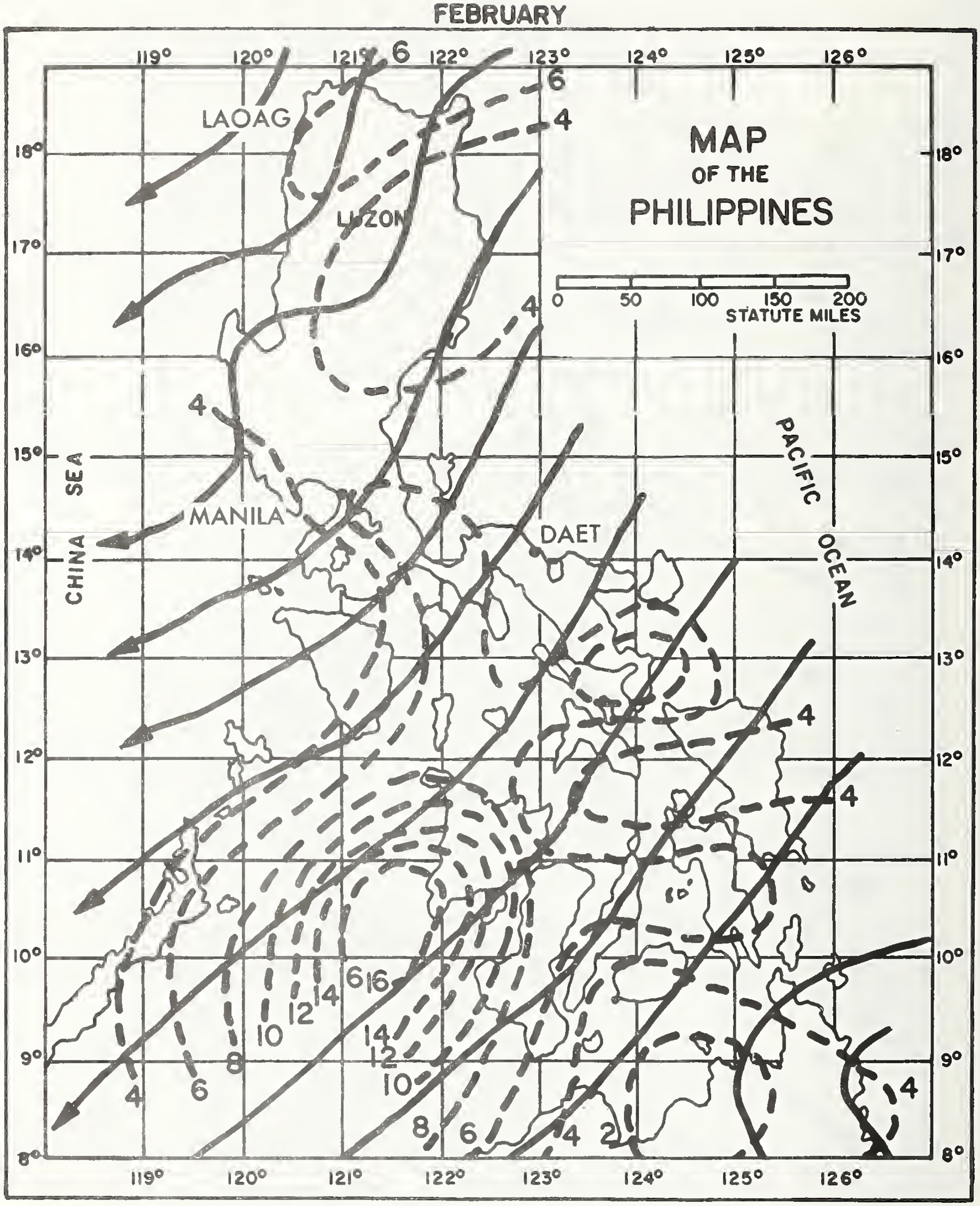

Fig. 2 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

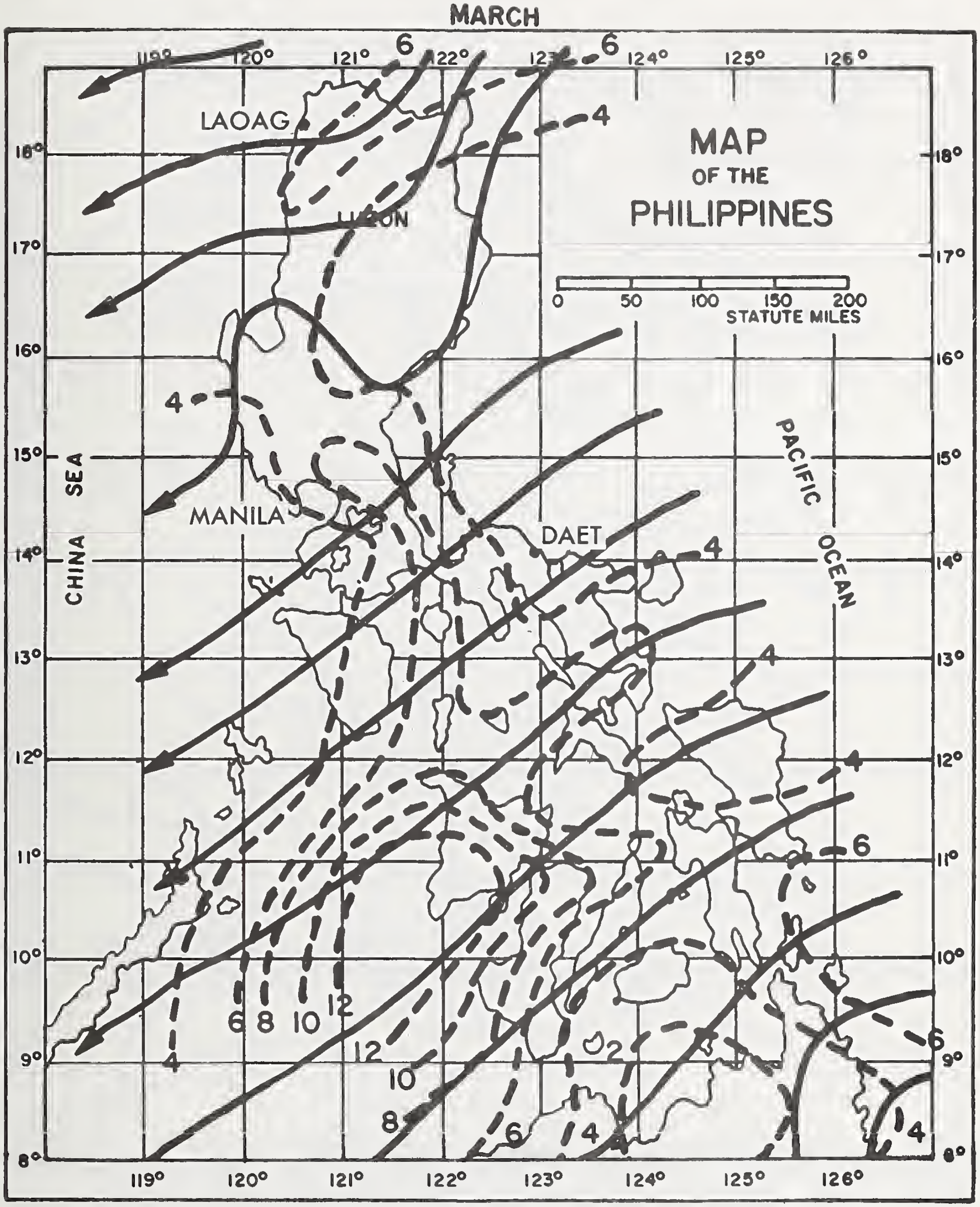

Fig. 3 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

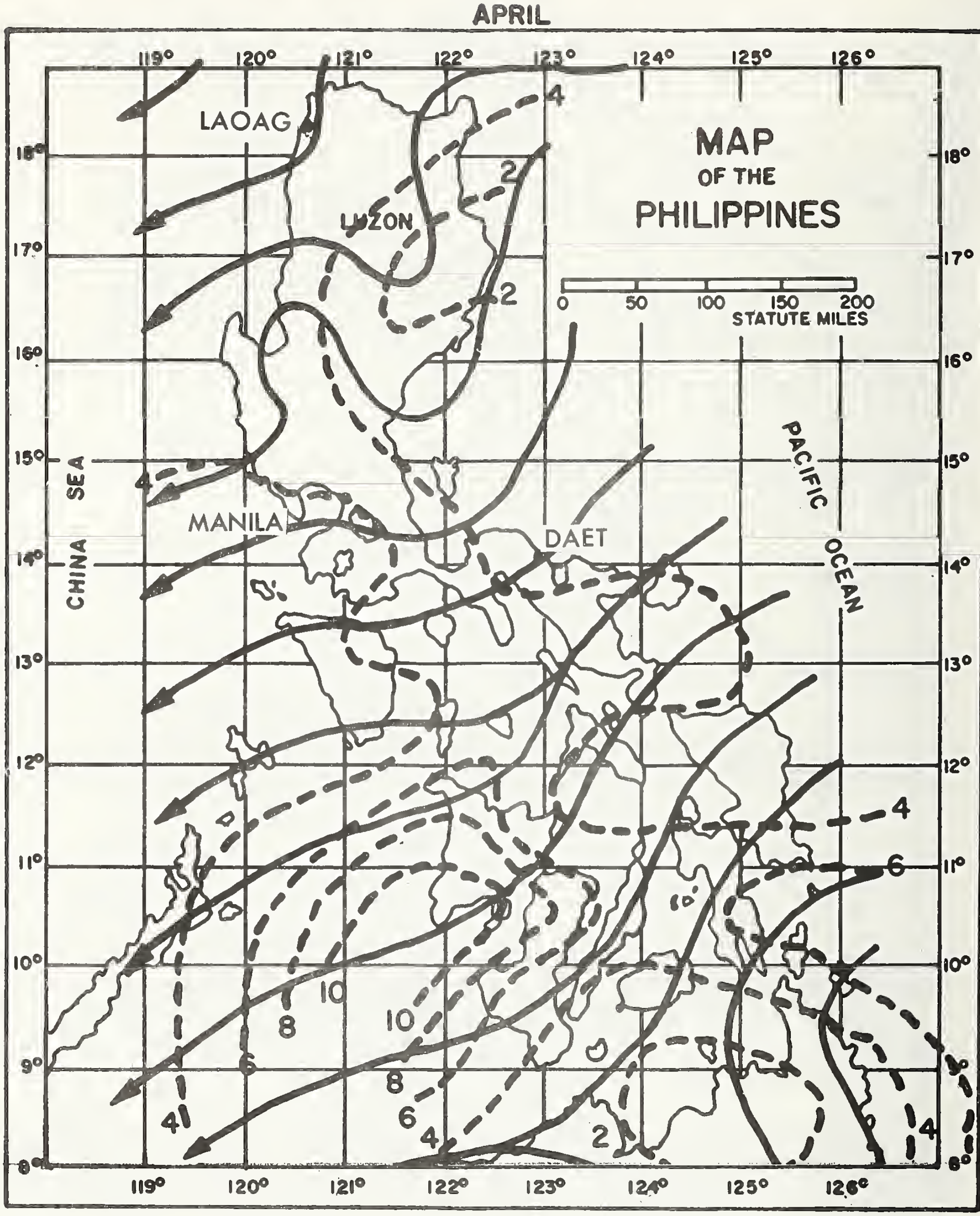

Fig. 4 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

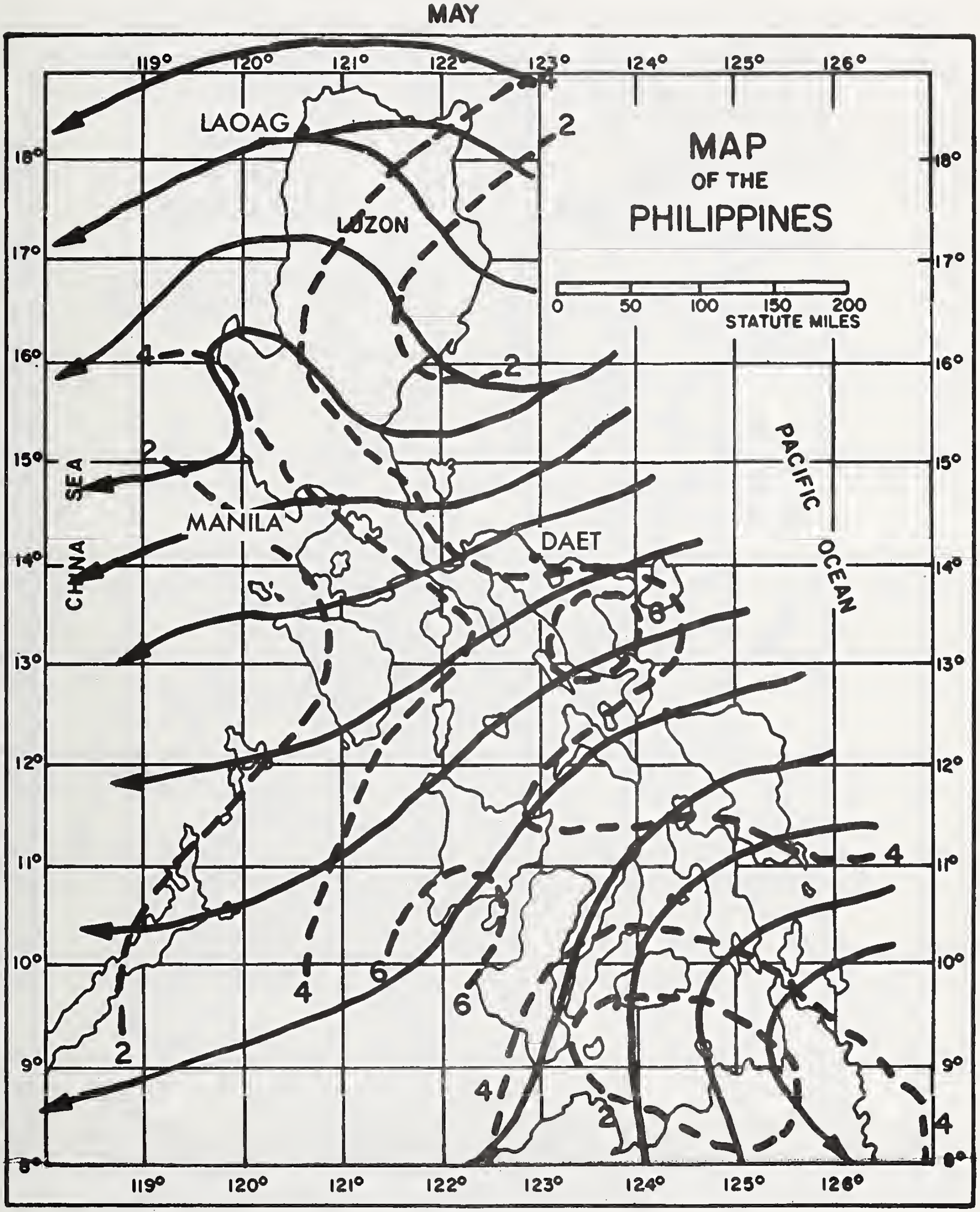

Fig. 5 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

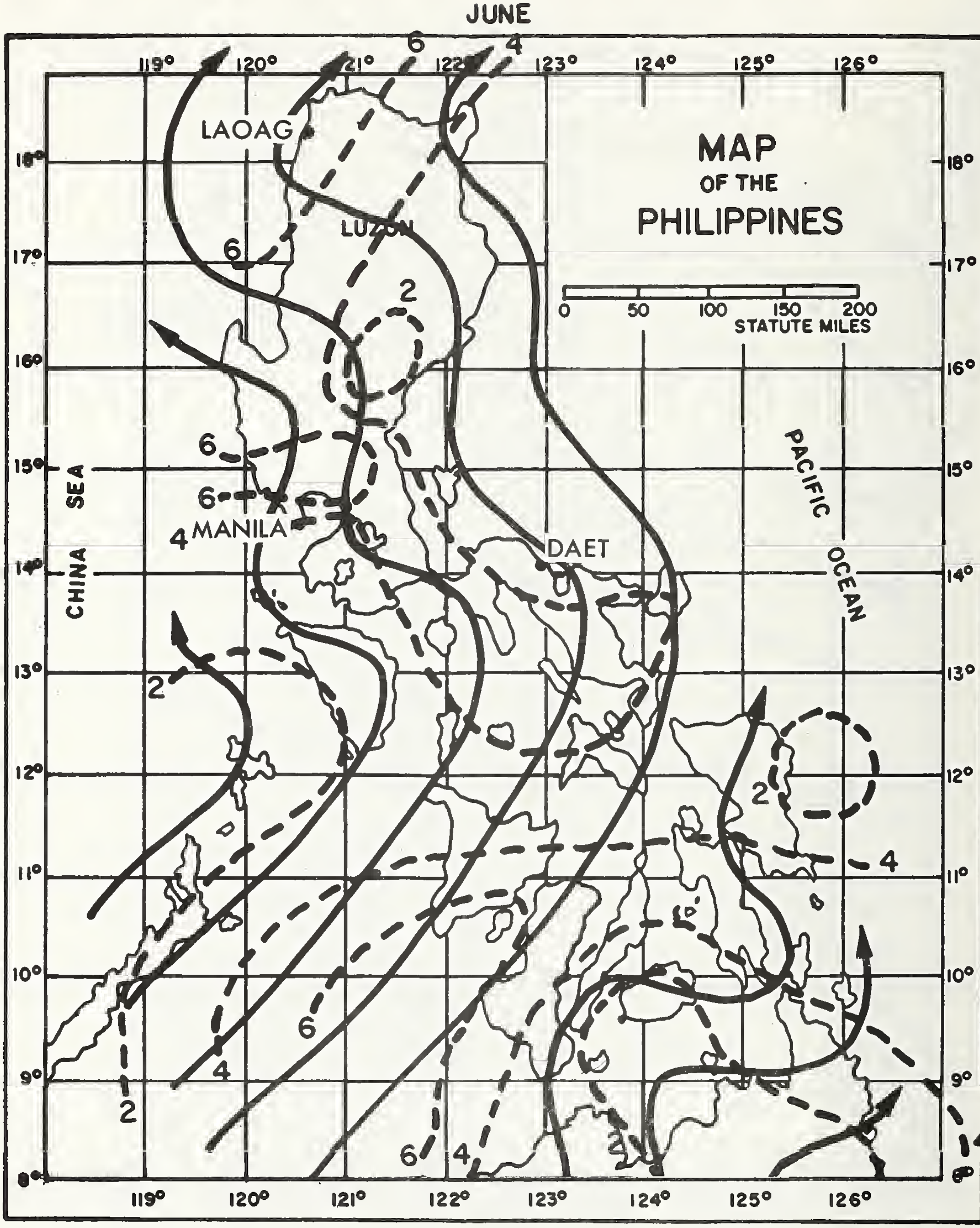

Fig. 6 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

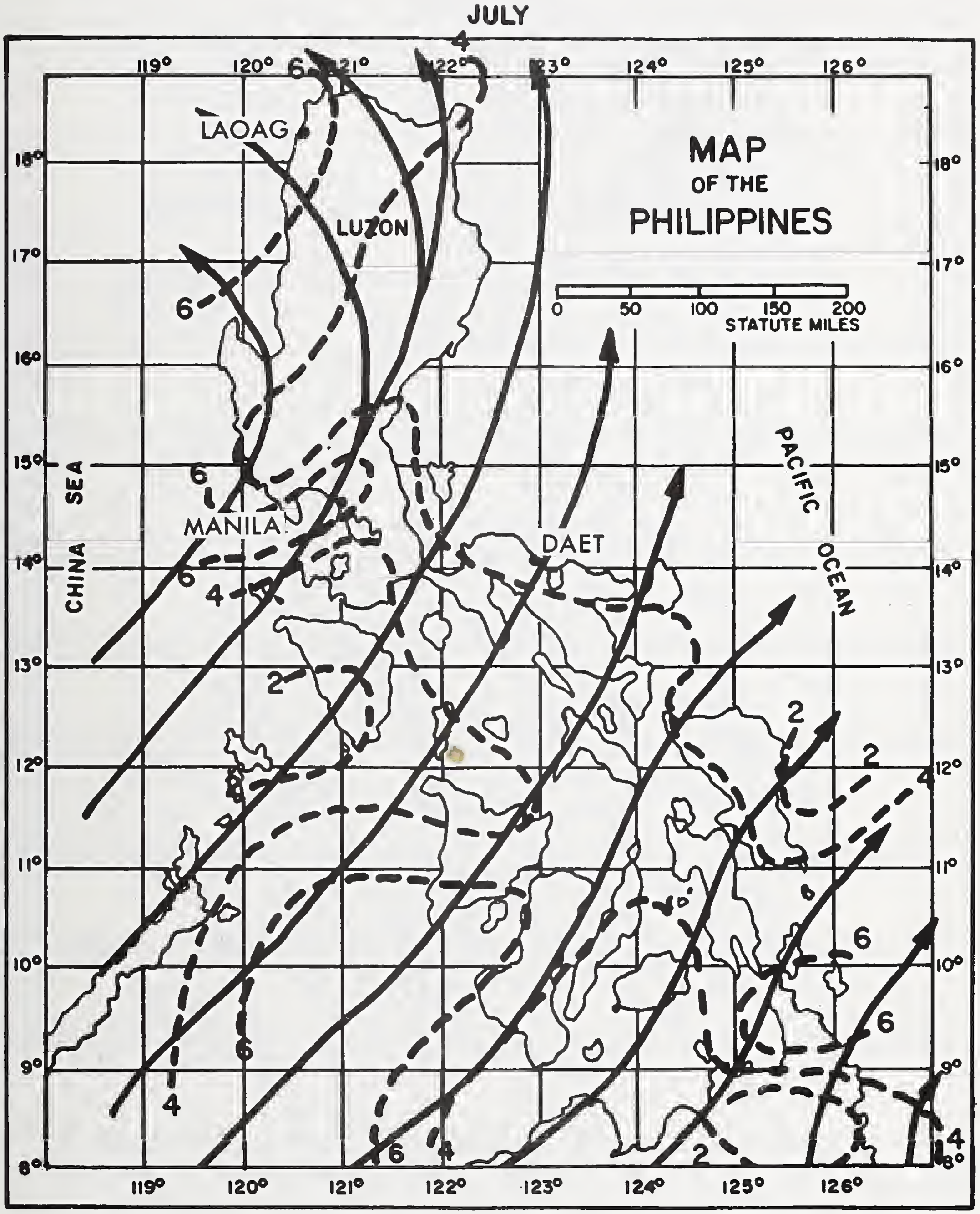

Fig. 7 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

AUGUST

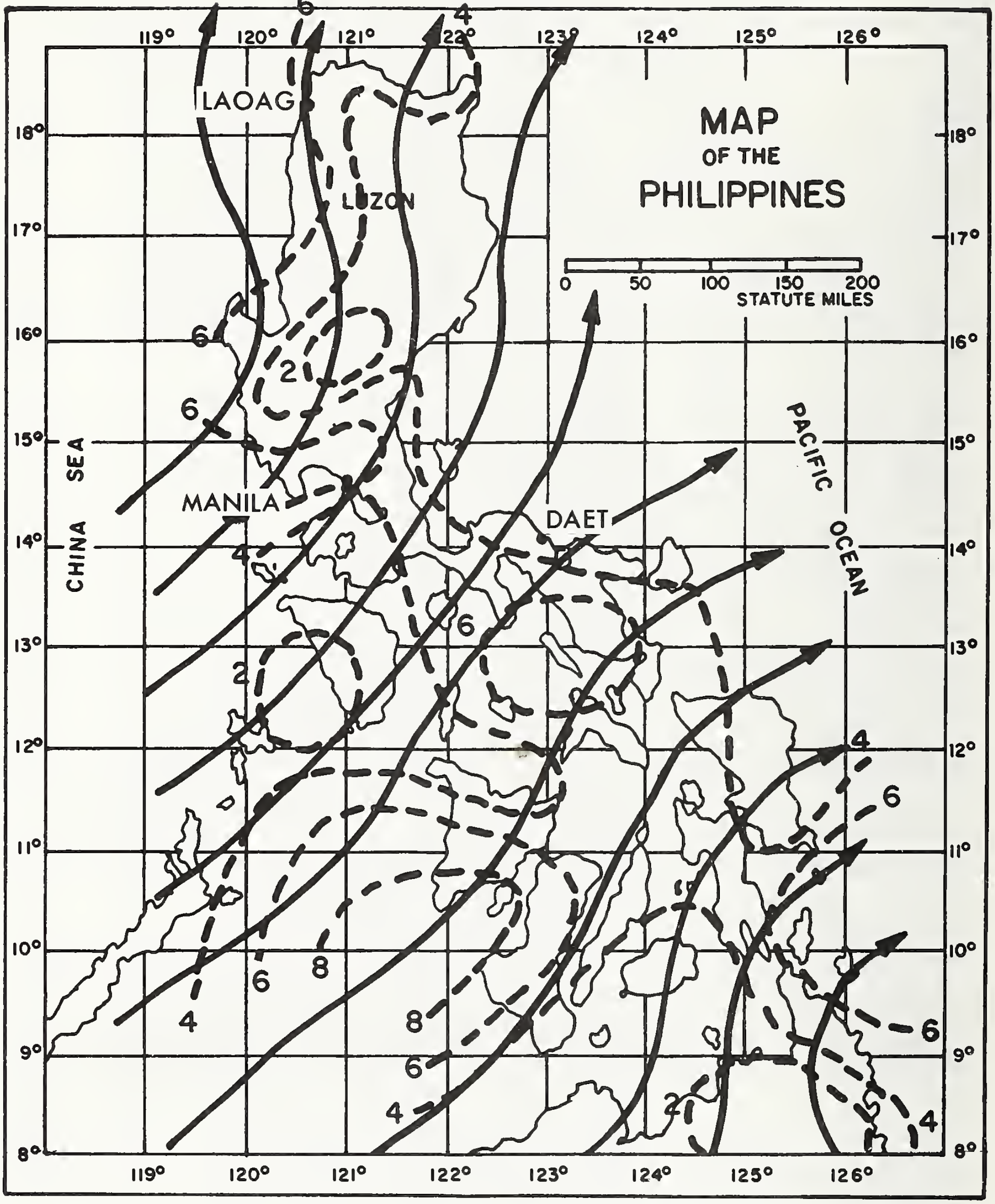

Fig. 8 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

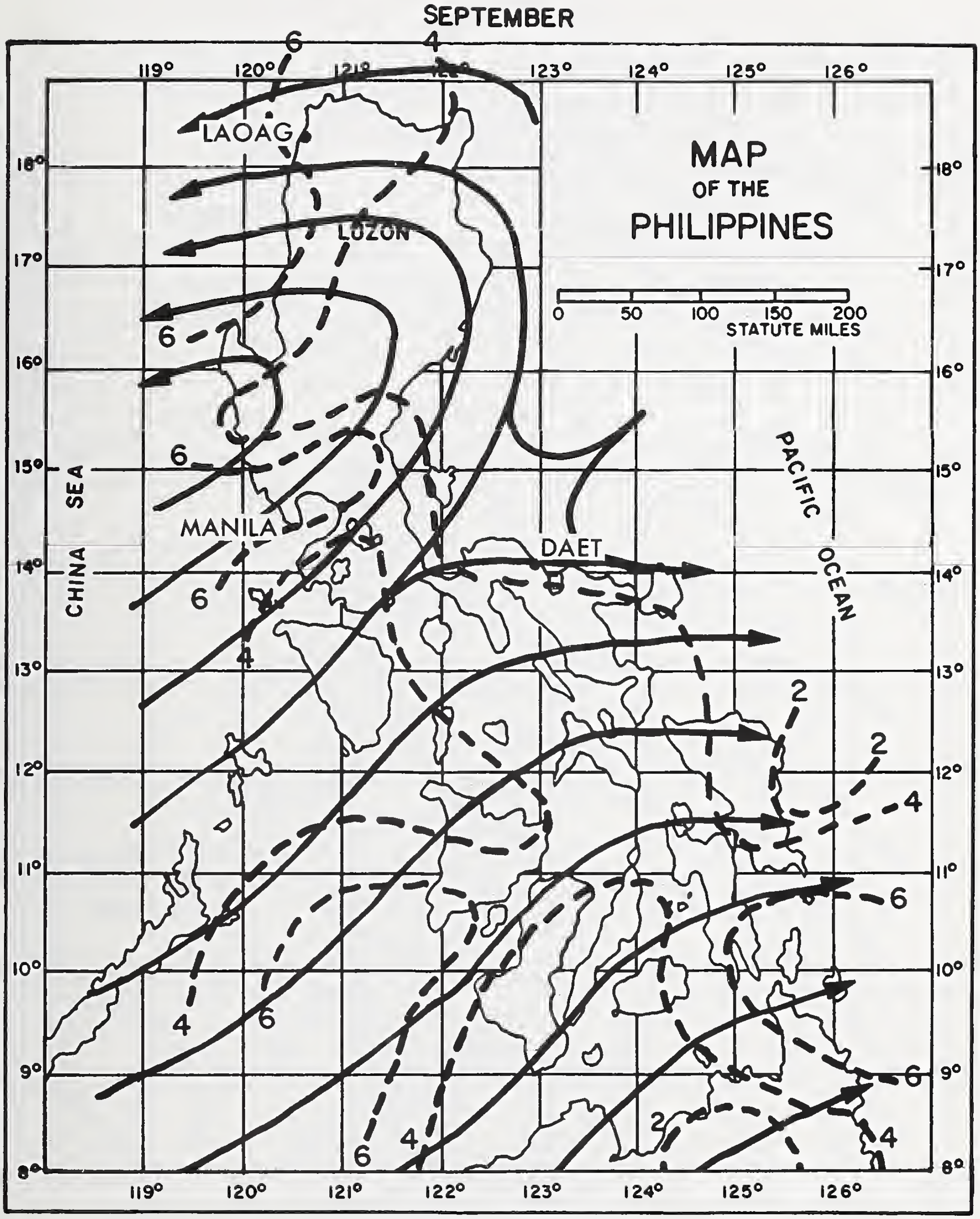

Fig. 9 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

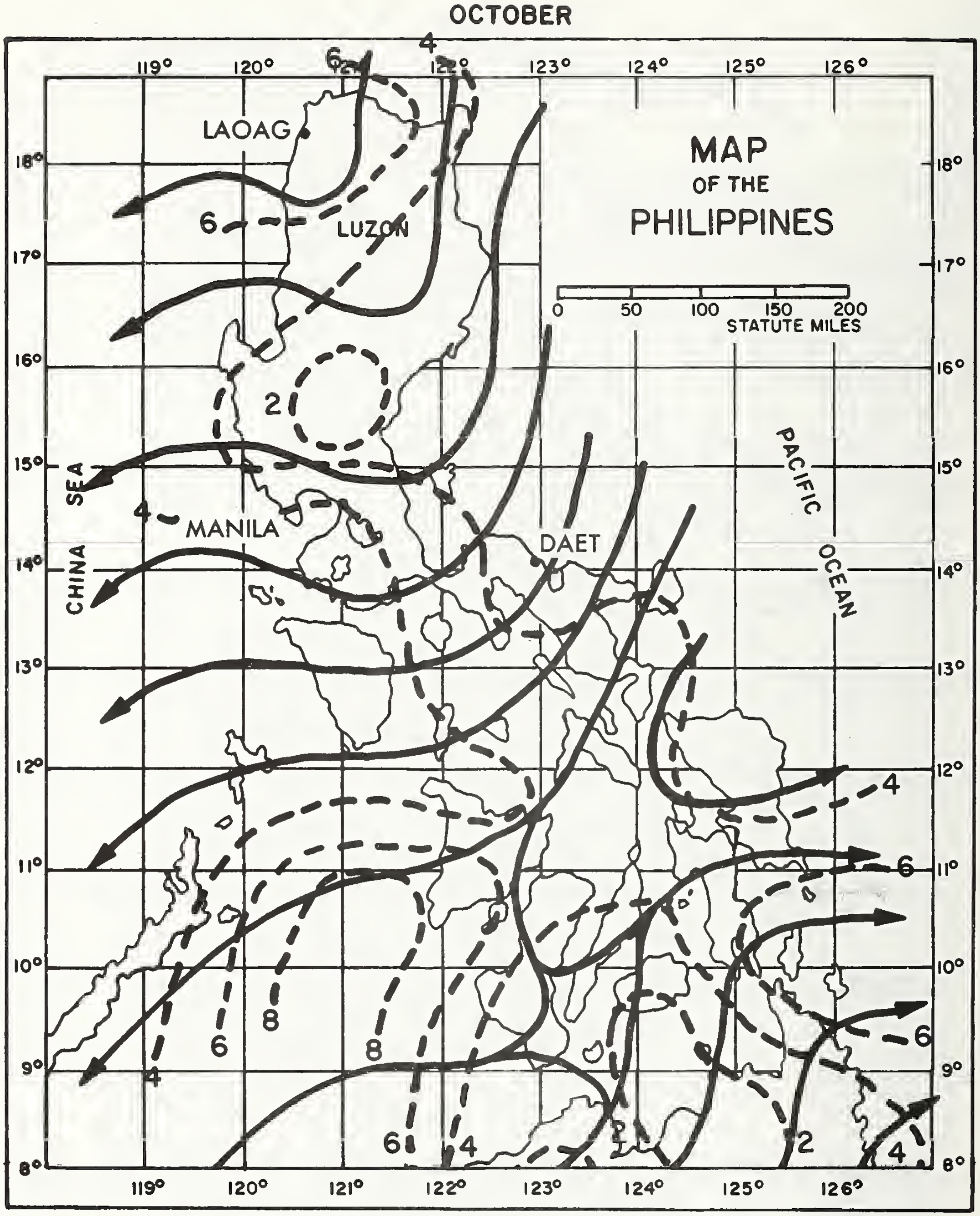

Fig. 10 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines -knots)

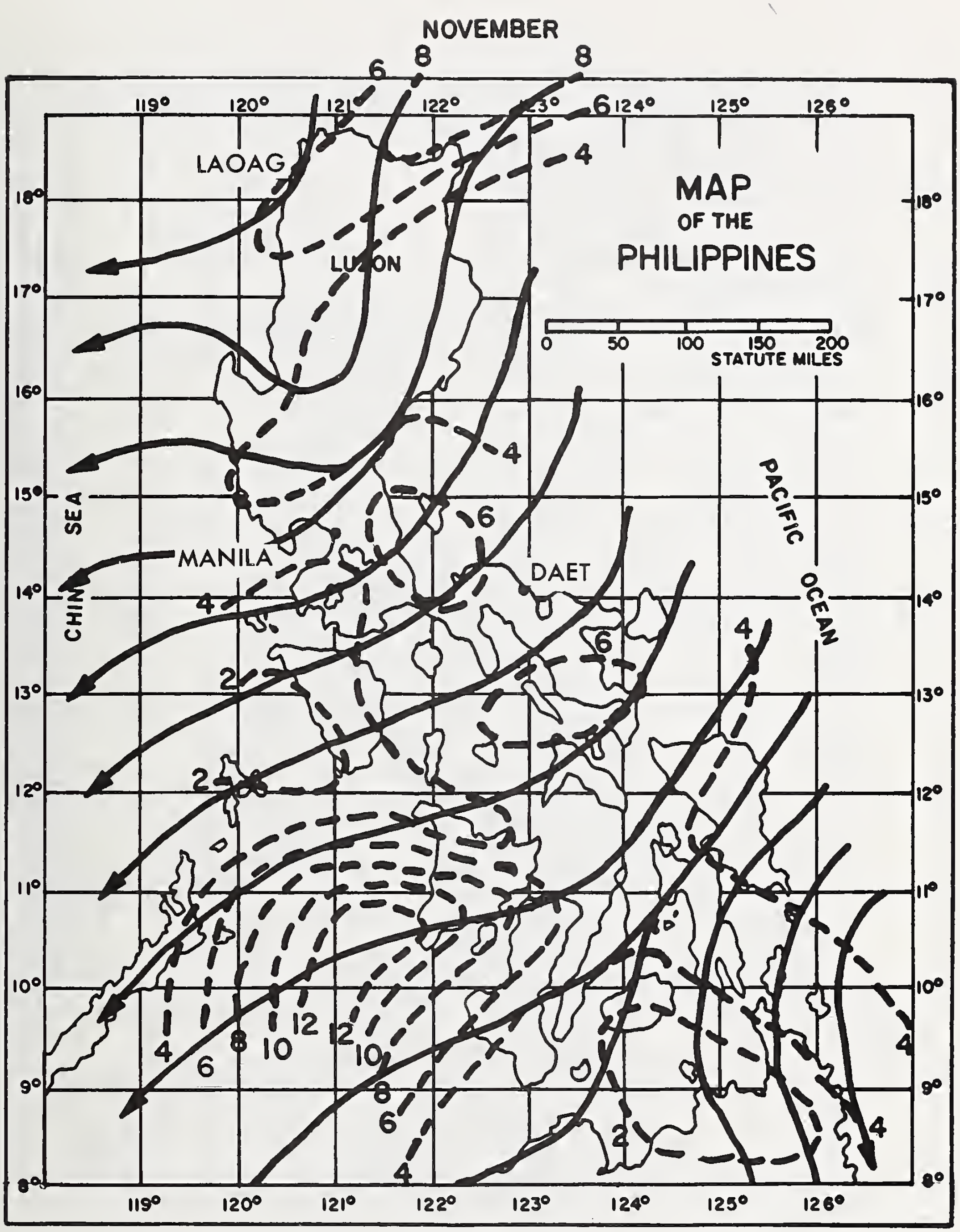

Fig. 11 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

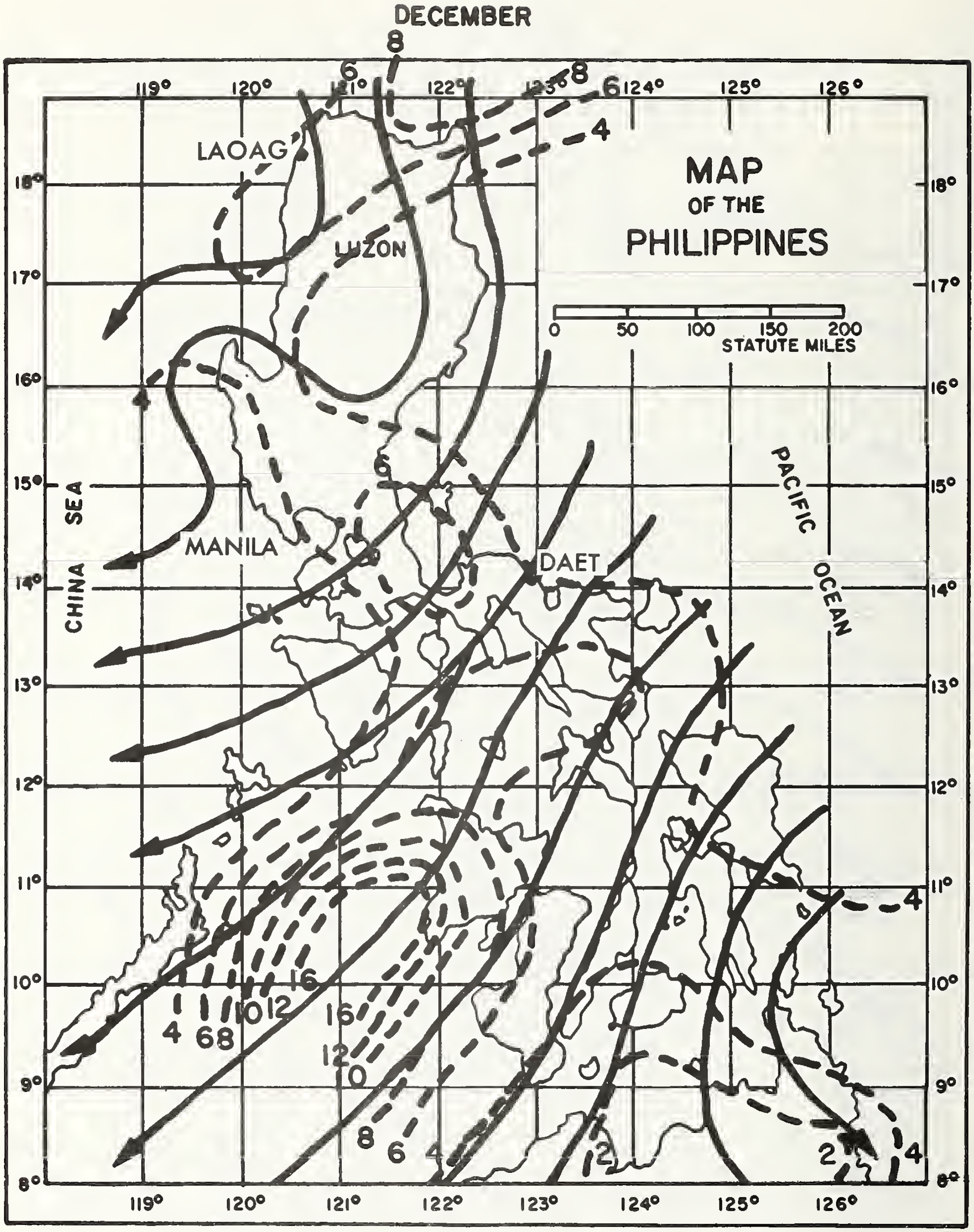

Fig. 12 Prevailing Surface Wind Streamlines (Bold Lines) and Isotachs (Broken Lines-knots)

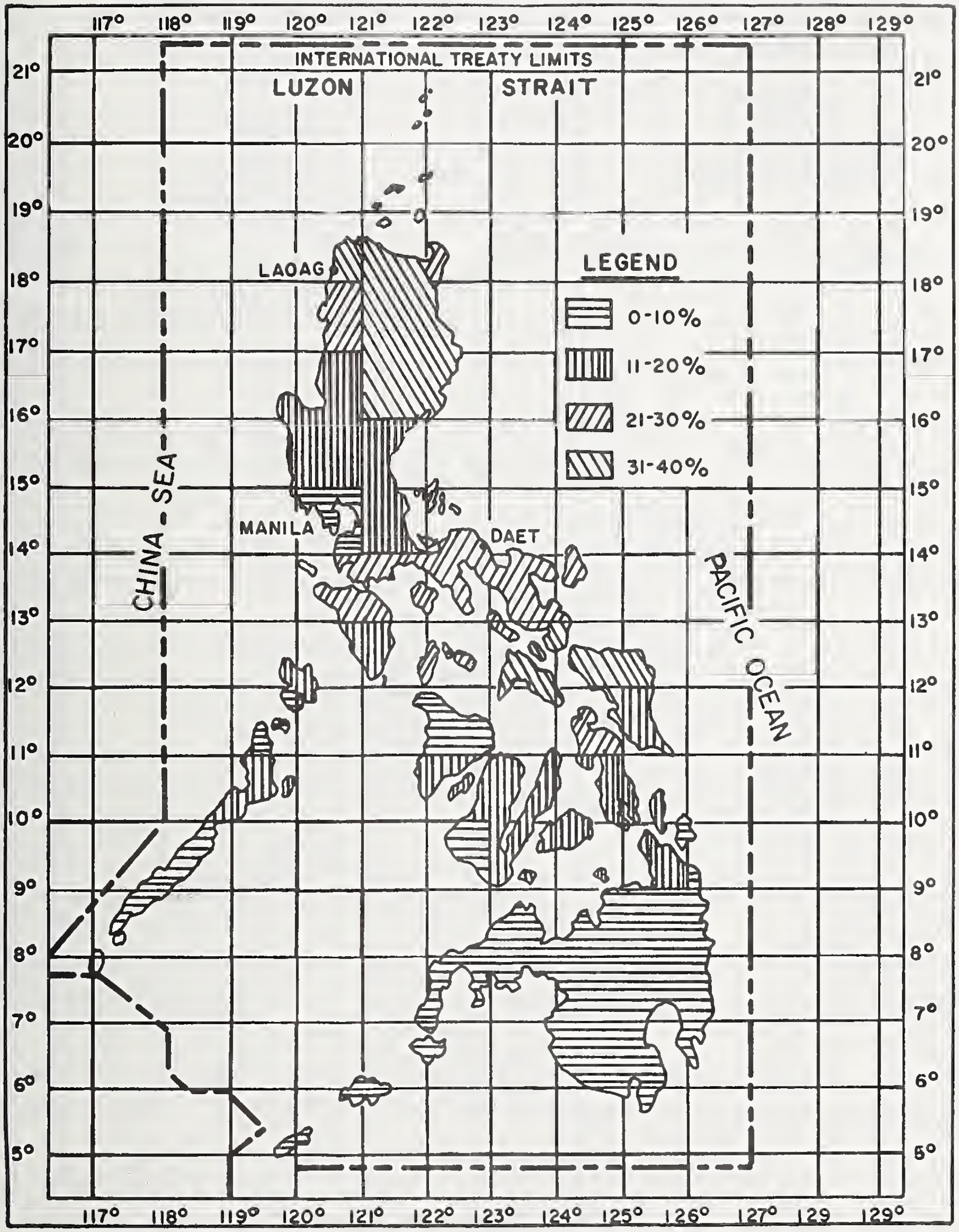

Fig. 13 Mean percentage frequencies of tropical cyclone passage in the different parts of the Philippines

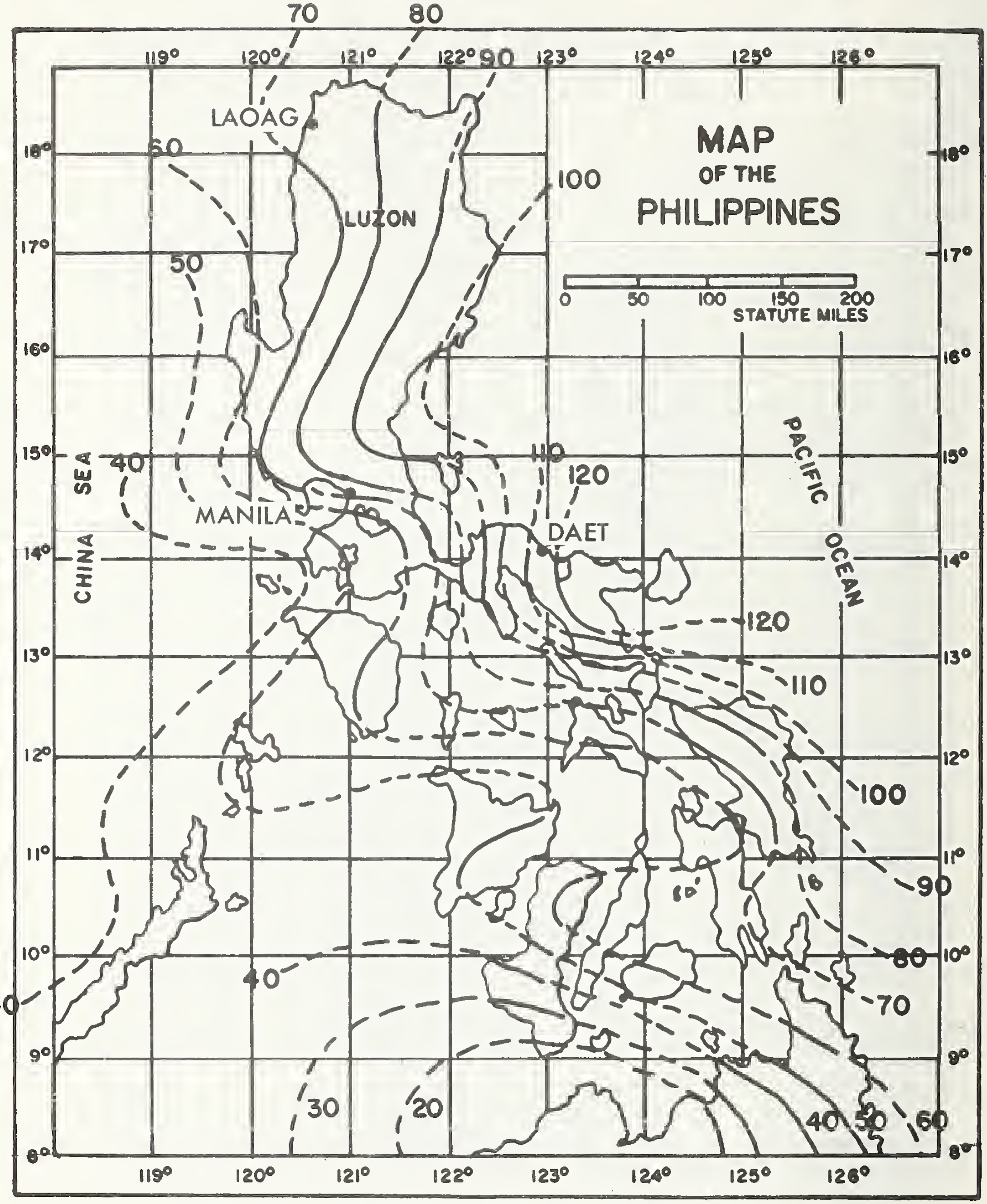

Fig. 14 Isolines of Annual Max. Wind Speeds at 10 Years Return Period

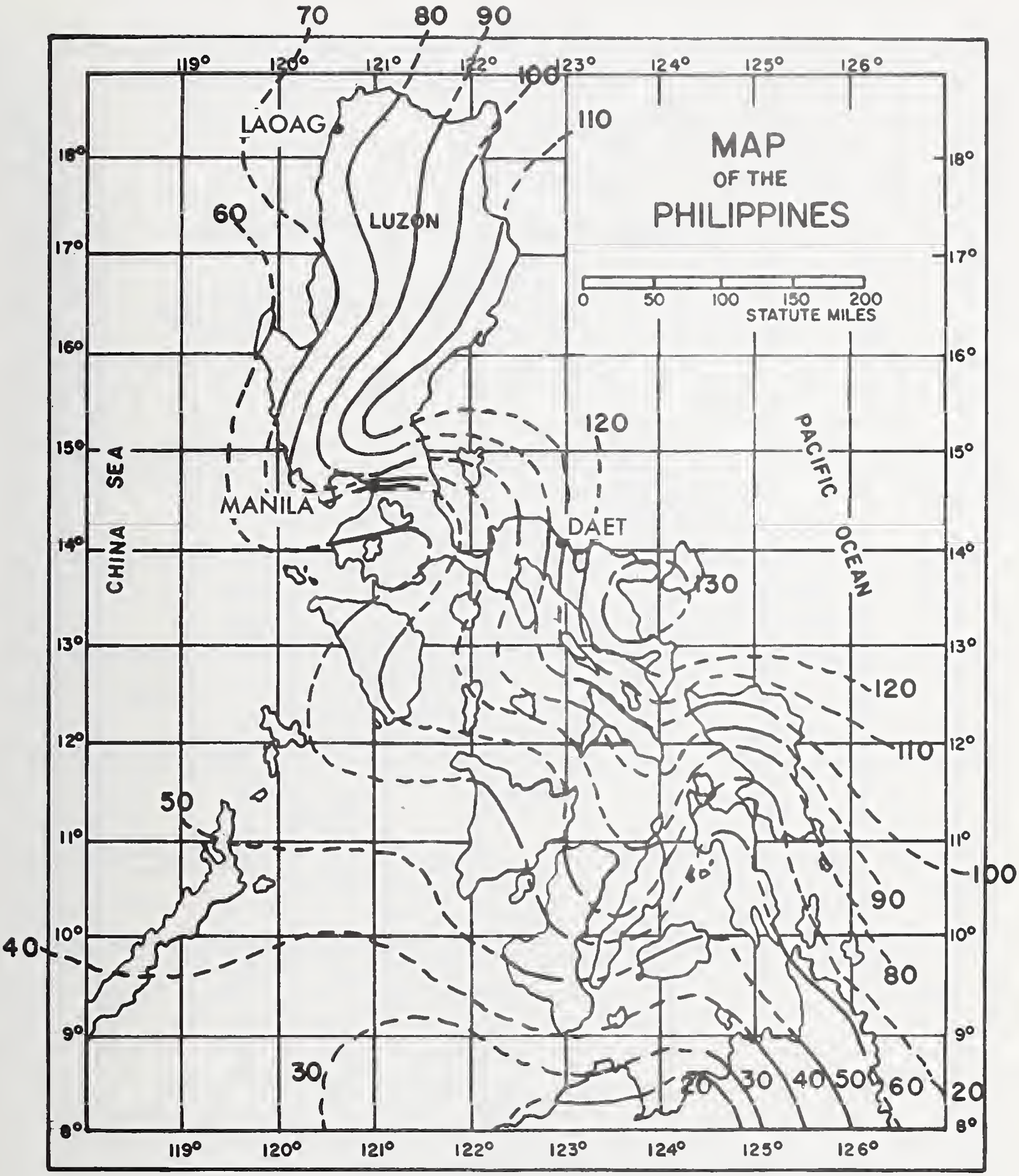

Fig. 15 Isolines of Annual Max. Wind Speeds at 15 Years Return Period

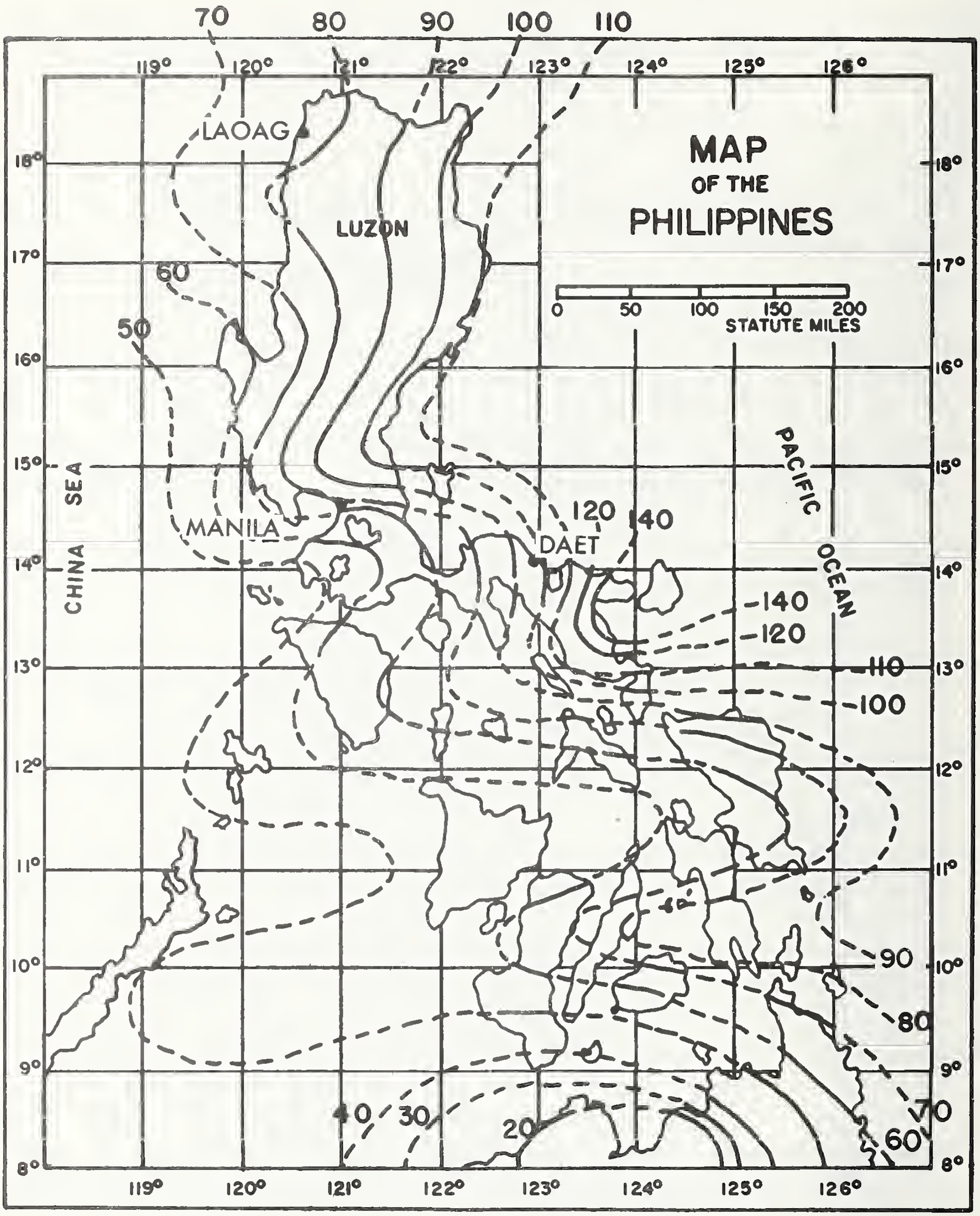

Fig. 16 Isolines of Annual Max. Winds Speeds at 20 Years Return Period

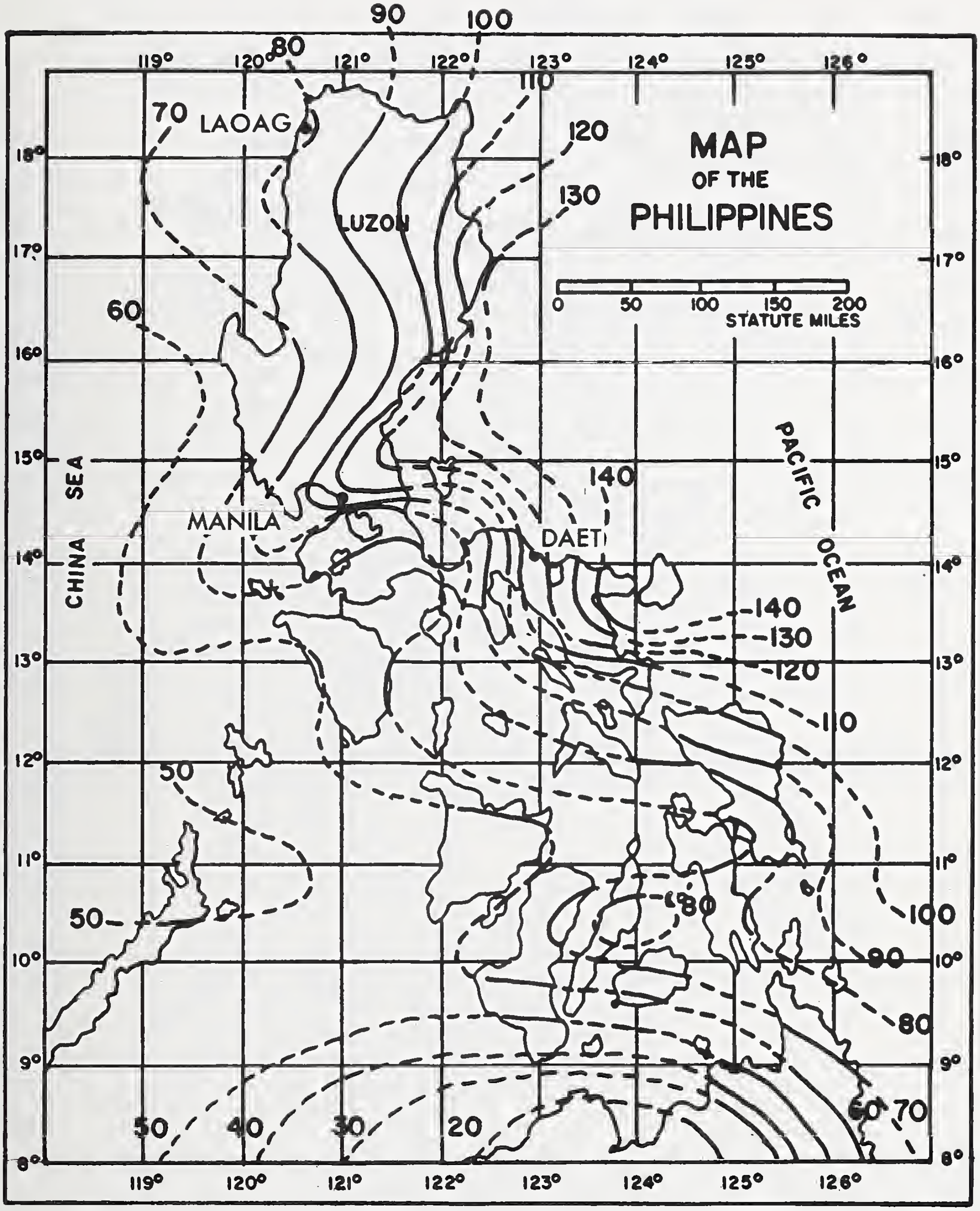

Fig. 17 Isolines of Annual Max. Wind Speeds at 25 Years Return Period

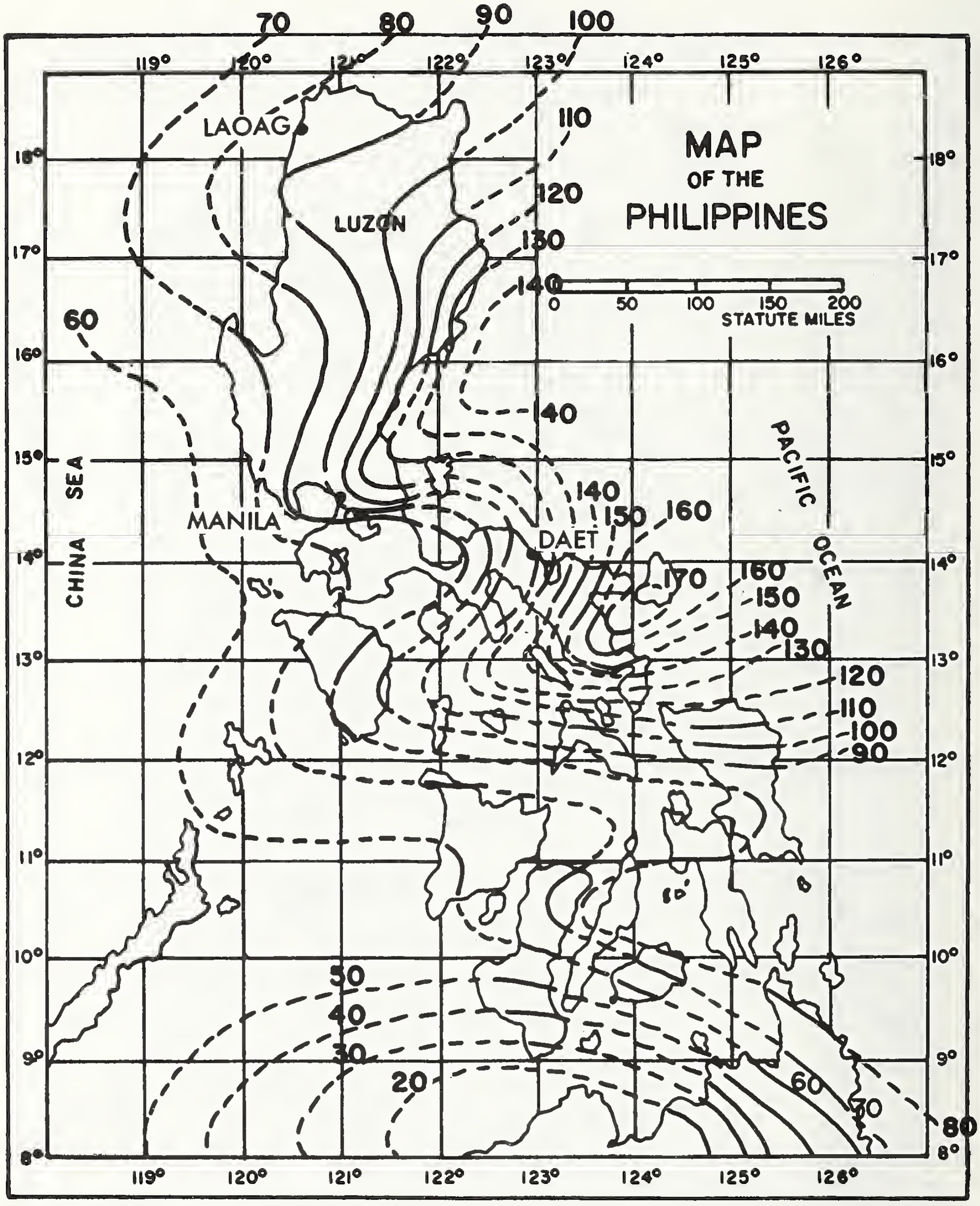

Fig. 18 Isolines of Annual Max. Wind Speeds at 50 Years Return Period

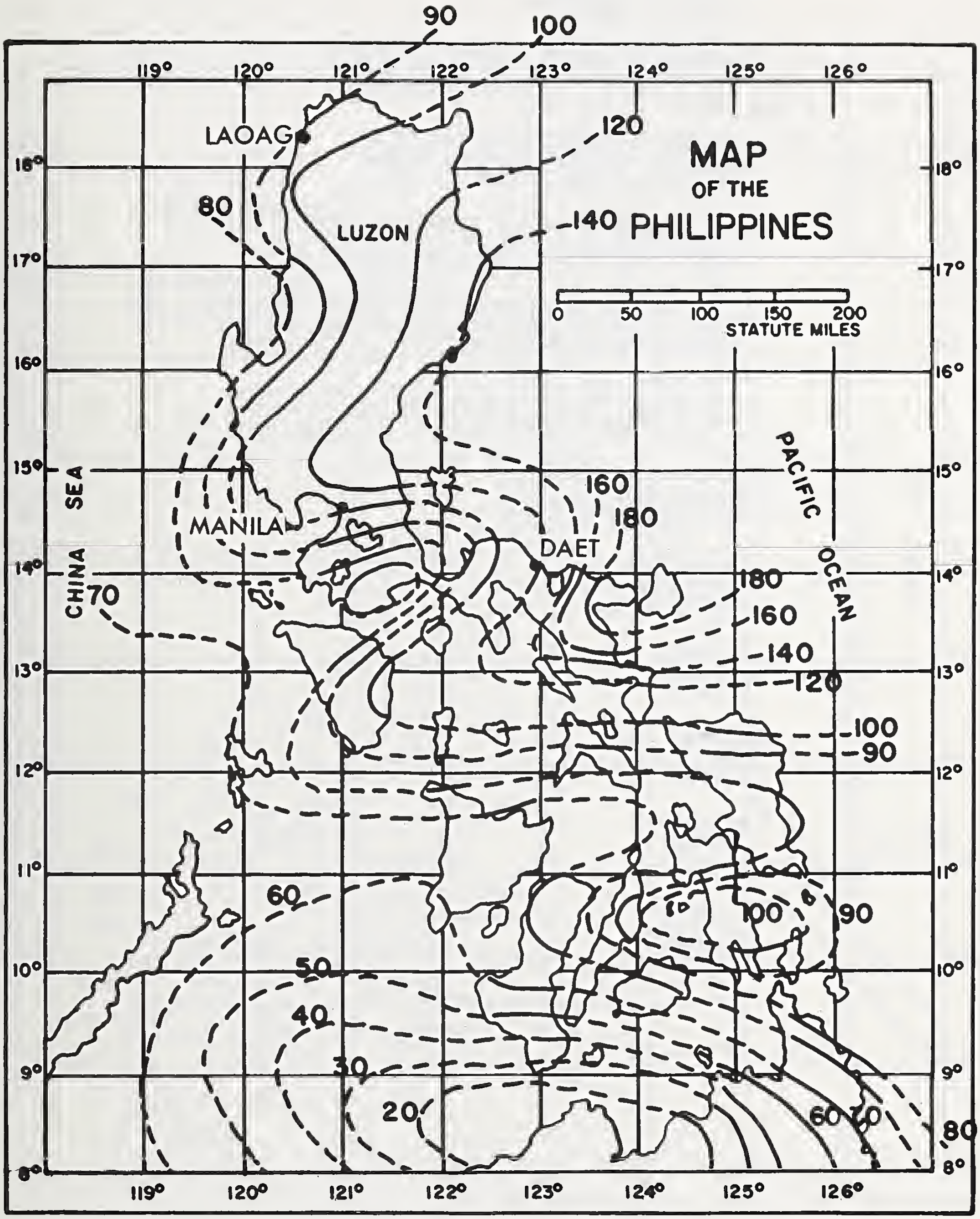

Fig. 19 Isolines of Annual Max. Wind Speeds at 75 Years Return Period

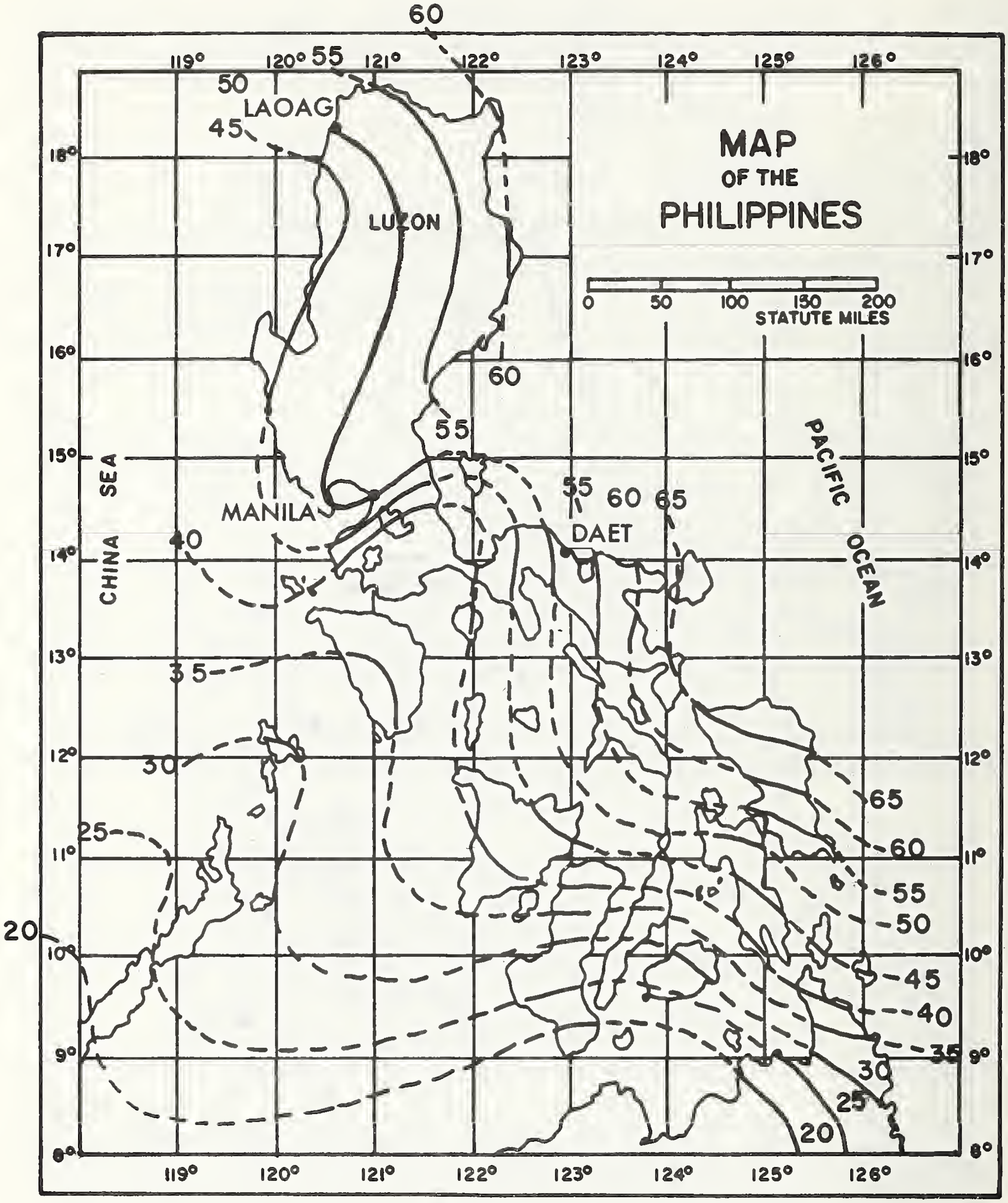

Fig. 20 Average Annual Maximum Wind Speeds

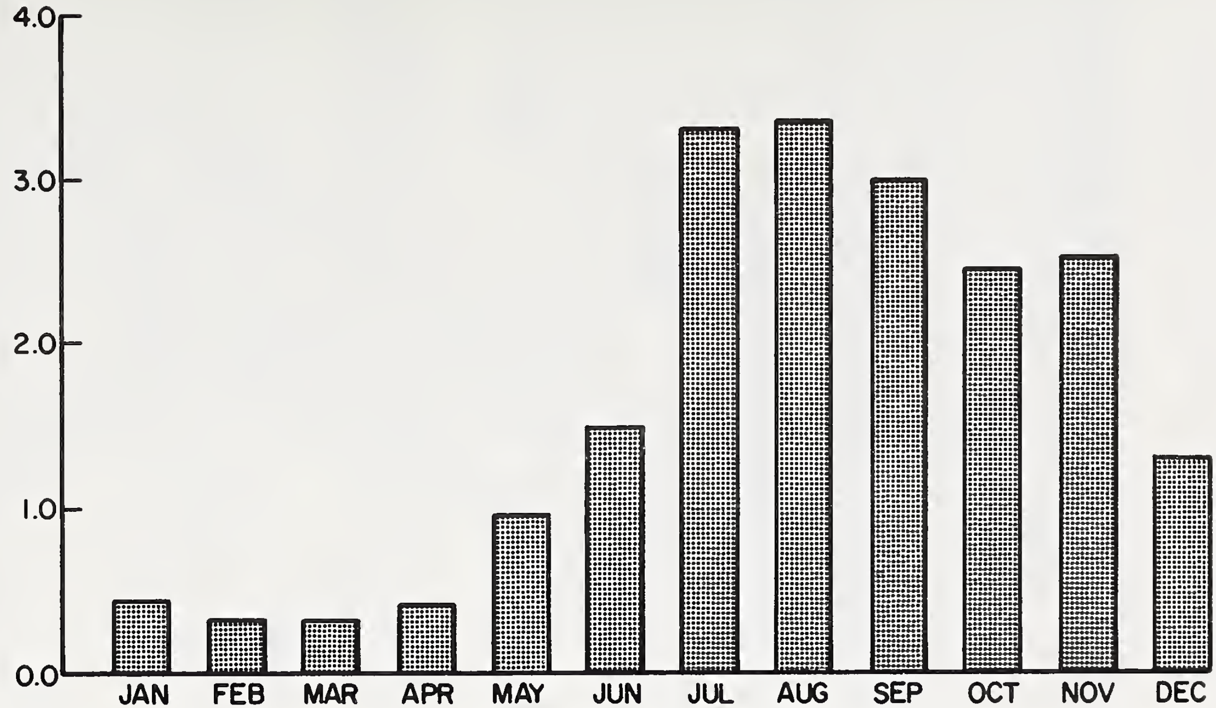

Fig. 21 Mean Monthly Frequency of Tropical Cyclones in the Philippine Area of Responsibility (1948-1971)

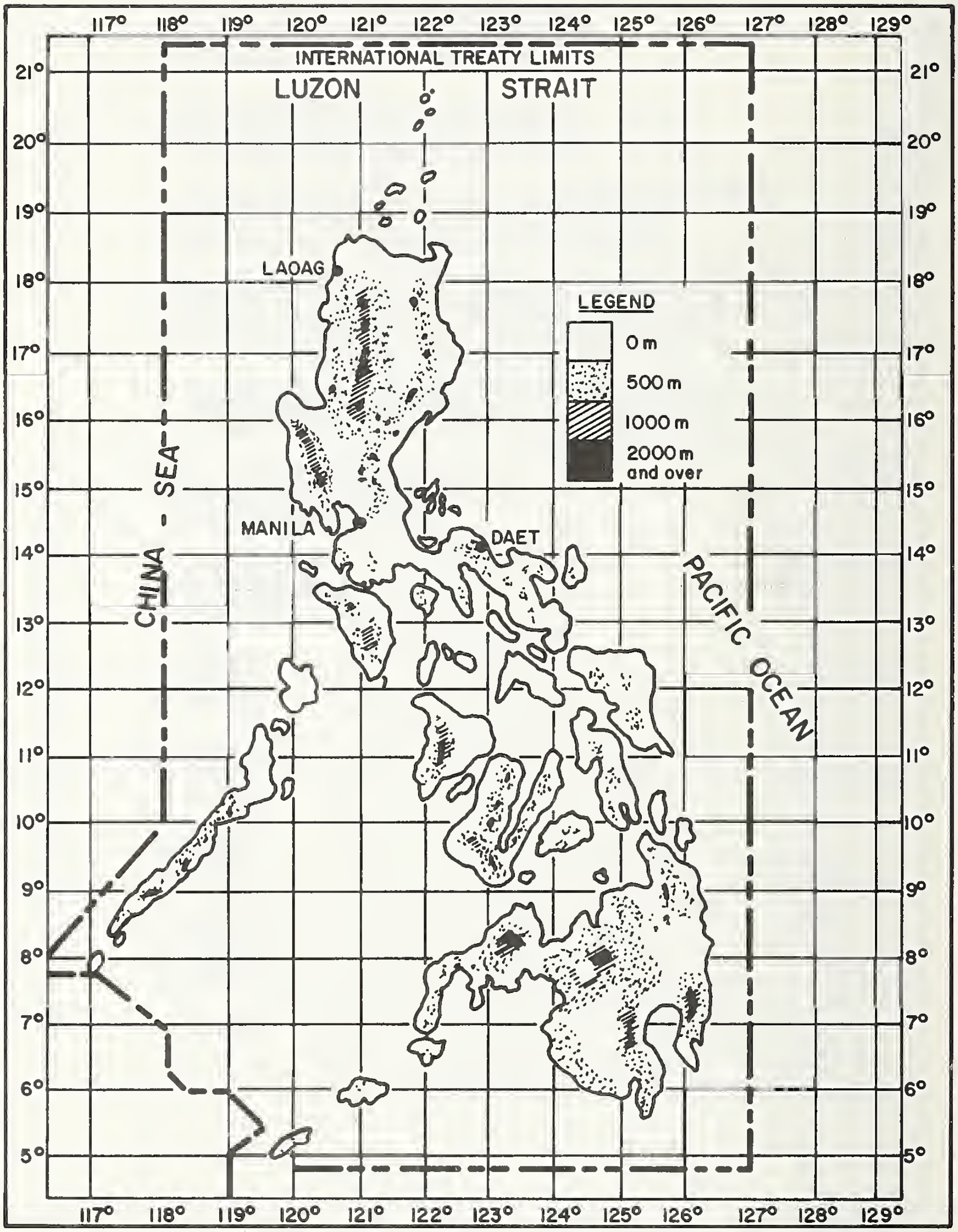

Fig. 22 Geographical and Topographical Chart of the Philippines

AERODYNAMICS OF STRUCTURES AND WIND TUNNEL MODELING

by

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This afternoon I would like to get into some of the technical aspects of the program and what people in other countries have been doing with the problem of wind effects on buildings and structures. But I think, in view of the fact that we had a very delightful lunch just a few minutes ago and because it is fairly warm in here, I find it better to reduce the scope of this presentation so that I won't put you all to sleep.

I would like to talk in terms of a flow chart in discussing the general problem of wind effects (Fig. 1). I think this is a rather convenient way to bring all of the aspects together. It is an interdisciplinary problem that involves many people of different backgrounds. In fact, that is probably the main reason why we find ourselves somewhat late in developing criteria to insure the satisfactory design of buildings to resist wind. We have climatologists, aerodynamicists, and structural engineers involved. I suppose that actually one of the most difficult problems to overcome has been one of communication rather than those of a more technical nature. But basically what is involved here is to take the climatology for the area in which the building site is located and the terrain of the area -- that is, the surrounding buildings, hills and trees, and establish the properties of the wind for which we are designing. These properties include such things as the mean velocity profiles and intensity of turbulence. As you all know, the wind speed increases with height above ground, up to a certain level which we call the geostrophic level. However, we generally do not use the wind speed at that level as a basic measure or basic reference for wind speed. Rather, as Dr. Kintanar pointed out this morning, we take the 10-meter height. This is pretty much standard, and although it might not be the best choice, it is one that has won universal acceptance -- and it is doubtful that we shall cease to use it in the near future.

The next item is to determine how the wind is going to influence the structure and for this we must know something about the building geometry. In the case of tall structures, we must also have some information about its dynamic characteristics. The wind tends to make the structure vibrate or oscillate -- and if the oscillations reach significant amplitudes, they can modify the wind field around the building.

I would like to confine this discussion to those cases where elastic properties are not important; to low-rise structures where building geometry is of primary importance. Knowing the building geometry and the properties of the wind, we can develop what is called an effective aerodynamic input. Ideally, we would like a mathematical model that could be entered into a computer; I say "ideally" because the nature of the problem is far from ideal. We could then enter the pertinent information and come up with design loads. While this is certainly a possibility in the future, we are not at that point with our present level of technology.

We have some theories that we can use on various parts of the problem, but we currently have no comprehensive theory that will carry us down to the lower boxes in this diagram. To do that, we have to resort to other techniques, particularly analogue techniques such as wind tunnel models or by measurements on full scale structures. And, of course, that is what I intend to address today.

We can think of the wind tunnel model as essentially constituting an analogue computer. We simulate, at a reasonable scale, all of the phenomena that are relevant to the problem, make the appropriate measurements, and by means of laws of similitude, scale this information up to the full scale case. Once we have the aerodynamic input, the next step would be a typical application of design, including the frame, the cladding, and the other elements such as windows and roofing elements.

Finally, we would certainly want to give some thought to the wind environment created by placing the building at a given site. For low- rise buildings, this is not the important consideration that it is for tall structures. Very tall structures tend to bring wind speeds at higher levels down to street level -- and we introduce rather severe gustiness in the pedestrian areas.

It is quite convenient to treat wind pressures in terms of dimensionless coefficients. Thus, for the pressure at a given point on a structure, we have the free-stream dynamic pressure at 10 meters(q) -- times an exposure factor, C_e, that takes into account the nature of the terrain, the height at which you are designing a particular element of a building -- whether it is 10 meters or 100 meters, a gust effect factor, C_g, that accounts for the turbulence of the oncoming wind and the local flow conditions caused by the building itself and, finally, a dimensionless coefficient, C_p. These coefficients are combined in the form $p = q\,C_e\,C_g\,C_p$.

The two factors that really concern us here are the last two -- C_g and C_p. In general, we have no theoretical techniques to predict these coefficients. These are determined by measurement, either by means of a wind tunnel model or a full scale structure. If we take the approach of a wind tunnel model, there are certain requirements that we should satisfy before we can expect any kind of realistic results. We refer to these as similarity parameters. And here I have listed what are probably the four most important parameters that have to be satisfied or should be satisfied if we are going to conduct a model study of an engineering structure in a wind tunnel (Fig. 2) using air as a fluid.

We have geometric similarity, which includes neighboring buildings, dynamic similarity, and thermal similarity. Dynamic similarity is important if we are modeling relatively flexible structures. Thermal similarity is important in those cases where we have an unstable thermal stratification. Fortunately, for most strong wind conditions, and these are the ones we want to model in the tunnel, we are able to neglect thermal stratification because of the very strong mixing in the vertical direction. And finally, the boundary condition similarity, which includes such things as the general terrain roughness and the turbulence in the oncoming flow. To satisfy this similarity, we model in the wind tunnel all the surrounding area and topographical features that have an influence on the wind speeds at the building site.

Perhaps I ought to say a word or two about the source of some of the coefficients that we find in existing codes and standards. I believe that most of the coefficients in use today, except for those codes that have only recently been revised, can be traced back to two primary documents - the Swiss Building Code and, particularly in the United States, the ASCE task committee report on wind forces on structures. Most of those coefficients were obtained by using unrealistic wind tunnel techniques. A building model was simply placed in a wind tunnel and the pressures were measured and reduced to dimensionless coefficients. No attempt was made to simulate the boundary layer profile, that is, the change in wind speed with height. Nor was any attempt made to simulate the natural turbulence or gustiness of the wind. And finally, the pressures themselves were measured in a rather arbitrary way.

The instrumentation available at the time was not capable of measuring fluctuating pressures. So, the pressures that were measured were generally just mean pressures. In other words, they did not give a true picture of what was happening to the structure. The philosophy, of wind loading, of course, has greatly changed in the last 10 to 15 years. We certainly realize now that this approach was not satisfactory. In some cases the results are somewhat conservative, but there are just as many cases where they are on the unsafe side. So, there is quite a bit of activity now in a number of countries to develop techniques, wind tunnel techniques, that will insure the reliability of the information gained from wind tunnel modeling.

This is a picture of the NRC V/STOL tunnel at the National Aeronautics Establishment in Ottawa (Fig. 3). It is an enormous tunnel, approximately 10 meters square and some 30 meters long at the test section. We happen to be looking upstream, and this is a model of a downtown portion of Montreal. The scale is 1:400 and the flow is established by a number of spires across the tunnel at the entrance of the test section to initially generate a sheared flow. Following the spires, there are some roughness elements that are representative of the city of Montreal between the spires and the model, and they tend to generate turbulence of a scale and intensity that corresponds to the full scale case. I want to emphasize here very strongly that the spires themselves would not induce a proper flow. It takes both the spires and the roughness elements.

This is another wind tunnel model study, using essentially the same technique (Fig. 4); I believe this is a 1 to 600 scale. This particular tunnel is located at Monash University (Australia). It has a 2-meter square test section with a length of approximately 15 meters.

Obviously, there is quite a bit of sophisticated instrumentation needed to make the measurements, but I shall go into this subject this afternoon when we visit the field test site.

Here we have some typical mean velocity profiles that were obtained in a wind tunnel for two classes of roughness, and they show two rather interesting things (Fig. 5). First of all, the agreement between the experimental data and the theoretical variation of wind speed with height, following the power law, is quite good. Certainly, one can argue that a power law is not a good approximation of the mean velocity profile. In fact, it has no theoretical basis whatsoever and one might argue that the log law is a better approach. My only comment here would be that the power law is somewhat simpler to use, and it does seem to work. The other interesting thing about this is that it gives you some feel for the difference in velocity profiles for different surface roughnesses. They are all plotted on a non-dimensional scale at the bottom -- that is, the local mean velocity divided by the wind speed at the top of the boundary layer. You see that for the grassland case we reach the top of the boundary layer much faster than we do over an urban area. So that all matters being equal, the wind speeds are lower for rougher surfaces at a given height. This is somewhat offset by the fact that the gustiness is higher in an urban area.

Wind tunnel modeling is a very powerful tool. The only problem is that no matter how hard we try and no matter how ingenious we are, we simply cannot satisfy all of the similarity parameters simultaneously. There is simply no way to do it. So, we are forced to resort to full-scale measurements, mainly to confirm the validity of the wind tunnel results. And that, by and large, is the strongest argument for doing full-scale studies. Of course, there are other arguments if we get into those cases where we have dynamic response of the structure. We have to model the structure both geometrically and dynamically, and that again is not an easy matter.

This is an aerial view of a test site at Great Falls, Montana, where we have in the past conducted full scale studies on two houses (Fig. 6). The area is rather interesting in that we have quite different exposures, depending on the wind direction. If the wind is coming from the top of the picture, it is rather open country. If it comes up from the bottom left hand side, we have a number of 2-story buildings upstream and the flow properties are going to be significantly different. Subsequent to the full scale studies, we conducted some preliminary wind tunnel studies and attempted to correlate the two sets of data with some success. I will get back to this in a moment.

This is a detailed plan of the immediate area around the test house, the test house being on the left (Fig. 7). There are similar houses in the immediate area. All of these houses were modeled in the wind tunnel.

The next figure (Fig. 8) will give you some idea of the geometry of the structure. It is what we in the United States refer to as a ranch style house. It is rather low, only some 2.6 meters to the eaves, and the roof pitch is quite flat. In the upper right corner are the locations of the transducers that were used in both model and full scale.

The model scale that we used was 1:50, which is rather unconventional. We were forced to that by the fact that a scale of 1:200 or 1:400 would have resulted in a minuscule model, and there would be absolutely no way to get the pressure transducers into the model. We are now looking at non-dimensional velocity spectra obtained from full scale and from the wind tunnel model (Fig. 9). The straight lines on either side represent the slopes of a theoretical expression for the velocity spectrum.

Here we have a couple of pressure spectra (Fig. 10). Again, in model and full scale for a typical point on the roof.

Another measure of the similitude is the coherence function which indicates how the pressure fluctuations correlate with each other at two points for different frequencies (Fig. 11). I believe the separation distance for this case was some 4 meters.

This next slide shows the time history of a typical record, say, of pressure at a point on the roof (Fig. 12). Obviously this is a random process. You can't predict ahead of time, on the basis of what has happened, what the pressure will be. It's changing in some unknown manner. But the fact that it is random allows us to make some rather educated statements about it. In fact, we depend on the data being random to come up with some parameters, some coefficients to be used in design. And in this, it is convenient to make some definitions. Of particular interest are the mean, the root-mean-square and the peak values.

If you will recall, in the original expression that I gave you, we had three factors that I said we were interested in. Two of them must be determined entirely by experimental measurement -- C_g and C_p. We can express C_g in terms of a peak factor g, a fluctuating pressure coefficient C_{pf}, and a mean pressure coefficient C_p. I have indicated here how we define the peak factor g, which is simply the maximum pressure minus the mean pressure, divided by the standard deviation. In other words, it is the peak excursion from the mean over a given zero crossing interval. And finally, I have expressed this in terms of the mean pressure coefficient and a size reduction factor, R. $C_g = 1 + \frac{1.5\,(1 + |C_p|)\,R}{|C_p|}$

One of the assumptions that we have to make here is that the fluctuating pressure coefficient can be expressed in terms of the mean pressure coefficient. If this is true, it essentially cuts our work in half, because we can deal then with only one pressure coefficient for a given point. The justification for doing this is the subject of the next slide (Fig. 13).

Here we have a plot of the fluctuating pressure coefficients versus the mean pressure coefficients for full scale data. We have obtained a quite similar plot for the wind tunnel data. This indicates that by constructing an envelope for these points, and granted they are rather scattered, there is some relationship between the fluctuating pressures and the mean pressures. From a theoretical point of view, I am certainly at a loss to justify this. Nonetheless, the full scale measurements do give us reason to believe that this is a workable approach to the development of a gust factor.

Well, that is really about all I have to say at this time. And I believe that with the visit to the Science Garden this afternoon, we will have a chance to go into some of this in more detail.

In closing, I would like to announce that Dr. Keith Eaton of the Building Research Station will be speaking in place of Mr. Kramer tomorrow afternoon. He also is involved in some very interesting full-scale measurements and wind tunnel model studies. He has consented to give us a presentation tomorrow. I am sure that he will get into some areas that I haven't covered today and we are very fortunate in having him here.

I would now like to call on Prof. Alejandrino to continue with this segment of the program. He will discuss some features of the university wind tunnel facility. Thank you.

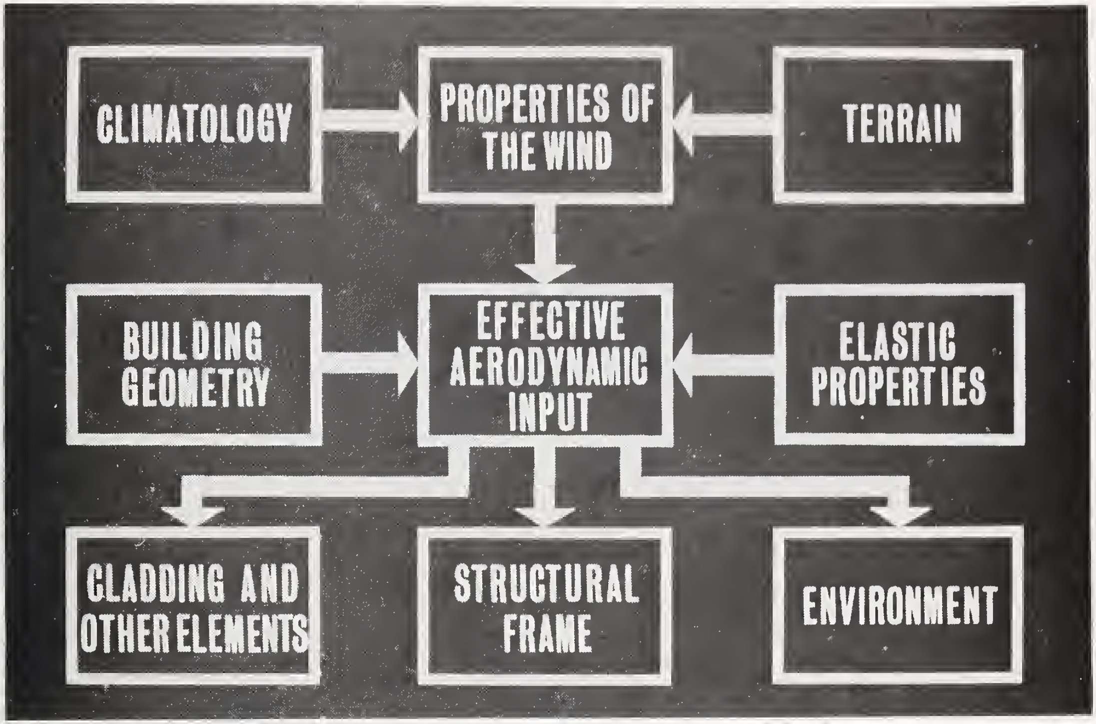

Fig. 1 Wind Effects on Buildings

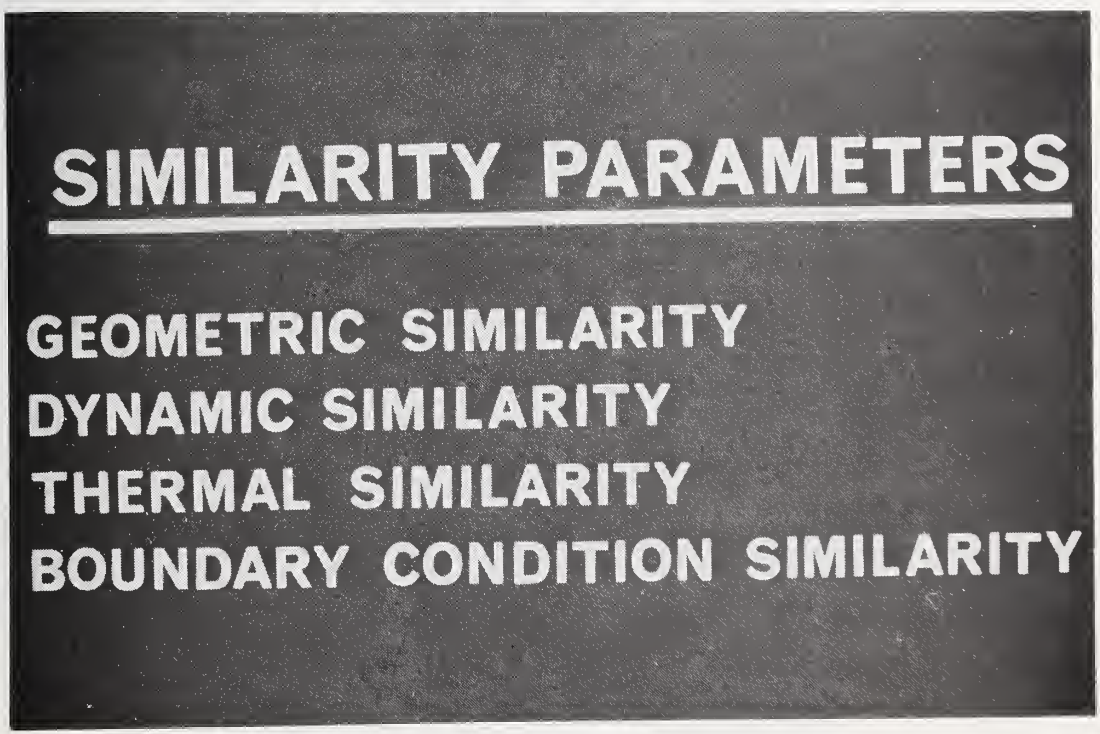

Fig. 2 Similarity Parameters

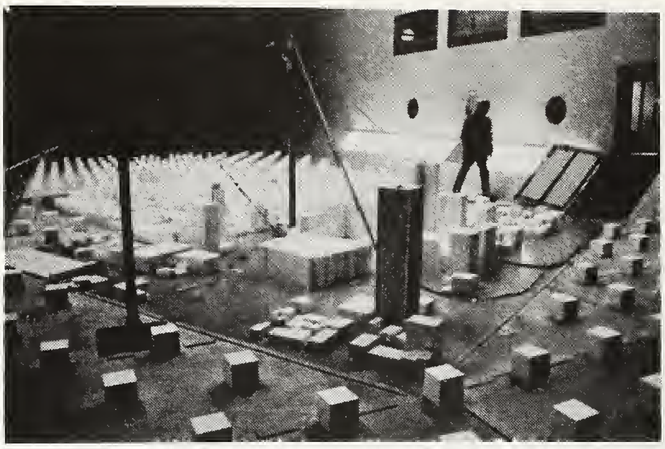

Fig. 3 National Aeronautics Establishment Wind Tunnel, Canada

Fig. 4 Monash University Wind Tunnel, Australia

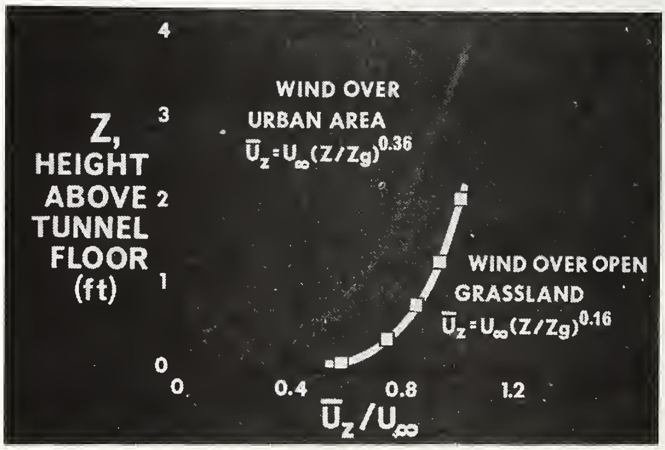

Fig. 5 Mean Velocity Profile

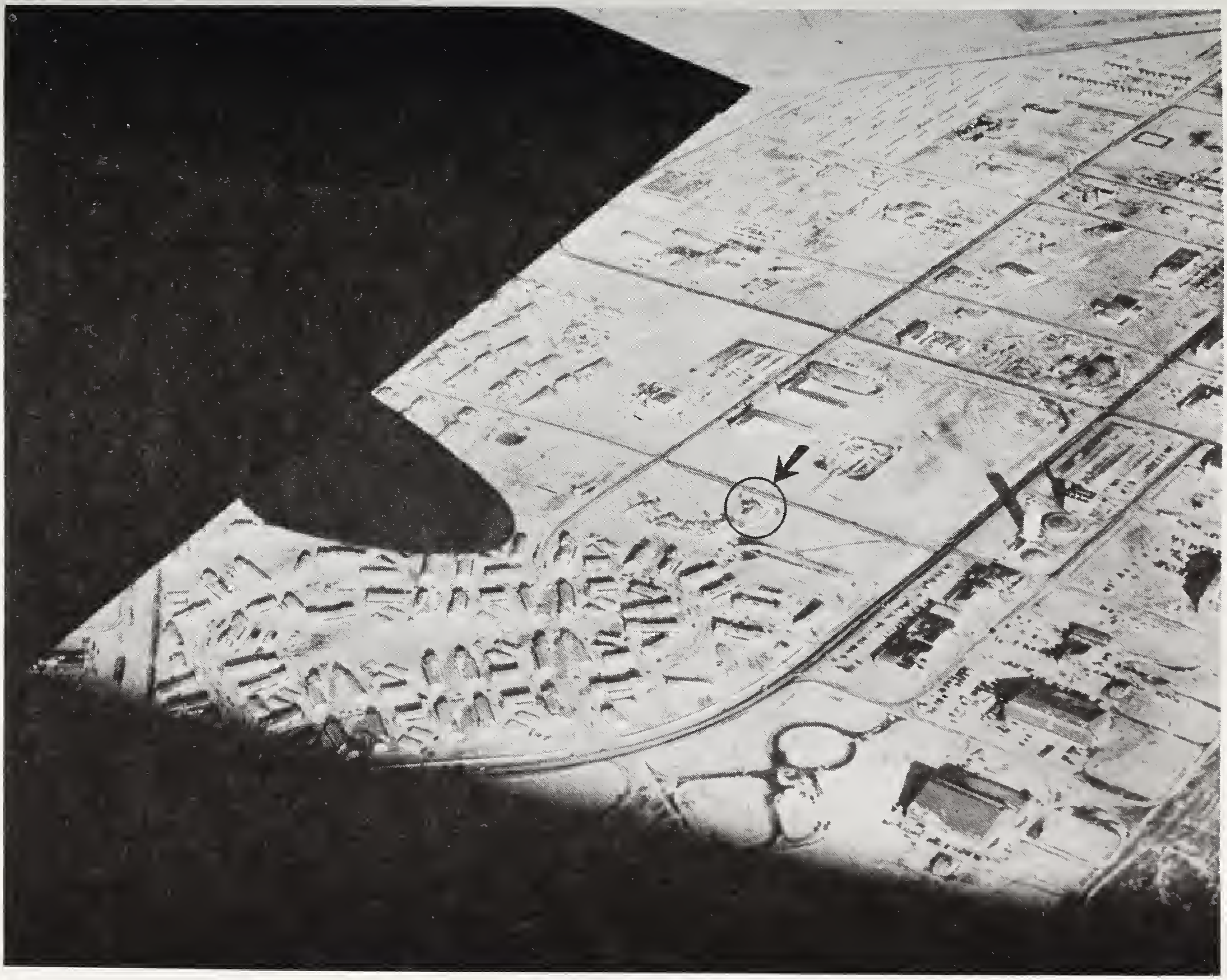

Fig. 6 Field Test Site - Great Falls, Montana
The test house is located at the photograph's center
(See identification mark)

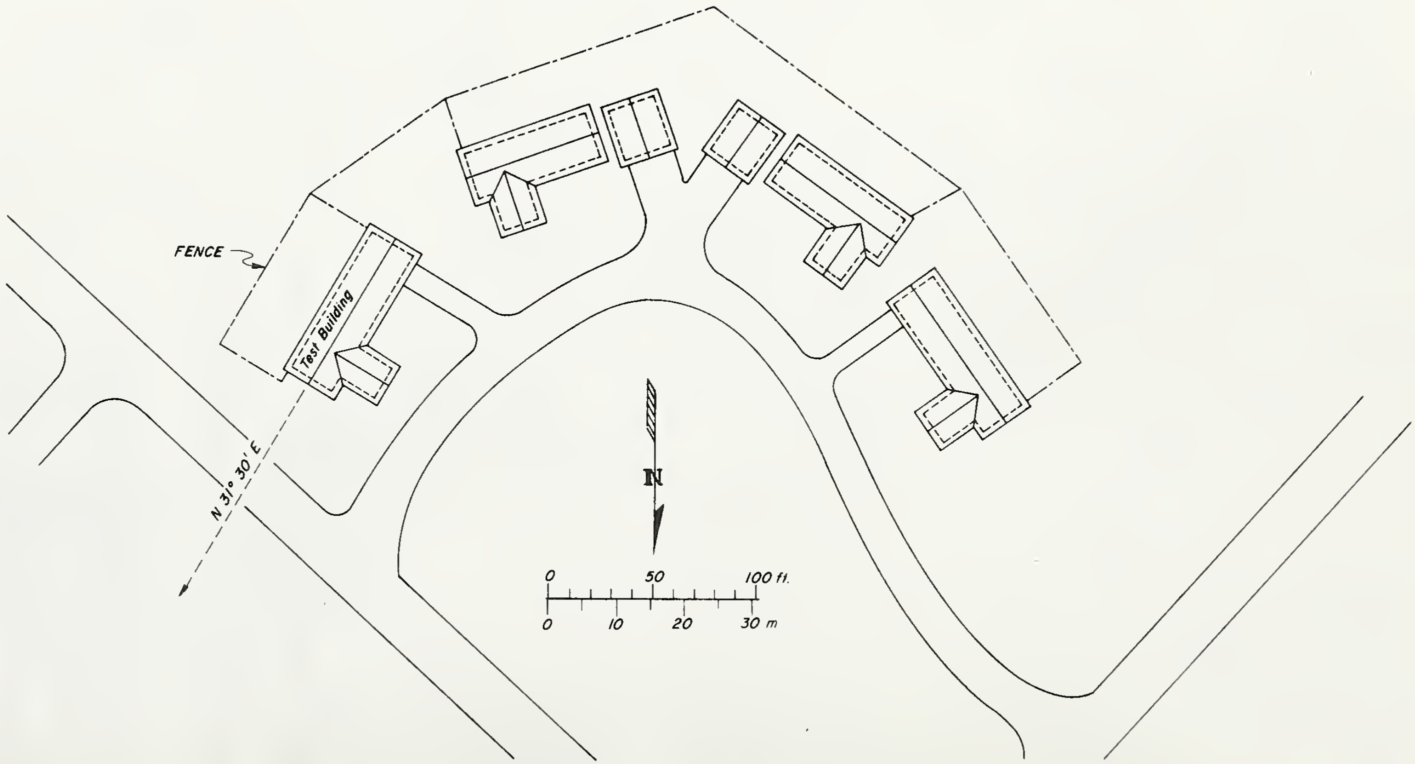

Fig. 7 Test Site Plan

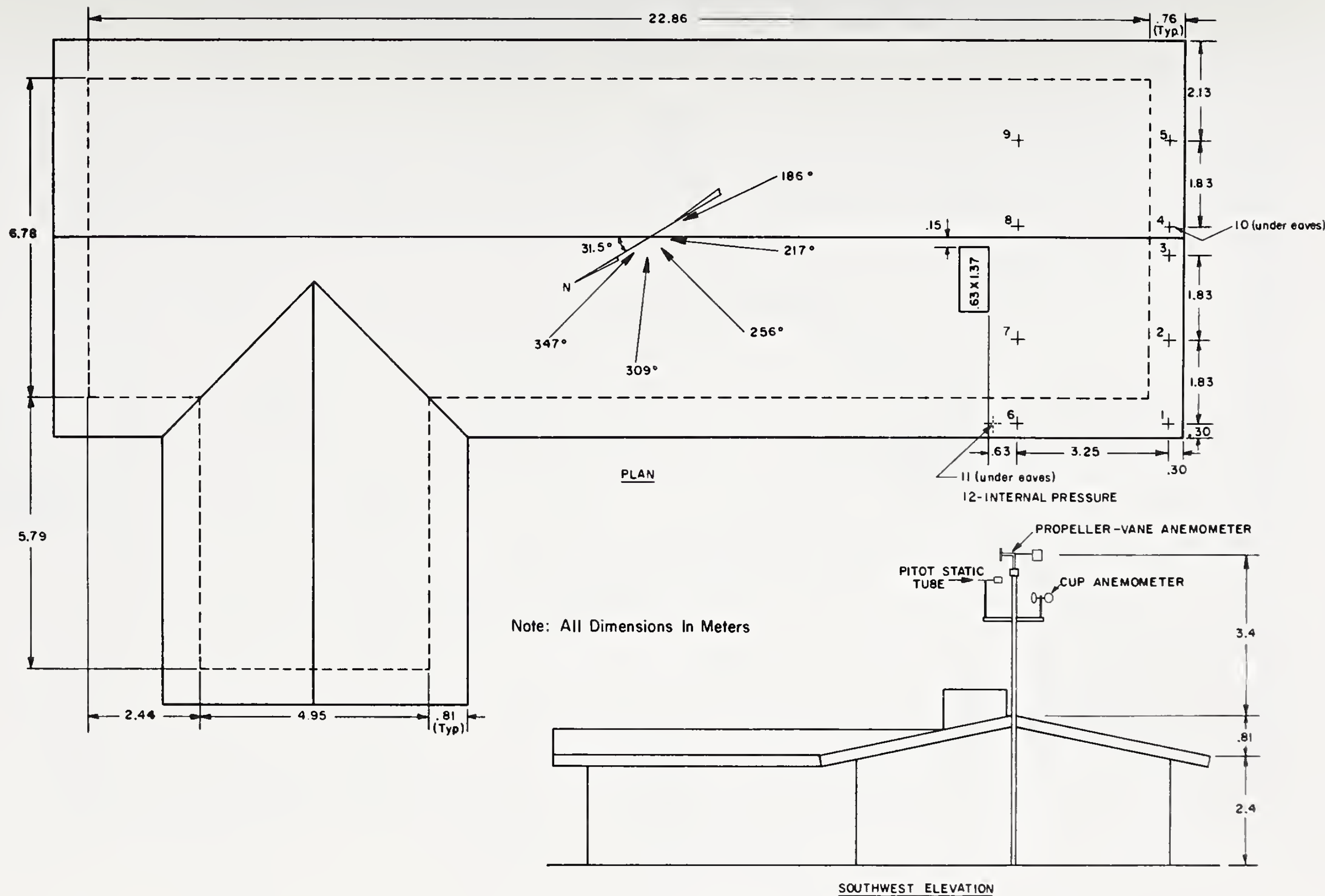

Fig. 8 Test House and Pressure Transducer Layout

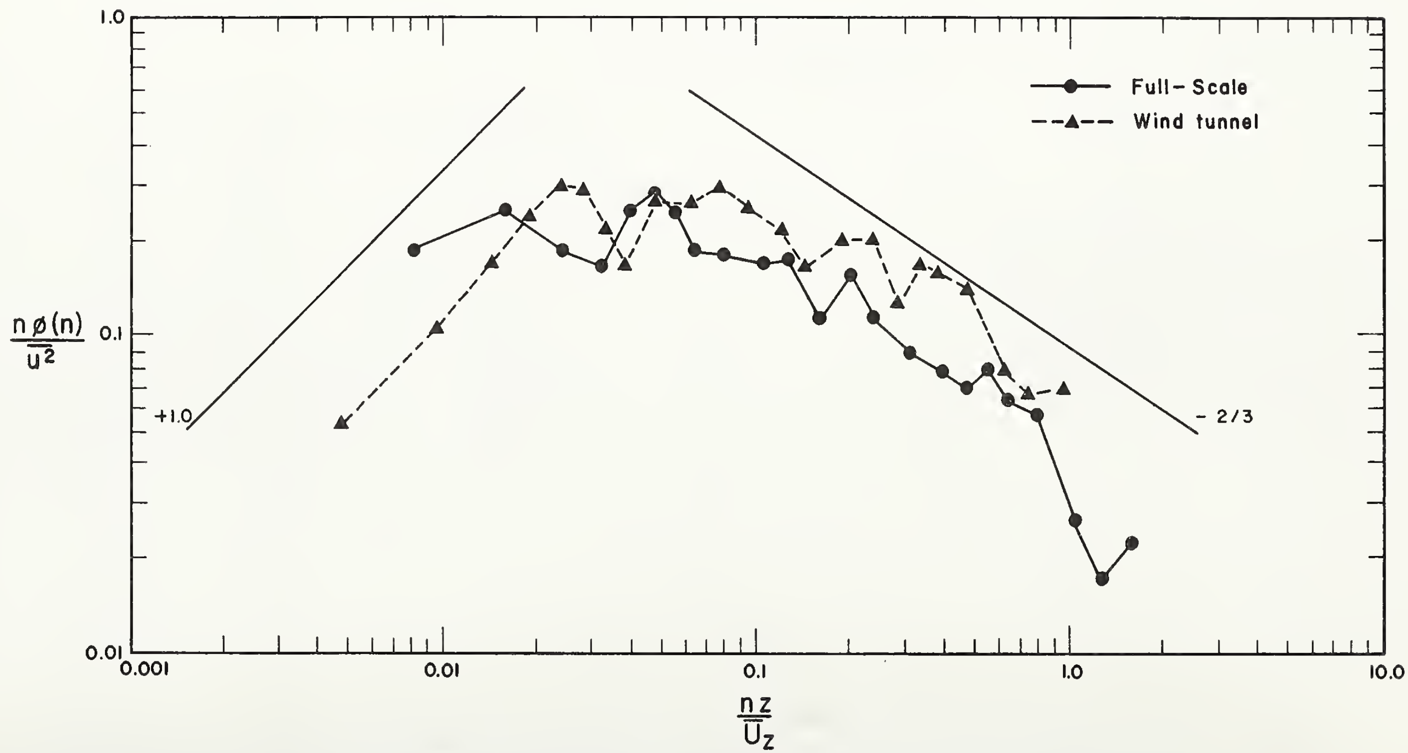

Fig. 9 Velocity Spectra

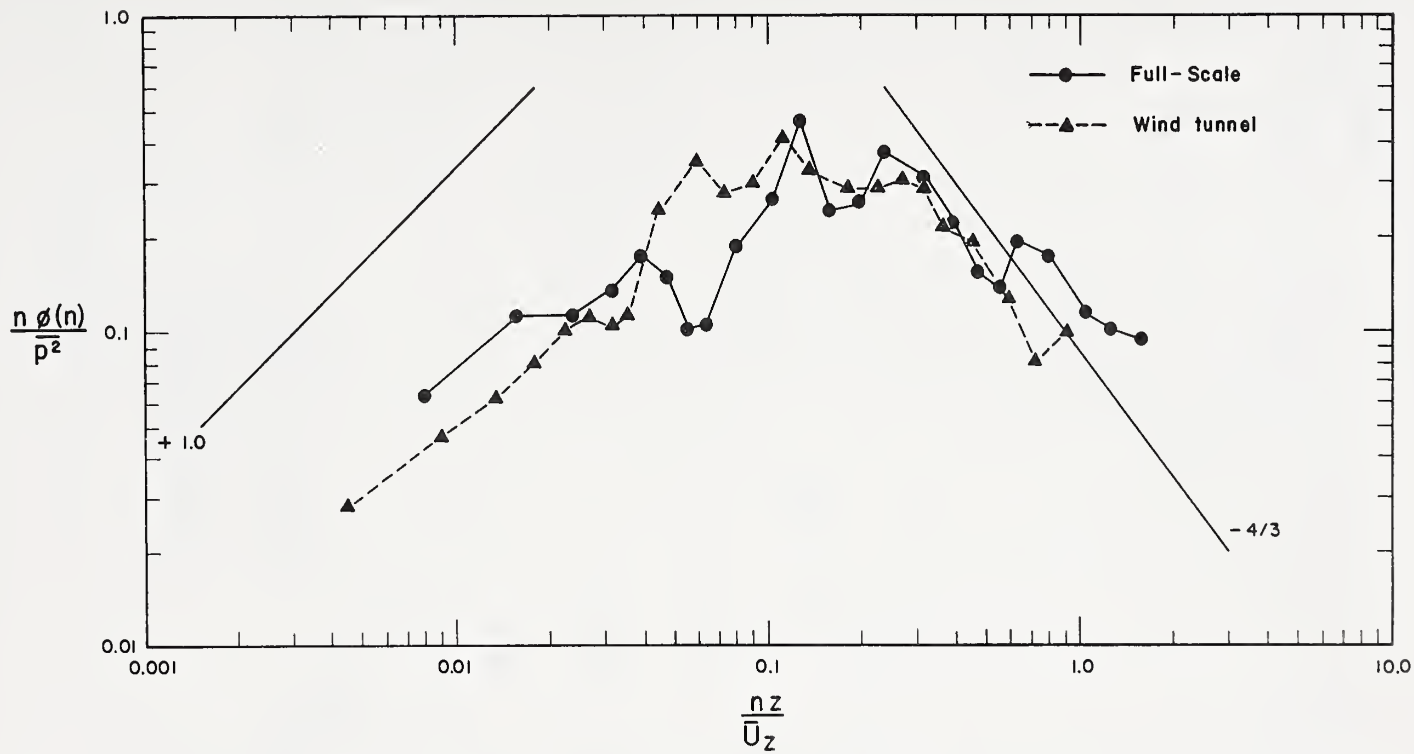

Fig. 10 Pressure Spectra

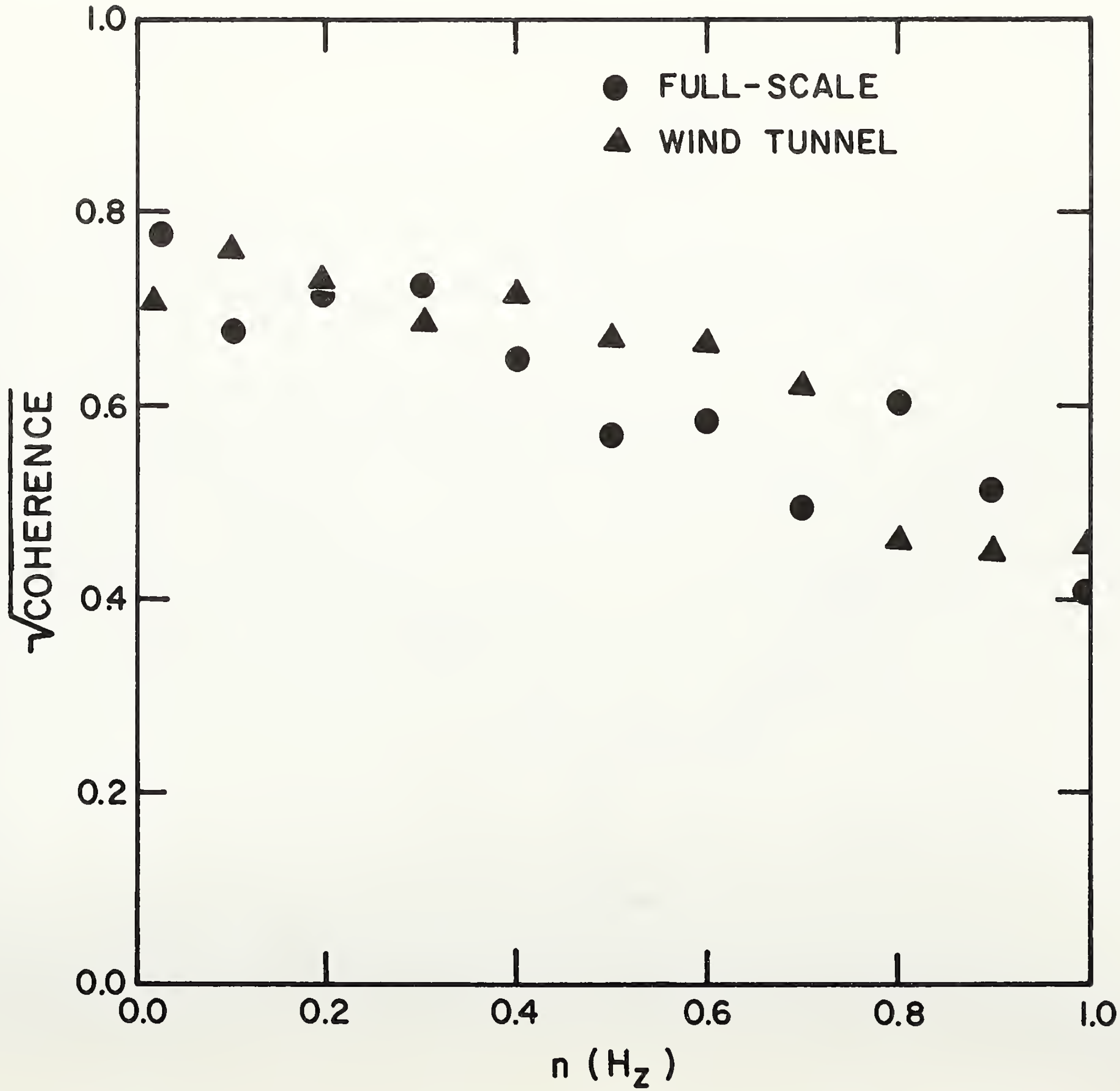

Fig. 11 Coherence Function

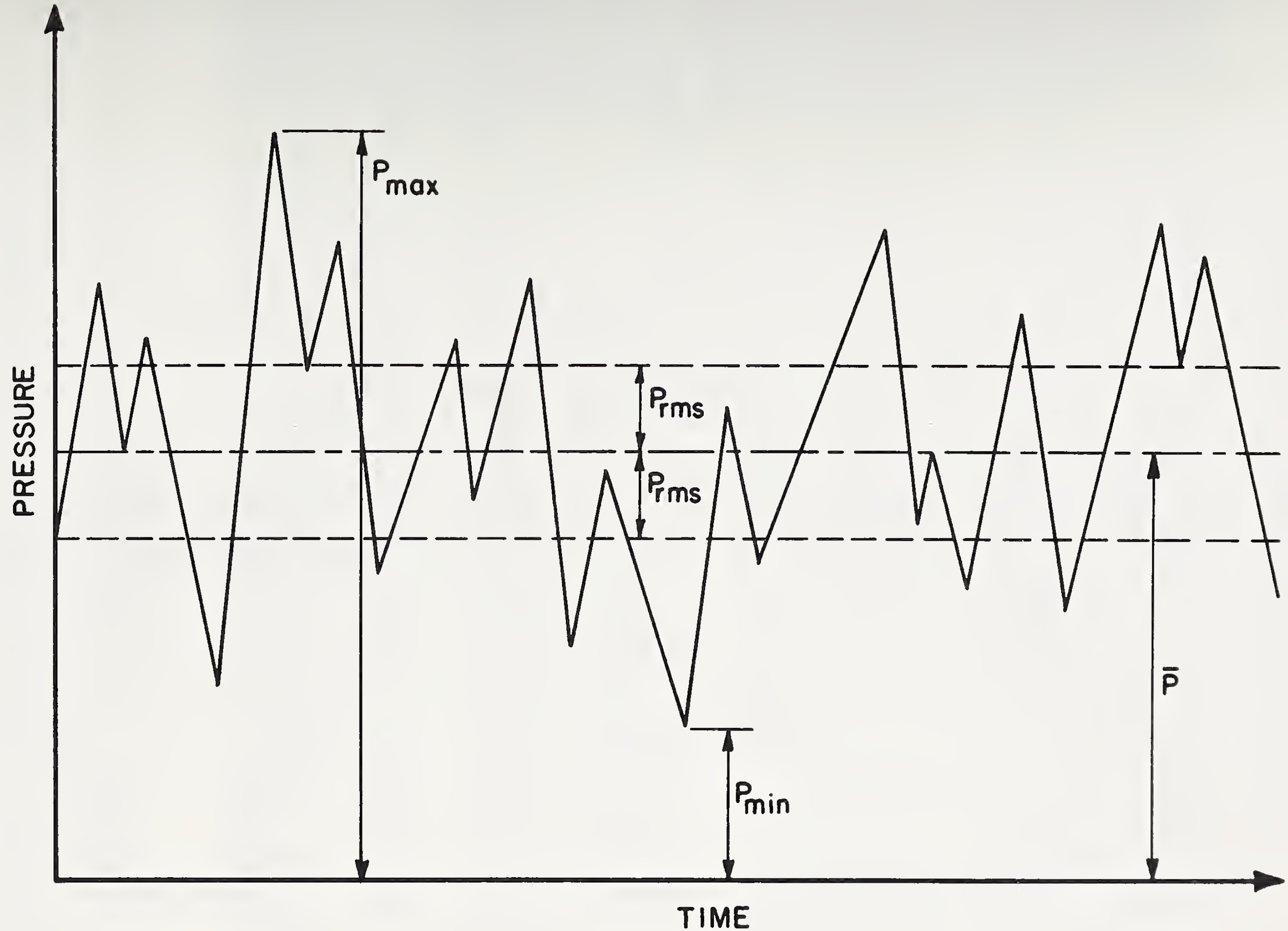

Fig. 12 Typical Pressure Time History

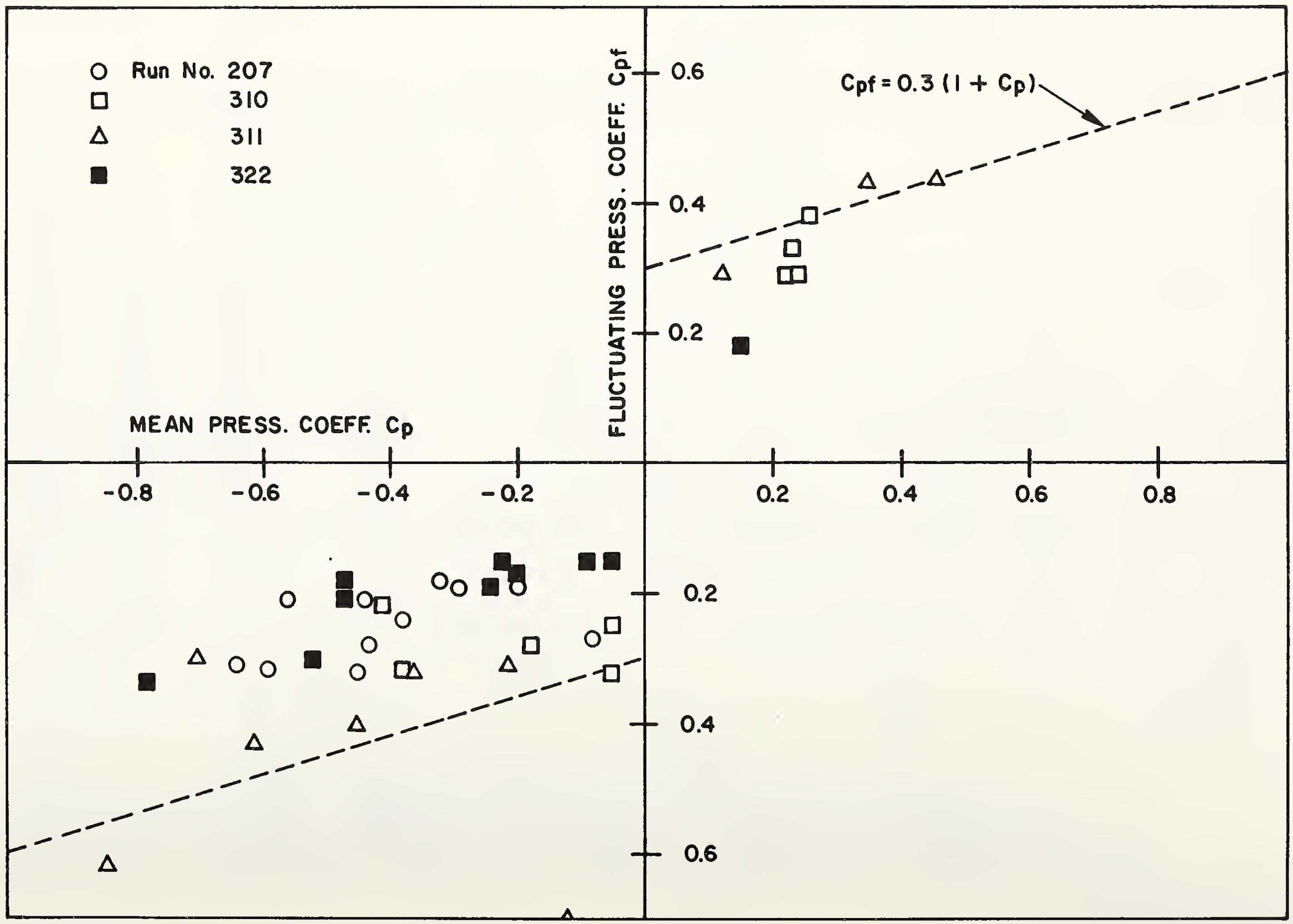

Fig. 13 Cp vs. Cpf - Full Scale

REMARKS
by

Angel A. Alejandrino
Director, National Hydraulic Research Center,
University of Philippines, Quezon City, Philippines

As Noel pointed out this morning, this project of ours on wind effects, a complementary portion of the full scale tests on the building is the model investigation in the wind tunnel. My own contribution to the workshop at this stage, since our work has not yet started, is to commit the personnel and facilities of our research organization.

We must admit, however, that the bulk of our work is on hydraulic model testing, and we have very limited experience along wind tunnel investigation. There is always a first, however, and for which we are willing and very enthusiastic about this project. We hope that the transfer of experience in hydraulic model testing would be of help in the wind tunnel tests. After all, water and air exhibit some common properties of fluids in general.

Our wind tunnel at the Hydraulic Center has a 4 feet by 4 feet test section, 12 feet long. As Dick has pointed out, this is in the marginal size. But since this is available at this time, the tests will be conducted there. The tunnel proper is constructed of wood and plywood panels with transparent glass windows in the test section. We are able to achieve wind velocities to about 75 feet per second by means of a 60-inch axial flow fan whose speed is controlled by a direct current motor. The instrumentation for this project, consisting of among the latest in sophisticated measuring equipment -- which, as Dick pointed out, he would like to have himself - is being provided for by the National Bureau of Standards through U.S. AID. With the expert guidance of Dick, we are quite confident of attaining the desired results of this project.

Another factor which should work in our favor is in the unique managerial structure of our research organization. What follows, therefore, Ladies and Gentlemen, is a word from our sponsors.

The National Hydraulic Research Center is recent. It has been organized about the past three months only. It is a unit of the University of the Philippines under the management of a private, non-profit organization -- the U.P. Engineering Research and Development Foundation, Inc. This unique arrangement enables us to respond quickly and effectively to the challenging demands of research since we are able to avoid the many bureaucratic constraints of a government organization.

Although this structure is quite recent, the nucleus of our personnel and facilities, however, have been drawn from the Hydraulics Laboratory of the University of the Philippines where we have conducted hydraulic studies for the past 20 years.

With this project, we shall be expanding our research capability - and that hopefully by the next workshop, we should be able to convey more information on the results of our investigation rather than on the promise and propaganda we have presented. Thank you.

SOME PROBLEMS IN THE ANALYSIS OF LATERAL WIND FORCE RESISTING SYSTEMS

by
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and DCCD Engineering Corporation

1. INTRODUCTION

The conventional design process for structures is divided into several phases:

1. The determination of an equivalent static lateral force system to replace the dynamic effects of the wind;

2. The analysis of the structure under the action of this force system, of the vertical loads, and such appropriate loading conditions;

3. The proportioning of the individual members of the structure (design) to resist, with the requisite margin of safety and acceptable magnitudes of deformations, all pertinent force system combinations; and,

4. When necessary, re-analysis and redesign of the structure when initial guesses as to member sizes prove to be too much in error.

This paper will not cover the first topic, even though it may well be the most important phase, since other papers in this workshop will discuss this aspect extensively.

Attention will be devoted solely to the second phase and such aspects of the third phase as directly affect analysis in order to emphasize two points, first, that the analysis of a structure, particularly of a tall structure, is far from being a cut-and dried procedure, and second, that many problems and even uncertainties are present in currently (1973) available methods of analysis. Nothing original is presented herein. However, this paper is written in the belief that there is need to collect in one place a discussion of the many problems that have been encountered in the analysis of structures, of the different means proposed to overcome them, and the references available in the Philippines where the interested structural engineer can obtain more detailed discussion than is possible in this paper of the foregoing.

For lack of a definition as to what constitutes a "low-rise" structure, the author arbitrarily set any structure below 20 stories as a low-rise structure; 20 to 50 stories as medium-rise; and above 50 stories as high-rise. This is consistent with the relative necessity for the use of shear walls in resisting lateral loads as governed by the number of stories suggested by Khan (KHAN, 1967) for the purposes of this paper.

With respect to the definition of "low-cost", the author would prefer not to even attempt one because the rapid changes of prices of construction material currently (1973) obtaining would make any estimate academic.

2. BEAM AND COLUMN STRUCTURES

This lateral load resisting system is by far the one for which the greatest number of methods of analysis is available. The different methods may be broken up into two major groups: manual and digital computer methods.

Most manual methods are usually restricted to planar rigid frames. Those methods which can be made to yield adequately accurate results, such as the traditional moment distribution, become too laborious to be practical when used for large structural systems, even in plane rigid frames. Approximate methods such as the portal method, the cantilever method, the Factor method, (MORRIS and WILBUR, 1960) etc., which are still being used in this country can also yield acceptable, albeit approximate, results provided that the assumptions on which they are based are reasonably well satisfied. The author of this paper knows of only one manual method for analyzing a three dimensional, rectangular rigid frame (PCA, 1954). This method makes the assumption, the method then derives formulas from which a convenient tabulation based-solution will yield end moments for each member of each floor due to the imposed lateral load including torsion due to any eccentricity between the lateral load resultant and the computed center of rigidity. All the foregoing manual methods are severely restricted in that calculation of displacements are very tedious. This computation of displacements is now receiving much attention particularly in tall structures (CHEN and ROBERTSON, 1972) because human comfort is affected by their magnitude. Another factor which may severely restrict the use of manual methods based on planar frame analysis is the requirement of new building codes of an analysis for torsion even for nominally symmetric structures.

It is the considered opinion of the author therefore, that for meaningful results to be obtained in structural analysis, both for internal forces and deformations, a digital computer solution is an absolute necessity.

Fortunately, there are a large number of digital computer installations in existence in the Philippines although only three, as far as the author knows, have the necessary software (programs) for structural analysis. These are:

1. The computer Center of the University of the Philippines,
2. The Data Center Services of IBM Philippines, and,
3. The Computer Services Center (of the Meralco Securities group of companies).

From the point of view of software there are two types, the general type which can handle any type of structure; truss, grid, rigid frame; whether planar or three-dimensional; and, the special type which can handle only one type of structure.

The general type of program package is available in all three computer installations and is the MIT-developed STRESS (Structural Engineering Systems Solver) program (FENVES, et al, 1964). Since the size of the core memory is the major factor limiting the size of the problem that can be handled and since the computers in the foregoing installations are of different sizes and models not to mention different types, it is best for the potential user to consult the particular installation as to the maximum structure size that may be handled using stress.

The special type of programs, being restricted to specific kinds of structures, can handle a much larger-sized structure than STRESS. The author knows of only two and these are both at the U.P. Computer Center and were developed by Dr. Salvador F. Reyes (REYES, 1973) to analyze planar, rectangular rigid frames (program named CE550020) and three-dimensional, rectangular rigid frames (program named EQANAL).

All the digital computer methods yield displacements as well as internal forces.

The foregoing discussion has made one tacit assumption that only first-order effects are of importance and that secondary effects are negligible. These secondary effects are due to stability effects (moments due to column axial loads, P, acting over lateral sway displacements, D; i.e., P x D) and to axial shortening of columns (due to axial forces in columns or temperature differentials between adjacent columns) which if unequal induce additional fixed end moments in beams Fig. 1. Several studies (GRUNDY and WATHEN, 1971; FINTEL and KHAN, 1965: KHAN and FINTEL, 1966; KHAN and FINTEL, 1968; WEIDLINGER, 1964) have shown that these are not negligible particularly for tall buildings. All the references cited discuss either necessary modifications in the stiffness matrix of the individual member or the approximate methods to be used to account for these secondary effects. However, existing digital computer programs, those mentioned in particular, can be used in iterative fashion to account for these effects which are non-linear in nature. In the case of axial load effects and temperature differentials between columns, the axial length changes can be calculated from the first-order solution. The necessary fixed-end moments in the beams can be calculated by then multiplying the axial load in the particular column by the sway displacement between the ends Fig. 1. These fixed-end moments than can be input into the computer program and another analysis run. Examination of the changes in the final moments and displacements due the secondary effects can then be made and a decision made as to whether further recalculations need to be made. These are then superposed on the first-order analysis. The procedure is relatively rapid in convergence and does not require, except for unusually proportioned structures, as a maximum, more than four cycles. Grundy and Wathen recommend as a matter of routine the use of the second order analysis even for medium rise structures specifically for stability effects.

3. TUBE STRUCTURES

This lateral force resisting system is characterized by a single, cantilever resisting system for lateral loads. There are different types of tube systems currently in use.

Tube Structures of the Shear Core Type

The first type consists of a central core, usually the elevator and utilities shafts, made up of shear wall assemblies. This has become quite popular in particular in conjunction with slipform construction where the central core is constructed first and the floors then constructed in such a way that they are supported jointly by the core and ties which are in turn suspended from a supporting member at the top of the core, Fig. 2.

The analysis of the bending moments, shear and axial forces for this lateral force resisting system is very simple since it becomes merely the analysis of a cantilever once the lateral forces are determined.

The distribution of bending and shear stresses, in combination with the normal component due to axial force, among the different elements is an entirely different matter. It is this regard that many uncertainties exist.

The core which is made up of shear wall assemblies is essentially a thin-wall structure. Structural steel textbooks (McGUIRE, 1968 and TALL, et al, 1964) indicate that for a given aspect ratio (i.e., the ratio of the lesser dimension of a rectangular panel to its thickness), elastic buckling will take place when the compressive stress reaches the critical stress. Proportions of shear wall elements and the compressive stress in practice are such that plate buckling could take place. However, in one of the studies on shear wall assemblies (BRETTLE, 1971) mention is made of other research involving actual experiments on thin-walled, reinforced concrete, closed tubes of typical shear wall proportions showed that no buckling took place and instead failure compressive stress of the order of $0.85f'_c$ to f'_c were attained depending upon the amount of reinforcement used. Whether these results are typical is still an open question.

Another uncertainty is how much of the flange elements of a core assembly is effective in view of shear lag. Some designers locally use the rules for effective flange widths of Tee-beams specified by the ACI (ACI318-71). No theoretical or experimental justification of the practice is known to the author.

In view of mandatory analysis for torsion now required by most codes, warping of cross-sections of core elements needs to be taken into account. Again, from structural steel textbooks, a non-circular thin-wall section will warp under torsion but will undergo no longitudinal stressing for as long as freedom to warp at every section is provided. In the case of a shear-core assembly, its attachment to what normally is a massive foundation prevents warping at this end. As a result longitudinal stresses will take place. The magnitude of these stresses will vary from that, where the beam elements spanning the openings in the core structure are so flexible that the behavior is that of an open tube, to that of a closed tube, when the beam elements are infinite in stiffness. Fig. 3 shows the deformations in the neighborhood of a core structure. A study using Vlasov's theory for torsion of members made up of thin-wall elements (TARANATH and STAFFORD-SMITH, 1973) shows that normal stresses due to warping are of the same order of magnitude as the primary bending stresses and should, therefore, always be taken into account. This study derives some formulas which can be used for calculating these longitudinal stresses. Methods of taking into account the stiffening elements of the floor bridging the openings are also given. It is interesting to note that the presence of beam or slabs bridging these openings can produce a significant reduction in longitudinal stresses. Another investigation (TSO and BISWAS, 1973) using the continuous connection techniques derives a 5th order linear differential equation which when solved with the appropriate boundary conditions yields for a general three-dimensional shear wall assembly, the deflections and rotations along the height of the structure as well as the effect of axial deformations.

A fourth uncertainty is: should the analysis of a core be based on the uncracked state of the wall elements (a state in which the core is at its stiffest) or should they be based on the cracked state (a state in which the core is least stiff) considering that at one time or another in the lifetime of the structure the lateral loads can conceivably reach values which will produce an excursion of the structure into the cracked state. This is particularly important when one considers the associated problem: if the stiffest state is used, the deflections which may be critical will be understated; on the other hand when the most flexible state is used, the deflections may be overstated. In either case one's judgment is distorted and unnecessary measured may be taken in the design.

A number of other problems for this type of lateral load resisting system exist but will be discussed in conjunction with the frame-shear wall system where these problems occur more frequently and are more serious in nature.

Framed-Tube Structures

This lateral load resisting system is of fairly recent vintage but has been applied to what is now the world's tallest structure at 1454 ft. above ground level, the Sears Roebuck Building in Chicago (Iyengar, 1973). Complicating matters in reinforced concrete is that repeated excursions into the inelastic range which can take place throughout the loading history of the structure can lead to an increasingly degraded resistance of the component elements of the structure. Whether a modified limit analysis similar to that of structural steel taking this into account can be developed or not remains to be seen. A typical plan of this structure is shown in Fig. 4. One will note immediately that although for practical purposes this is essentially a conventional frame structure, spacings of columns are much closer than in ordinary rigid frames. Also stiff spandrel beams are used. The columns and the spandrels then form a rigid exterior grid which is designed to exist the entire lateral load. This explains the use of the term "framed tube". The behavior of the tube system has been described (KHAN and AMIN, 1973) as consisting of two resistances: a resistance to overturning which results in compression and tension in the columns and a resistance to the shear from the lateral load which is provided by frame action by the two sides of the building parallel to the direction of the lateral load, Fig. 4. Because these frames are not solid webs, considerable shear lag takes place and distribution of compressive forces in the columns is non-uniform. Khan and Amin in their paper have proposed an equivalent "channel flange" to account for this and have provided influence charts which are of sufficient scope to allow a reasonably accurate preliminary design. The final analysis of such a system needs to be done by computer. This constitutes a considerable problem because of the number of joints resulting from the configuration which will require a large computer. The reference listed in the foregoing presents a means of approximating the full-sized building into one with fewer floors to fit available computers but which still attains sufficient accuracy for final design purposes.

Other variations of this system exist. Among them is the use of a shear core system inside the building so that in effect the whole structure is a tube within a framed type. Another variation is to subdivide the interior or the building into sections by interior columns spaced at the same distances as the exterior columns so that the whole system becomes a system of "bundled" framed tubes.

The use of the framed tube has not yet been tried in the Philippines perhaps primarily because existing computer facilities do not have the size of core memory to handle the structure without too much approximating.

4. SHEAR WALL STRUCTURES

This category is by far the most popular in the Philippines and if one were to judge from the number of papers in existence is also the most popular in the world. Several subtypes are found in this system.

Shear Wall Systems

In most apartment and residential structures where the partitions walls are fixed in identical locations from floor to floor, the walls themselves become the load bearing, as well as lateral force resisting elements.

As long as the walls are solid without any openings, the analysis is straightforward but is complicated only by the problem of what effective width of the slabs are to be used in the frame analysis. Some proposals have been made, ranging from the whole span (BARNARD and SCHWAIGHOFER, 1967) to variable effective widths depending upon properties of slabs and walls (QADEER and STAFFORD SMITH, 1969). To date, this remains a problem (DERECHO, 1973).

When walls have openings then the problem becomes more difficult. Actually, the existing computer programs can be used for the analysis (SCHWAIGHOFER and MINORS, 1969) by considering the component walls and the beams spanning the opening as a wide column rigid frame with the individual centerlines of the walls and the beams defining the centerline of the equivalent frame; by considering the cross-sectional properties of the walls as the cross-sectional properties of the equivalent columns; and, finally, by using the cross-sectional properties of the central portion of the beams as the cross-sectional properties of the central portion of the equivalent beams but now using an infinitely rigid portion of the ends of the equivalent beams framing into the walls. There is some divided opinion on how much is to be considered infinitely rigid. Originally, the whole portion starting from the intersection with the face of the wall up to the centerline of the wall was so considered. However, recent work (MICHAEL, 1967) has shown that this is not correct. A rigorous method is proposed along with an acceptably accurate simplication of assuming the infinitely rigid portion to start within the wall an amount equal to 1/4 the beam depth beyond the intersection of the beam and the wall at ends intersecting the wall.

The only drawback in using the computer solution directly is that one has to guess the initial properties of the walls and the connecting beams. If the guesses are grossly in error, the continual iterative use of the computer can be quite expensive. So there is need for a rapid manual method that can be used to arrive at a preliminary solution sufficiently close to the final one so as to minimize the number of computer runs to arrive at the final design.

The best known of the manual methods is the technique known variously as the continuum method, the continuous connection technique, Rosman's method, etc. The method originally credited to Chitty has been elaborated on by Beck (BECK, 1962), Rosman (ROSMAN, 1965) and by Coull and Choudhury (COUL and CHOUDHURY, 1967a and COULL and CHOUDHURY, 1967b). The method essentially consists of substituting of the connecting beams spanning the openings between the walls with a continuous medium with an equivalent stiffness per unit of height to that of the beams. A whole series of papers showing how different loading conditions can be handled using different conditions of supports are available (in addition to the foregoing cited references; COULL, A., 1973, COULL, A. and ADAMS, 1973; COULL and IRWIN, 1969; COULL and IRWIN, 1972; COULL and IRWIN, 1973, COULL and PURI, 1968; GLUCK J., 1969; GLUCK, J., 1970; MacLEOD, I., 1970; PAULAY, T., 1970). This procedure yields the normal and shear stresses in the walls, their deflections and rotations as well as the shears and therefore moments in the connecting beams.

Frame-Shear Wall Systems

Quite apart from the previous type of shear wall system is the combination of shear walls with rigid frames.

Here the primary problem is the analysis of the proportion of the shear that is resisted by the frame and that by the wall. Fig. 5a shows pattern of a shear wall resisting lateral loads alone. But when both are combined, Fig. 5c, the deflection pattern of each component system is different from that when each resists its own share alone. Thus it is absolutely necessary to analyze the systems in combination if meaningful results are to be obtained.

The analysis can be performed by any of the computer programs now available in the Philippines (STRESS and the Reyes programs). The major limitation is the maximum size of structure that can be handled because of the size of the computers available. One way around the problem is to find a substitute frame which results in a smaller size problem but which can represent the original structure adequately. Several approaches to the problem are available (WYNHOVEN and ADAMS, 1972; BAZANT and CHRISTENSEN, 1973). While perhaps no exact substitute frame can be found, for practical purposes, that indicated by the quoted references can be used.

Again, a computer solution can be very expensive if used in the iterative procedure to arrive at an optimum final design. Some convenient manual procedures using either formulas (HEIDEBRECHT and STAFFORD-SMITH, 1973, MacLEOD, 1970b) or charts (KHAN and SBAROUNIS, 1964) are available which allow the structural engineer to guess at an initial solution analyzed by these methods and revise as many times as necessary until the frame shear wall system is judged to be sufficiently close to the final after which a computer solution can be used.

In all of the previous discussion, it has been tacitly assumed that the walls are all in the same plane as the frame to which it is connected. When shear wall assemblies are connected to two or more frames, then the problem of modelling the system becomes very difficult. All the problems discussed under tube structures of the shear core type along with the problems discussed under frame-shear wall systems come into play primary of which is the adequate representation of the assembly of the shear core elements. Perhaps a modification of Tso's method (TSO and BISWAS, 1973) which is slightly more convenient to handle than that of Taranath (TARANATH and STAFFORD-SMITH, 1973) could be used in developing a stiffness matrix for the assembly before use in a standard computer program.

Another serious problem common to all of the lateral load resisting systems so far discussed has been the assumption that floor slabs will act as rigid diaphragms. A computer-based solution which includes in-plane deformations of slabs is available (GODLBERG, 1967). Inclusion of this effect can increase the size of the problem to be handled and can be limited by existing computer facilities but may be necessary since errors in the frame analysis can be serious particularly when shear walls or lateral load resisting systems in use are of the same order of magnitude in stiffness as the slabs.

A serious problem that is not even mentioned in most papers is that of providing adequate foundation anchorage for the lateral load resisting system. This is particularly true when the system resists a major portion of the lateral load while at the same time is supporting a very minor fraction of the vertical load. This normally requires very stiff foundation beams in the order of magnitude of that of the components of the system. It is thus necessary to analyze footing tie beams as part of the frame in order to take into account automatically the effect of the stiffnesses of these tie beams rather than make some arbitrary assumptions as to the fixity of the lateral load resisting system at the foundation levels. The two Reyes programs have provisions for this as well as for including elastic resistance of the footing-soil system.

One and Two Story Structures

In the Philippines, one- and two-story structures are usually not specifically analyzed for lateral loading. The resistance to lateral loads is assumed to be there and is taken for granted to be adequate.

Structures of this type rely on diaphragm action to provide the lateral resistance to wind action, Fig. 6. For a great majority of cases, the use of sophisticated computer-based analysis is not justified. There exists, however, a manual method of calculation based on principles of strength of materials (BENJAMIN, 1959 and BENJAMIN and WILLIAMS, 1958a) which is very convenient for use and can handle openings in walls such as doors and windows. Although not completely rigorous because compatibility conditions are not fully satisfied, the technique is very attractive due to ease of application and to acceptable accuracy.

Diaphragm action can be provided in a number of ways. Walls made of brick, concrete hollow block properly reinforced, thin precast concrete panels, infilled frames (reinforced concrete columns and beams with space surrounded by them filled with masonry), plywood walls, wall studs and lintel beams sheathed, etc.

Theoretical and experimental studies on the strength of diaphragms made of brick (BENJAMIN and WILLIAMS, 1958b), reinforced concrete walls (BENJAMIN and WILLIAMS, 1959), and Infilled walls (STAFFORD SMITH, 1967) are available.. A design "manual" for timber and plywood diaphragm construction is also available (AMERICAN PLYWOOD ASSOCIATION, 1957). Actual field experience on behavior of timber and plywood diaphragms have been recorded (AMERICAN PLYWOOD ASSOCIATION, 1964) and show that this method of resisting lateral loads is extremely good.

The computational procedures of the foregoing references can be used immediately without any modifications. However, there is need for more research locally to develop allowable values for use in design. Two cases in point may be cited. Take the infilled frame diaphragm system. Stafford Smith has shown that the infill panel between the reinforced concrete columns and beams can be represented fairly well by an equivalent diagonal strut having a thickness similar to that of the infill itself. The width of this in the plane of the panel is variable and is influenced by the stiffness of the framing members relative to that of the infill, which in turn is affected by the proportions of the panel. The strength of the panel, whether failure is by diagonal cracking or by crushing is also influenced by these factors. While the properties of brick and reinforced concrete have been discussed by Benjamin and Williams and by Stafford Smith, no counterpart studies on crete hollow block masonry are known to be available locally by the author. Considering that concrete hollow block masonry is the most popular material, next perhaps only to wood, for one- and two-story structures in the Philippines, the need for such data is immediately obvious. In the case of plywood diaphragms, their resistance is shown by the design "manual" of the American Plywood Association to be dependent upon the thickness of the plywood panels, the nail spacing at the plywood panel edges and to some degree on the width of the wood framing members. Again no comparable data on Philippine plywood diaphragms is known by the author to be available locally.

While it may be argued that it is conservative to disregard the effects of infills and plywood panels on the strength of the structure and to let the primary members be designed to handle the entire lateral force, it is obvious that economy can result if these contributions are taken into account. Also, since diaphragms are very much stiffer than the frames made up of columns and beams, it may well be that under the action of lateral forces, these diaphragms can so change the distribution of lateral forces among the resisting elements, that the actual distribution may be sufficiently different from that assumed in the analysis to be dangerous.

One Final Problem

Conventional design is based on the idea that if the worst combination of the working load multiplied by a certain load factor is ever reached, the structure fails. Structural design in steel recognizes other possible modes of failure (NEAL, 1956 and SUIDAN and EUBANKS, 1973): incremental collapse, alternating plasticity and fatigue. A start along those lines has been made in reinforced concrete the predominate structural material in the Philippines.

5. CONCLUDING REMARKS

The problem raised in this paper can be divided into two broad categories, regardless of the type of lateral-load resisting system in use. All of these are indicated as fruitful areas for further study.

The first category is the need for simplified models of the different systems: (1) those that can be used manually, to arrive at a sufficiently accurate preliminary design and (2) those that can accurately reduce the size of the problem to fit existing and foreseeable computer systems for the Philippines.

The second category of problems is how to design individual component elements so that the assumptions made in the analysis as to their behavior can be realized.

A final note is that except for a few papers, no general analysis of structures in an actual dynamic situation has been carried out for the lateral load resisting systems mentioned. As has been borne out by experience the dynamic behavior of structures is very different and often disastrously so from the static behavior used as the basis for design.

On the note that so much more needs to be studied, the paper is closed.

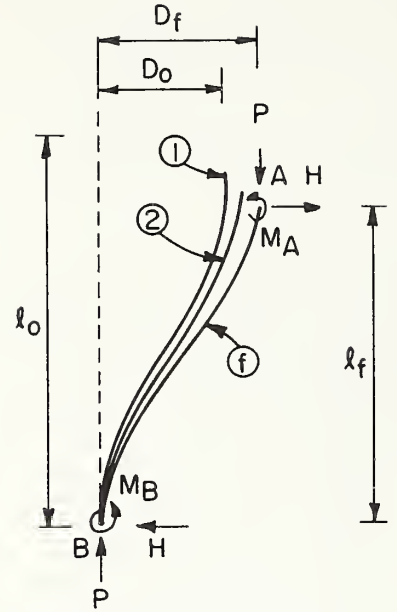

Fig. 1 Secondary Effects on Columns

Legend:

1 Deflected Shape, Only Primary Effects Considered

2 Deflected Shape, 1st Iteration Including Secondary Effects

f Final Deflected Shape

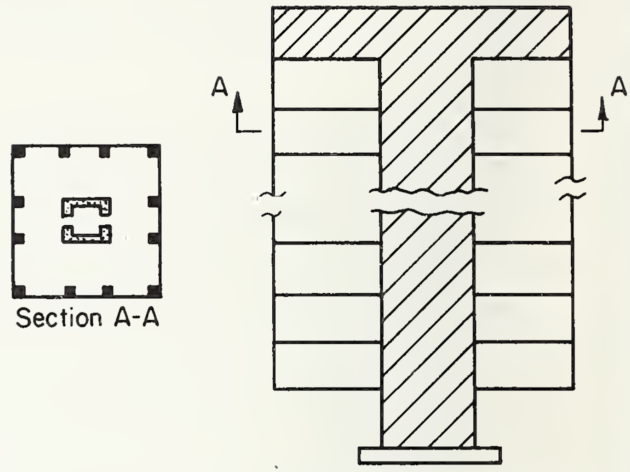

Fig. 2 Typical Shear Core System

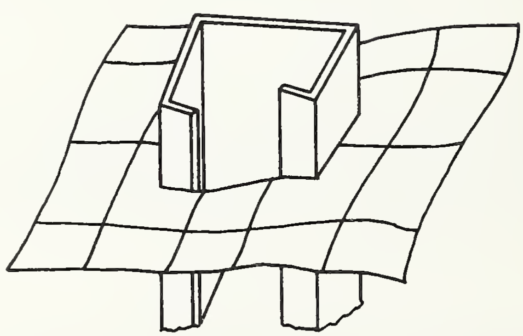

Fig. 3 Warping of Floor-Core Assembly Under Torsion

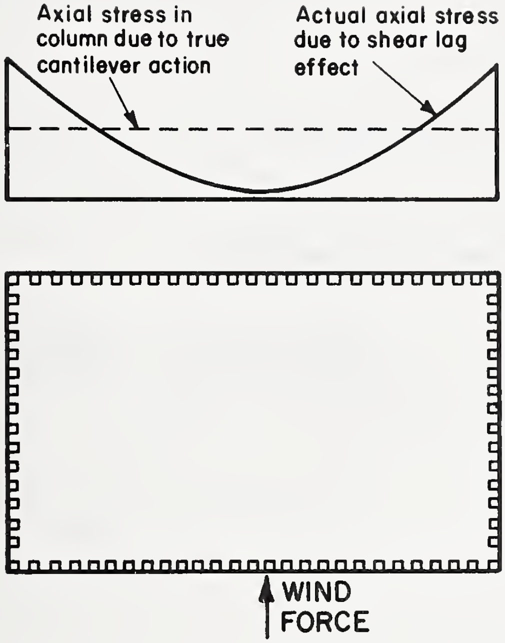

Fig. 4 Framed Tube Action

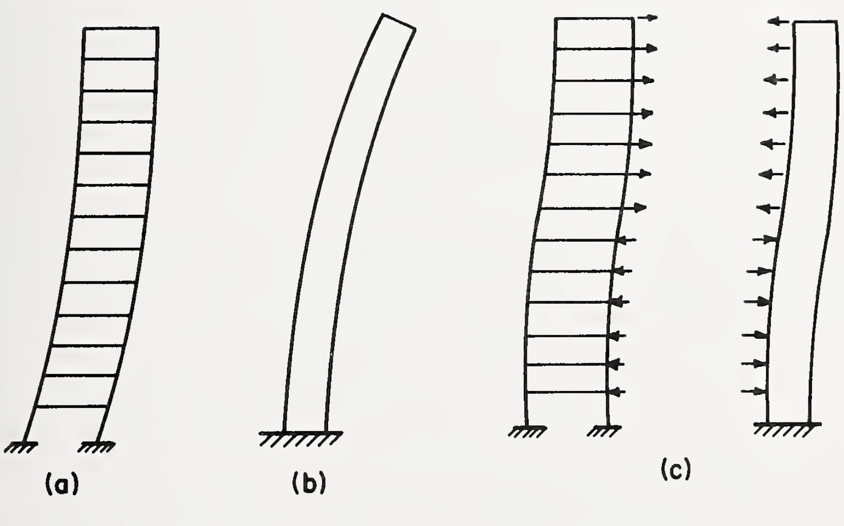

Fig. 5 Deflection Patterns of Different Systems

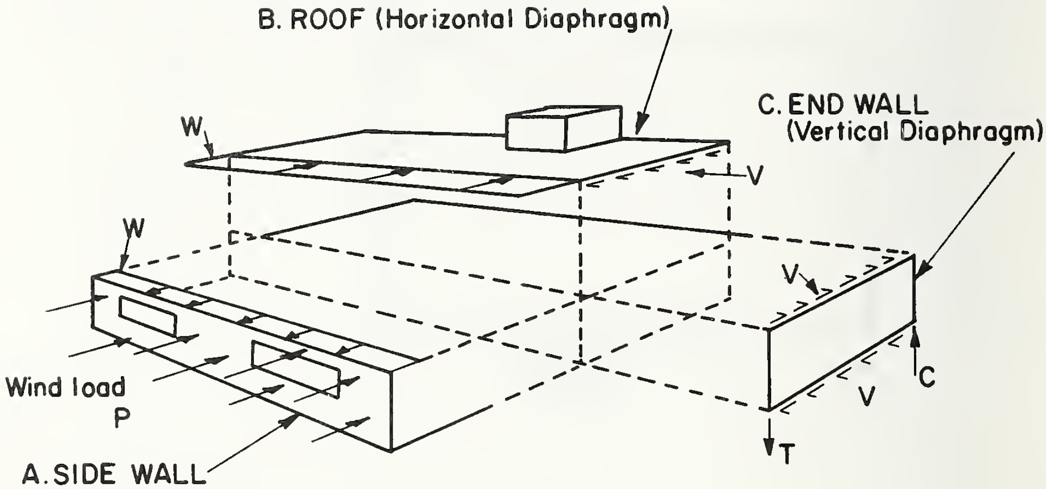

Fig. 6 Distribution of Lateral Loads on a One-Story Building

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SOCIO-ECONOMIC AND ARCHITECTURAL
CONSIDERATIONS IN HOUSING

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1. Housing Is Not Mere Shelter

It is in the home and its physical environment where the broadest range of man's existence is fulfilled. It is also in the home where the largest part of his experiences are made. The house therefore becomes the physical shell upon which the basic socio-economic need of man and his family is met.

The World Health Organization (1) defines "shelter" as an enclosed environment in which man finds protection against the elements, is safe and secure from hostile forces and can function with greater vigor, more efficiency and increased comfort and satisfaction, and in which he can safeguard his possessions and be assured of privacy for himself and his family.

On the same subject the WHO refers to "housing" as the "residential environment", "neighborhood" or the physical structures that man uses for shelter including the environs upon which the structures are disposed. This shall also include all necessary services, facilities, equipment and devices needed or desired for the physical and mental health as well as the social well-being of the individual and his family.

Clearly housing is not merely shelter, nor is it only the physical entity. It is more of a complex process involving various aspects and tasks like research, health, planning, architecture, engineering, economics, culture and social relations as well as the political and behavioral sciences. These are so inter-related and inter-twined that they become difficult to analyze in isolation. It is patent to state that since housing comprises a number of facilities, services and utilities which a family takes advantage of as its link to the community and eventually to the region, the more relevant approach for the development of housing is through community planning, design and management.

Inherent in the proper approach to the socio-economic considerations of housing is a study of the basic social elements and how these interact in the socio-cultural mileu upon which they survive.

2. The Filipino Family and Its Housing Needs

In most cultures, the basic unit of social organization is the family. In the Philippines, it is considered the strongest unit of society. In order to determine the housing needs of the present Filipino family, it is important to know, at the outset, what constitutes the Filipino family.

The Filipino family system is generally characterized by bilateral kinship which is extended to include not only families of both parents but also other blood relatives, often as far as the third or fourth cousins. It is, therefore, not unusual to find families with at least three generations.

To help one's relatives is also an obligation that is expected not only of the family but the society as a whole. This means that in time of crisis, one is expected to share his roof or his meal with the less fortunate members of his family. He is dutibound to extend support to his parents in their old age or to a widowed sister and her children.

The Filipino family also serves as the economic unit in the rural areas, as well as in the urban areas. Children are regarded as "economic asset", and a large family is considered as a means of achieving social security.

A community has been described as the simplest first grouping beyond the family. In the Philippines the community grouping has been recognized as the springboard for local unity. The "barangay" has been formalized to systematize the conscious sense of belonging or "we" feeling. This social grouping has shown its positive uses during times of crisis where community mobilization is of importance. In its physical sense a residential neighborhood is not an aggregate of houses but is a system or pattern into which the family unit with its occupations, specializations and activities is woven. The neighborhood or his community is the grouping besides the family into which the individual is inducted into social life.

An examination of families in any community will reveal great differences in the family composition as to the number of persons, age, or nature of membership within the family. While national figures indicate that about 80 per cent of all families are nuclear families, several studies reveal a different picture. (2) In a survey of selected low-income areas around Metropolitan Manila, the percentage of extended families, embracing parents, in-laws, married children, and other kinsmen, varies from 42 to 55 per cent. (3) This is an evidence that a relatively large number of extended families exists in the urban sector. The same survey shows that family size ranges from 7 to 11 with at least 18 per cent consisting of 9 or more members.

Another important consideration in housing is the economic nature of the family, for the most important factor that affects the choice of housing is the income of the family. A general rule of thumb tells us that a family should spend no more than one-fifth of its monthly income for rent, or no more than twice its yearly income to purchase a house. This rule may not be easily adaptable if we consider the general economic situation of the Filipino family. It is an unusual case that as income increases, the proportion of income spent on housing decreases. How many urban families can afford to spend 20 per cent of their monthly income to get decent housing at minimum price? Housing experts and economists estimate that only 14 per cent of urban families can afford housing in the open market; 36 percent can afford home ownership provided they are extended long-term financing at reasonable interest rates; and the rest--50 per cent — cannot afford adequate shelter even at reduced rates.

This general housing situation reflects the way the underprivileged Filipino family is housed. Housing statistics shows that ranking cities in the Philippines have from 10 to 45 percent of their populations either in slums or in squatter areas, although the national average is only about 5 to 6 per cent.

In a research study made of Metropolitan Manila in 1972 (4) some 85% of the low wage earners had basic economic problems. The families either had no jobs or not enough income. This poor earning capacity has spawned other dysfunctions for living like malnutrition, ill health and environmental health hazards. The low-income had limited personal and community resources like low education and low levels of urban skills. This is expected since most of the low wage earners are mostly new migrants from the rural countryside.

On the positive side is that their resourcefulness is unlimited, and they can rely upon themselves in solving their present predicaments. This is fully substantiated by the findings of Hollnsteiner (5) in her study of Magsaysay Village. They are generally optimistic and they want to work and improve their family's level of living. Contrary to common belief that squatters are a thieving, shiftness, dangerous slum dweller, they are a manifestation of an economically deprived social structure where rising expectation motivates them to try their luck where probabilities of success are great.

Generally housing the urban poor is not of renewal and upgrading the conditions of the shelter. It is more of strategies of how to arrive at a system where urban poverty, deprivation and miseducation can be eliminated.

The general housing shortage will give us a wider picture of the situation. The yearly need of urban housing in the Philippines averages 100,000 units. This need includes the provision of housing due to population increase, new family formations, and replacement of slum and squatter houses. An interesting phenomenon is that while the population in general increases at the rate of 3.01 per cent per year, the squatter population increases at the rate of 12 per cent. The effects of poor housing conditions to the social and economic life of the family need not be elaborated.

Another major factor that affects the family housing need is the high cost of land and building materials. The cost of land is coupled with the problem of lack of available land for development within the urban areas. In many cities, the cost of land has also affected the cost of rental.

A marked increase in wholesale and consumer price indices occurred within the last two or three years. Although the average increase for all commodities is only about 25 per cent, the cost of most construction materials increased by 40 to 60 per cent.

The foregoing discussions have shown the various socio-economic factors affecting the provision of housing for Filipino families. Through an understanding of these factors lies the desirability of any design for housing, whether architectural and structural.

Man always expresses his social and economic aspirations through the physical improvements he places in the environment. This is greatly manifested particularly in the domestic structures that shelter his family.

3. Housing Characteristics

How are families in the Philippines housed? There are several ways by which dwelling units may be classified. The Bureau of the Census and Statistics classifies dwelling units into the following categories: ownership, type of structure, type of construction materials, and type of drinking water, lighting, cooking and toilet facilities. (6) In addition to these, the Population Institute National Demographic Survey (7) includes the number of rooms occupied per household, density (persons per room), type of refrigerating method and lot ownership. Using the latest available data Tables 1 to 10 in Annex A show some general housing characteristics.

These statistics alone do not, of course, reflect a wide perspective of the housing situation. The accuracy of the data is even subject to scrutiny. For one thing, not any of these data give the actual condition of the dwelling themselves, except the barong-barongs, which comprise only 4.4 and 5.4 per cent in Metropolitan Manila and the Philippines, respectively.

4. The Right to Housing

Because housing brings into focus the social, economic and aesthetic aims and needs of a country, it is considered a major government responsibility. The housing activity takes place within a legal framework delineated by the Constitution of the land together with other laws of the country. Santiago (8) states that in the Philippines, while there are no explicit declaration of the right to housing, there are enough provisions which show that the right is amply recognized. She further states: "Aside from such Constitutional provisions concerning the right of a person to property; the right against arbitrary deprivation of property; right to security within their houses; liberty of abode and travel, there is the newly incorporated provision in the 1973 Philippine Constitution which declares that: 'The State shall establish, maintain, and ensure adequate social services in the field of education, health, housing, employment, welfare and social security to guarantee the enjoyment by the people of a decent standard of living."

5. Occupancy Schemes of Urban Public Housing in the Philippines

Occupancy schemes in urban public housing in the country are: tenant, tenant-purchasers, purchase, hire-purchase or mortgage. (9)

Tenant occupancy refers to rental housing wherein the dwelling units are leased to eligible applicants. A tenant-landlord relationship exists between the occupant and the housing agency. The tenant is obliged to pay rentals fixed on the basis of the residual of capital and recurring cost minus subsidies given by government.

The "tenant-purchase" or "rent-to-own" scheme is where the tenant is given the right to ownership if he pays rent for a certain length of time. Discount adjustments are occasionally made for early payments. The tenants who would have occupied their dwelling units continuously for a certain number of years and have faithfully observed the conditions of lease have the option to purchase their dwelling units and lots at the appraised value at the time of the offer to purchase.

The purchase type of public housing outrightly awards the units from the start of their occupancy. The purchases are obliged to pay monthly installments for a period of years after which they shall become the absolute owners of their dwellings and the lots on which they are erected.

The hire-purchase scheme have awardees who are required to deposit with the housing agency a lump sum, the amount of which is a proportion of the capital cost or subsidy. Interests on the deposit are credited to the awardee until he earns the right to own the property. The right normally comes upon completing the installment payments within a specified period. Until such payments are completed, the occupant is considered a lessee. The required period to earn ownership is reduced if the occupants pay the full cost of the house under certain stipulated conditions. The PHHC has not implemented this scheme to date.

As a mortagagor-mortgagee, the financing by the agency is considered a loan to the awardee. Until the loan is fully repaid by the occupant the property is mortgaged. Many of the occupants of PHHC housing projects have mortgaged their house and lot to government financial institutions. The homeowners who are either members of GSIS or SSS mortgage their property to secure loans for financing the improvements of their dwellings.

An integrated social development scheme where housing is used as a component for development is being studied by some entities. The project aims to utilize the integrated approach for increasing the resources of the household and for increasing the confidence of the community to manage its own activities. Some aspects of this scheme are:

1. A financing-construction package that will deliver dwelling units of acceptable standards at a price affordable by the worker assuming the income maximization component of the project produces expected results.

2. A social services staff as part of the management group of the housing complex to assist the resident community and to provide opportunities for acquiring the capability for managing the housing complex itself, the industrial and commercial components, the community affairs and programs, as well as their own family and business affairs.

3. An income generating component in the project that will offer the opportunity to members of resident families to augment the breadwinner's income through employment right at the housing site.

6. Roots of Settlement Forms in the Philippines

Archeological findings indicate that Stone Age settlements in the Philippines were small and scattered. The settlements were located by the sea or by rivers and other bodies of water. It was important for the inhabitants to pick settlements with riverine or coastal orientations for they depended so much on water for their livelihood. They made use of water for transportation, as a source of their food, and for watering their fields. This is still the situation in the rural areas of the country.

The attachment of the Filipinos to the low-lands and water-logged areas caused the development of a unique type of dwelling that is typical in Southeast Asia. This had very strong indications of environmental adjustments. A drive along the roads of any provincial town away from Manila will show the array of regional variations of the typical rural dwelling. It has a raised floor on stilts. This dwelling type appeared in the area some 6500 to 5500 years ago. The choice of materials and designs reflect the adaptations to tropical living. Sixteenth century communities in the Philippines were formed essentially by independent households based on extended kinship structures. The size of a community would not be much larger or smaller than the barrios found in today's agrarian settlements. Association would normally be based on political, social and economic activities as well as on ritual obligations and ethnic attributes.

The Pre-Spanish community was called a barangay, after the name of the boat used by Southeast Asian migrants. There were no public buildings upon which community life can focus.

The communal activities normally clustered around the houses of the village elders who were also the religious and judicial functionaries. The major affairs of the village generally rested in the hands of the chieftain. Today the same community organization has been formalized into a barrio, the smallest political unit of local government.

One always asks why are there no stone structures or buildings of worship in pre-Spanish Filipino settlements. Authorities have cited numerous reasons, but cogent are:

a. The Philippines was in a marginal position in relation to Chinese or Indian centers of culture, thus receiving no direct impact.

b. There was no strong political or religious structure which can capably direct the erection of massive edifices.

c. The people had impermanent settlement for they had a shifting form of agriculture.

d. Religion was centered on kinship groups called anitos and ceremonies were conducted in abodes of religious functionaries.

7. Conclusions and Recommendations

In the development of criteria for the study of the effects of high velocity winds on low-rise structures the following considerations have to be taken:

1. The long tradition of indigenous building can help in the development of concepts towards architectural adoptations in a harse environment. This subject could form part of tropical design which is offered in architectural schools.

2. Cultural practices and beliefs of the people should be a parameter in the design of their shelters. It is not merely economics and technology that should be considered, but also the sociological and psychological implications of space. This is particularly important in the rural areas where building beliefs border towards fantasy.

3. Environmental design and landscaping approaches may in the over-all analysis give better benefits in finding ways to optimize resistance of structures to harse winds. The proper grouping and siting of structures can assist in the development of wind shields. Similarly, the proper application of landscaping can develop windbreaks which can help minimize the harse effects of gusts.

4. The systematic analysis of building component not only for resisting harse winds but also other environmental elements should be the approach in the development of the study program.

ANNEX A

Table 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	4.4	5.4
Commercial Building	1.0	1.3
Other or No Response	8.3	6.9

Table 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

Table 3. Type of Toilet Facilities for Household (Percent)

Type	Metro Manila	Philippines
Flush Toilet	44.4	10.4
Antipolo	29.1	16.1
Pail	3.3	3.5
Open Pit	4.9	30.7
Surface or None	4.6	30.7
Public Toilet	5.8	1.6
No Response	7.9	6.8

Table 4. Type of Cooking Fuel Used by Household (Percent)

Type	Metro Manila	Philippines
Electricity	17.5	2.5
Gas (piped or tanked)	16.3	3.8
Kerosene	45.2	8.9
Wood	13.0	77.6
Others	0.2	0.6
No Response	7.9	6.7

Table 5. Lighting Facilities of the Household (Percent)

Type	Metro Manila	Philippines
Electricity	88.7	22.2
Kerosene	3.3	69.7
Oil	0.2	0.8
Others	0.1	0.6
No Response	7.8	6.7

Table 6. Type of Refrigerating Method in Household (Percent)

Type	Metro Manila	Philippines
Electricity	26.0	4.4
Petroleum	0.0	1.1
Ice Box	2.1	1.0
None	64.0	86.8
No Response	7.9	6.7

Table 7. Source of Drinking Water for Household (Percent)

Type	Metro Manila	Philippines
Private Faucet Waterworks	63.0	10.2
Private Pump or Artesian Well	7.2	16.9
Public Faucet Waterworks	19.2	14.1
Public Pump or Artesian Well	2.8	13.8
Spring	0.0	8.3
River or Stream	0.0	4.6
Rain	0.0	2.3
Well	0.0	23.0
Other or No Response	7.8	6.9

Table 8. House Ownership (Percent)

Type	Metro Manila	Philippines
Owned	43.3	81.3
Rented	43.3	6.7
Rent-Free	5.5	5.3
No Response	7.9	6.7

Table 9. Lot Ownership (Percent)

Type	Metro Manila	Philippines
Owned	24.3	50.0
Rented	47.4	15.2
Rent-Free	20.4	28.1
No Response	7.9	6.7

Table 10. 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

LESSONS LEARNED FROM POST WIND DISASTER INVESTIGATIONS

by

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I wish to depart completely from the paper which I prepared for this morning's seminar after viewing your construction methods and your type of housing. Rather than talk about the subject of my prepared paper I thought it would be more useful to talk about lessons in housing that we learned in the United States after observing natural disasters and the resulting wreckage.

We will view a series of slides which were taken after certain hurricanes struck the U.S. Gulf Coast. One of the most interesting lessons about hurricanes is that we are getting the same lesson over and over again. So, it is about time that the knowledge we learn, in seminars like this, is put into practice.

One of the simplest lessons one learns after visiting the site of a hurricane, regardless of whether the buildings involved are low-rise or high-rise or low-cost or high-cost, is that it is not the individual members of the structure that cause problems. Very rarely does one find failure in a structural member per se. It is almost invariably the connection details which give the trouble.

To illustrate, let me relate our findings in post-hurricane investigation involving the two-pole type house, a house that is popular in our coastal regions for two reasons: 1) the additional comfort one gets by having air circulation along the house; and 2) the fact that water passes under the house and all we are faced with in terms of forces on the house itself are the wind effects themselves.

In some instances we have found such houses in reasonably good shape after being subjected to hurricanes. But sometimes we found only the poles remaining. The reason for this is that the tension ties-the proper bolting of the house to the poles-were missing.

What was the cost difference of two similar vacation pole type houses in the same seashore neighborhood, one of which was blown away while the other survived? Frankly, the owners of the houses spent exactly the same, although the contractor spent a little more effort on the one house. But we have the same type of house. Certainly we need to tie the frame to the supports at the various junctures. We need adequate ties at the point where the poles themselves are connected to the ground.

In the United States, we established some standard building details to prevent losses as described above. The value of establishing the standard details is that one can simplify the whole design procedure for the house. One does not have to worry about details that we know are workable.

Secondly, and probably even more important, is the enforcement official of the building regulation system. In the United States he is not a highly trained individual. He does not have an engineering degree. He is generally a former carpenter, or other craftsman. If we change the details very frequently his job will be much more difficult. This way he knows that by referencing the standard, he will need a 5-inch bolt for a certain situation. Economically this is a more feasible approach than trying to be sophisticated about constructing a building.

Next, we must tie down roofing materials and properly connect the truss or the rafters to the walls of the building. We should use details which are clean, simple, and where there is a straight-line transfer of load. Usually, you start getting structural problems as you tend toward indirect lines of load transfer. Clean, straightforward details are also preferable from the standpoint of enforcement and inspection. We have tables available which indicate for example, the capacity of a specific connection detail in terms of the load it can transfer. We know the size of nails to be used and, the number of nails. Thus, the inspector can simply count nails to see that they are there. In essence, we have a very simple enforcement job.

Frequently used to tie down rafters are standard sheet metal connectors. The manufacturers of these provide test data with a suitable factor of safety. Usually for a connector, we use a fairly high factor of safety on the order of about 4, sometimes as high as 8. This factor of safety is possibly a little on the conservative side. But again, it provides for a simple inspection procedure and it is a nice straight line of load transfer.

Next, if we have sheathing on the building, we can use the sheathing as a mechanism for transferring that load into the shear plate. So, we can carry that load very simply straight on down. If we don't have sheathing, if we have a panelized type of system, pre-fabricated, something of that sort, more likely than not we would tend to use strapping connectors to tie it to the shear plate. The shear plate in turn must be bolted to the footing. Again, we have standard details for this-to tie down into the footing and carry that load down to a point where the building can stand up.

I have observed that here in the Philippines your buildings tend to use about the same type of concrete block construction details as used in the U.S. But details must be attended to.

The message that I am trying to convey today is that you must have quality control in the construction phase through adequate inspection.

Another problem that we continually encounter is deterioration. Wood, for example, will decay if not properly protected and connectors will pull loose from wood members. In the United States, we recommend the use of a treated wood, something that is decay-resistant. I have seen, since I arrived in the Philippines, some cases that I would be concerned about. You might be getting into problems of this nature. I have seen tension devices that were in a situation where they would probably get water around them and yet they were not galvanized; they were not protected. I would be quite concerned about this problem.

We have found design errors in our post-disaster investigations, too. We found a very plush restaurant where cost was obviously no object. But what did they forget to do? Adequate connectors to hold the building together. They skimped on the bolts that were needed. So, we don't have to talk about high-cost construction or low-cost construction. These tension details that give us so much trouble are, by and large, very inexpensive items. They are common sense details, practical sort of details that we as professionals should be making sure are incorporated buildings.

Now, there has been some discussion earlier about the importance of shear walls in the shear resistance or the diaphragm action of houses. We find that in our buildings in the United States this is what we should call non-problem. However, what is happening in the United States is that we are running short of plywood which is normally used in the shear walls. So, we are replacing that plywood. More of the sheathing material we use in our house construction is now a composition board made up of vegetable fibers stabilized with a binder. In a typical house, even in a hurricane-prone region, we use 4 feet by 8 feet sheets of plywood only at the corners of the building; the rest of the building will have composition board material. We find that we are not getting into trouble with the diaphragm action or the shear resistance of these buildings. If we do get into trouble, it is invariably that we have inadequate nailing or connection of the plywood to the rest of the frame. We don't get the sheets of plywood buckling, we don't get them breaking. It just does not seem to be that serious.

We keep getting the same lessons and these are: to tie together our buildings; to be certain of our quality control, of our building inspection to watch out for deterioration; to watch out for those things that are frequently overlooked because they are so simple.

Finally, I would like to mention this publication, Building Practices for Disaster Mitigation which I will leave at the front of the room for the rest of the day. This is the result of a conference that was sponsored by the National Bureau of Standards and the National Science Foundation in the United States. We have sent copies of this report to you during a previous trip. They are available in the university library, but some of you may not have visited the library. What this report does in essence, is establishes a national blueprint or plan for the United States with regard to building practices for disaster mitigation. It addresses both the seismic and the wind aspects. I think that you might find this to be a useful document for your own planning here in the Philippines. Unfortunately, we do not have enough copies to make them available to all of you, but we could probably spare about a dozen copies. So, if those of you that have a real priority interest in this report would leave your names with me, particularly if you would be willing to share them with others, I would be very happy to make this available to you.

Thank you.

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

by

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ABSTRACT

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

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

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

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

Cyclonic storms originating in the Bay of Bengal very often hit the coastal areas of Bangladesh. They are most frequent in the month of October. Usually accompanied with storm surges, often up to 40 ft. in depth, they cause serious damage to human lives, cattle, houses and other properties. One of the severest cyclones devastated the coastal areas of Bangladesh in November, 1970. Wind speeds up to 150 mph have been recorded in recent cyclones. The C. I. sheet roofs of houses are usually blown away, but the damage to brick masonry walls and R. C. roofs is not severe.

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

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

1. INTRODUCTION

General

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

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

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

Population

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

Economy

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

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

2. THE HOUSING PROBLEM

Introduction

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

In 1960, there were about 9.60 million residential houses in Bangladesh. The average number of rooms per household was 1.77. A majority of households (53%) lived in single-room dwellings and the average density of occupancy was 3.2 persons/room. Table 1 gives the number of households classified according to number of rooms:

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* The figures quoted are unofficial estimates

Table 1

Number of Houses of Different Sizes*

(Figures in thousands)

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

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

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

Rural Housing

The bulk of the rural population of about 67.5 million belong to the poorest income group. Since the majority of this population depend on agriculture as their means of livelihood, the distribution of agricultural land holding has a marked effect on the pattern of rural housing.

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

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

Dwelling Units

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

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

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

Structural Conditions of Rural Houses

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

Urban Housing

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

Common Types of Houses

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

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

The stronger houses in urban areas are mostly made of burnt clay brick masonry walls with sand cement mortar (usually 10" thick for buildings up to 2 stories high) with reinforced concrete roofs. The roofs are almost invariably horizontal. In the design of such buildings, no account is taken of the wind forces. The walls being much thicker than necessary from gravity load considerations, even extreme winds do not produce stresses large enough to produce failure. Most of the buildings of this type which have suffered damage due to cyclones were either made of sub-standard quality mortar or the workmanship was poor. No damage to R.C. roofs have been reported. In the island of Manpura, one of the worst-affected areas of the November 1970 cyclone, the only R.C. elements which suffered damages were 'sunshades' which were about 2" thick, 1' -9" projections above window level. These failures might have been caused by uplift wind pressure or the pressure generated by storm surges.

* Source: Housing Directorate, Government of Bangladesh.

Some New Types of Houses

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

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

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

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

Current Housing Programmes

Bangladesh had the misfortune of suffering two disastrous natural calamities in 1970. In August 1970, flood waters destroyed about 80,000 rural houses completely; moreover about 224,000 houses were partially damaged. In the severe cyclonic storm of November 12, 1970, about 100,000 houses were completely destroyed. The liberation struggle of 1971 left about 2 million families homeless. Attention of international relief agencies and humanitarian organizations were naturally focussed on Bangladesh after this series of destructions. Sizeable housing rehabilitation and reconstruction efforts are now underway in rural areas. The Government of Bangladesh through its Rural Housing Rehabilitation Project envisaged the construction of 155,000 semi-pucca rural houses and 21,000 pucca houses in the coastal areas in 1972-73. The Government has also undertaken construction of 2-storied cyclone shelters in coastal areas which will also serve as community centres, schools, dispensaries and post-offices.

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

Table 2

Housing Programme of Different Relief Organizations in Bangladesh*

Name of Organization	Number of Houses: Target up to 1972-73	Number of Houses: Construction up to August 1972
1. CARE	12,500	5,600
2. CONCERN	2,000	50
3. R. K. MISSION	1,500	1,000
4. BERRS	45,220	24,003
5. CORR	300,000	185,260
6. Uncle Erik's Children Help	31	31
7. Service Civil International	925	135
8. SAWS	2,730	200

9.	AUSTEARS	2,668	2,668
10.	Baptist Mission	1,494	1,264
11.	Danish Association for International Cooperation	125	15
12.	EFICOR	581	95
13.	ICRC	991	991
14.	RDRS	15,060	2,960
15.	Salvation Army	2,331	1,081
16.	IPS	1,000	-
17.	BVSC	5,000	-
18.	BRAC	1,000	-
	Total	395,156	225,153

3. EXTREME WIND RELATED PROBLEMS

Types

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

(a) The Norwesters (Kalbaishakis')

(b) Cyclonic Storms, and

(c) Tornadoes

The Norwesters

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

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

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

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

(a) the Dacca Cell well expanded,

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

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

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

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

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

Cyclonic Storms

Storm Tracks and Frequency

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

A study of the storm tracks in the Bay of Bengal between 1891-1923 reveals that the cyclones may originate anywhere in the Bay of Bengal and then travel either North-west towards the Madras coast in India or North and North-easterly towards the head of the Bay. The Bay of Bengal is practically free of cyclonic storms in the months of January, February and March. In the months of April and May, Bangladesh has occassionally been struck by cyclones affecting the Cox's Bazar coast and the area East of Barisal. During the monsoon months of June, July and August, cyclonic storms are frequent but of moderate intensity and they do not affect Bangladesh; they form at the head of the Bay of Bengal and travel in West and North-westerly direction to the Orissa and West Bengal coast in India. Cyclonic hazard is greatest in Bangladesh in the period starting from September and ending in December. Cyclones are then most frequent and severe and may attack any of the coastal areas at Madras and West Bengal in India, Bangladesh and Burma.

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

Table 3*

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

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

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

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

Table 4*

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

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

Disastrous Cyclones of the Past

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

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

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

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

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

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

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

* Source: Op. Cit.

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

Probable Areas of Attack by Cyclonic Storms in Bangladesh

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

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

Tornadoes

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

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

4. PRESENT DESIGN CRITERIA

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

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

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

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

$$p = 0.003\ V^2$$

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

$$Pn = \frac{2 \sin \phi}{1-\sin^2 \phi},$$

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

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

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

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

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

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

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

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

$$\begin{aligned} \phi &\le 20^\circ &:\quad p &= -0.7q \\ 20^\circ \le \phi &\le 30^\circ &:\quad p &= (0.07\ \phi - 2.10)q \\ 30^\circ \le \phi &\le 60^\circ &:\quad p &= (0.03\ \phi - 0.90)q \\ \phi &\ge 60^\circ &:\quad p &= 0.90q \end{aligned}$$

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

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

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

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

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

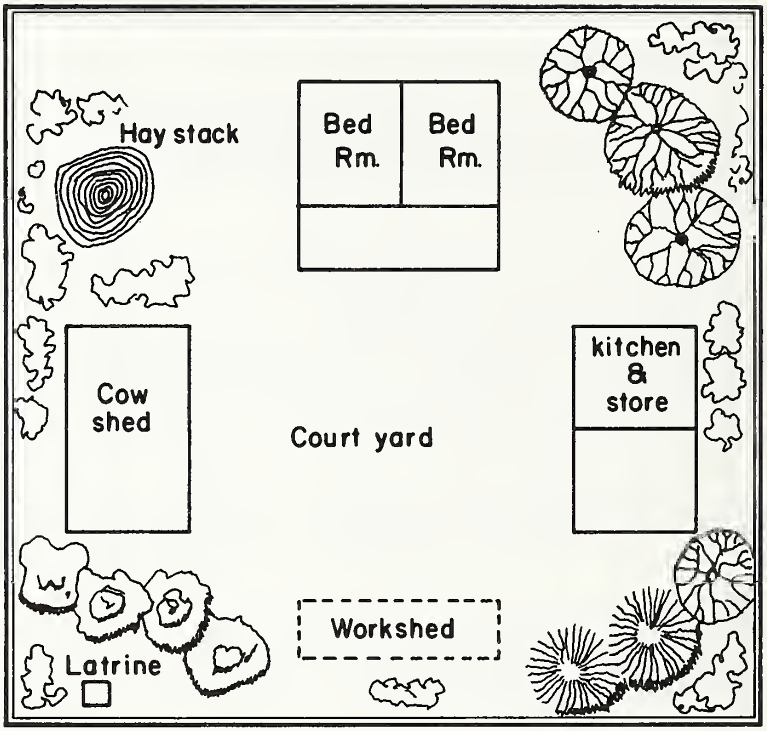


Fig. 1 Lay-out of a typical Rural house

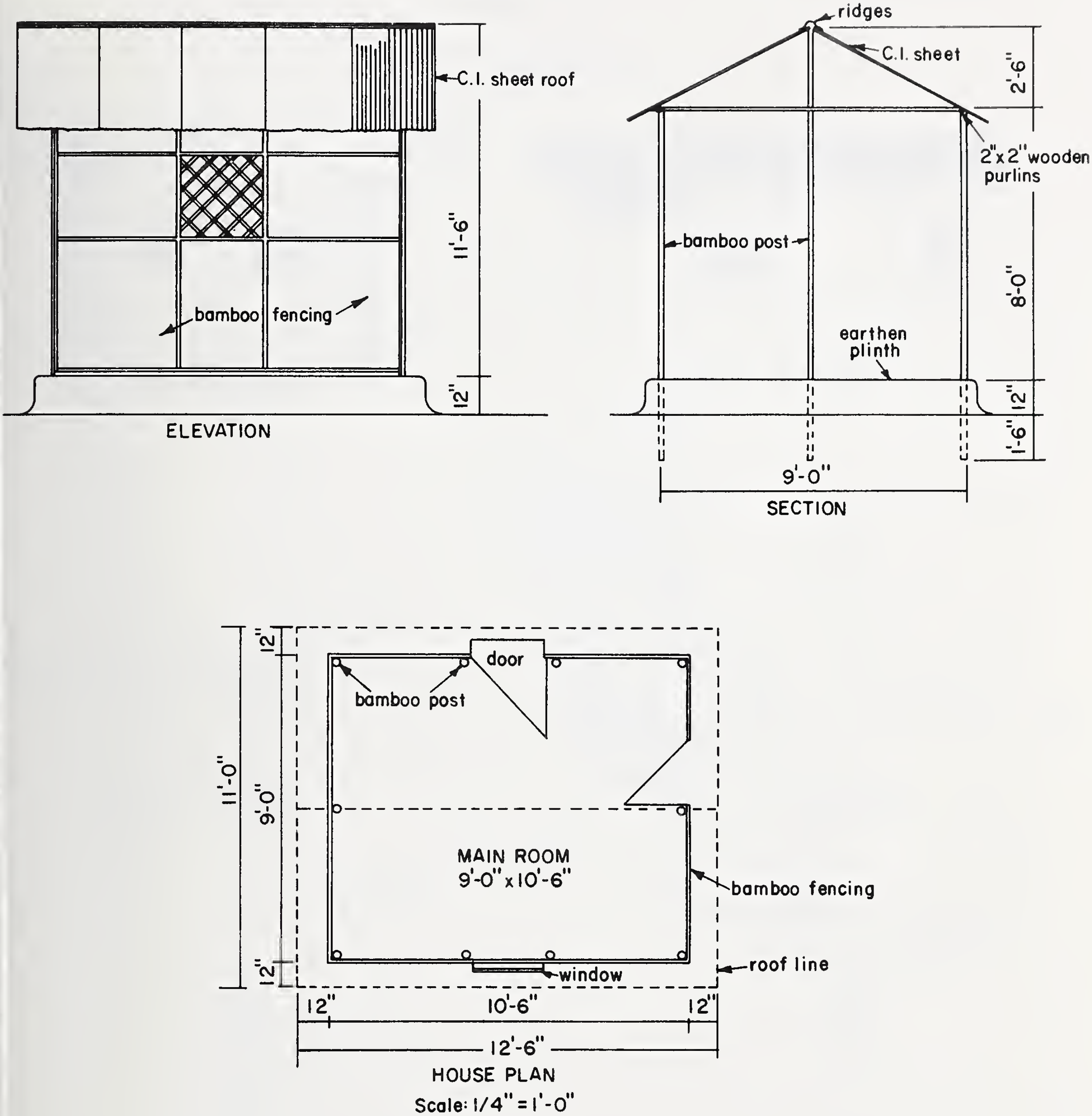


Fig. 2 Details of a typical Rural house with bamboo.

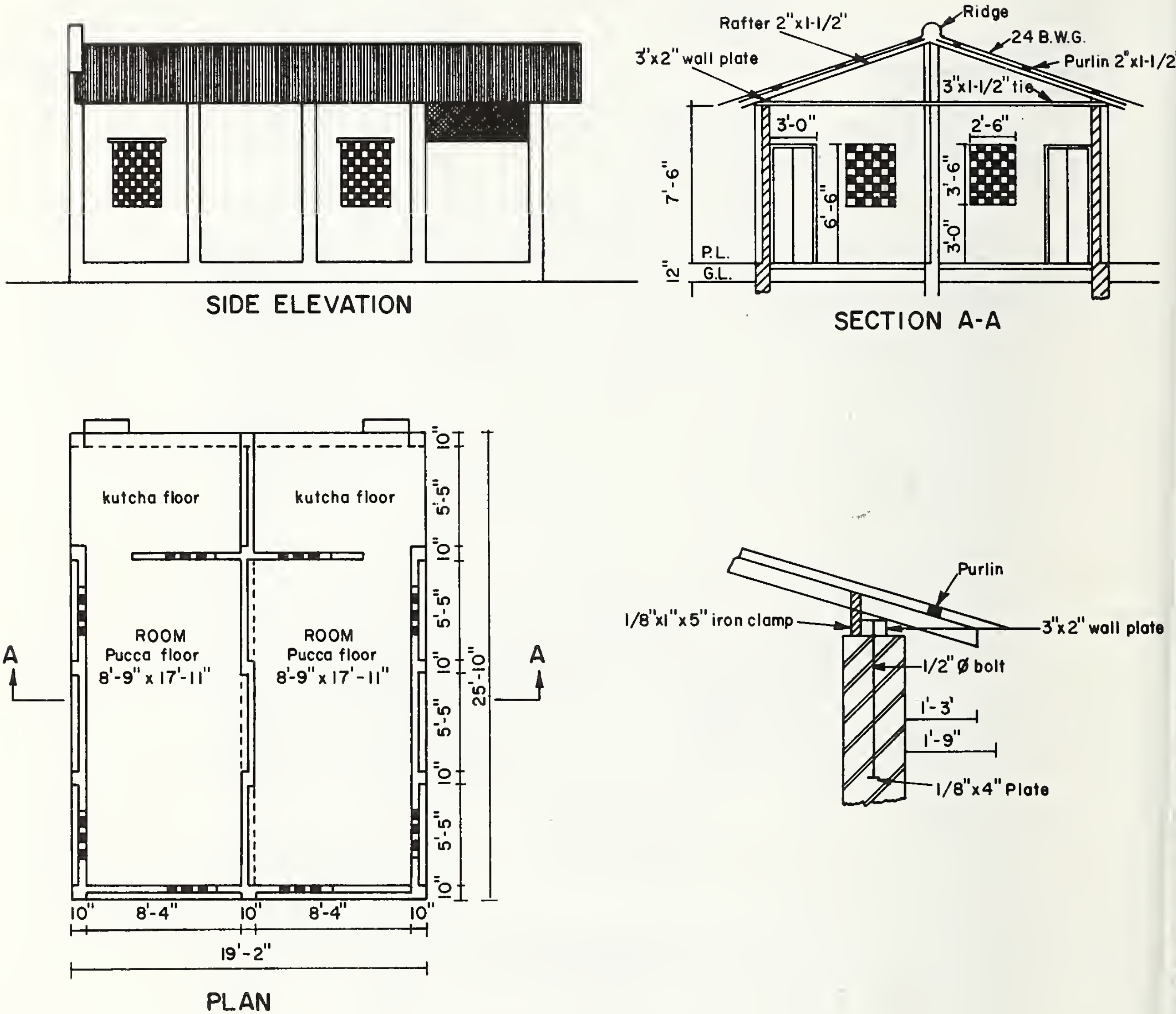


Fig. 3 Details of a typical low cost house with brick walls

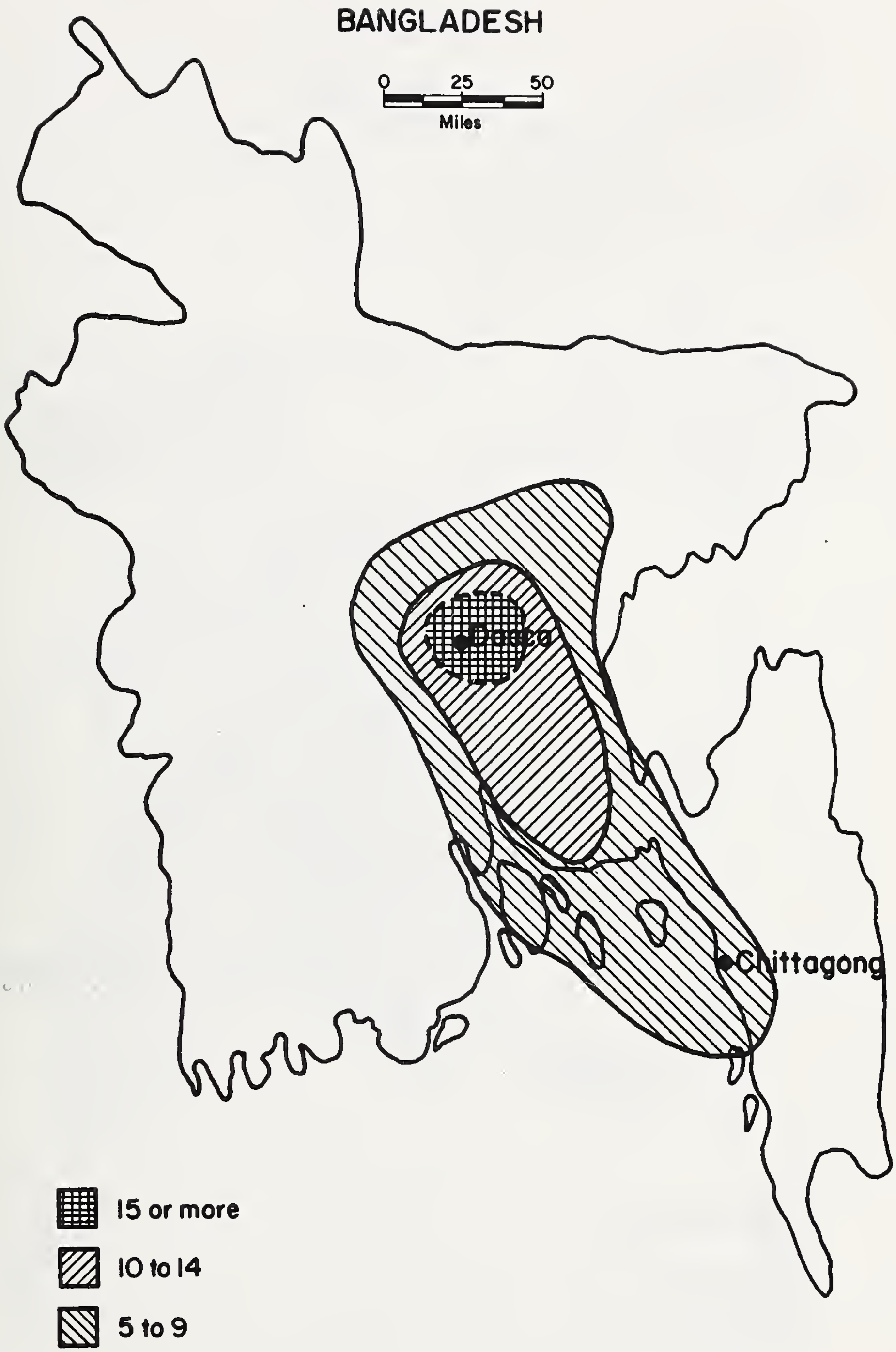


Fig. 4 Area distribution of norwester squalls (March)
(Figures indicate total no. during the period 1955-61)

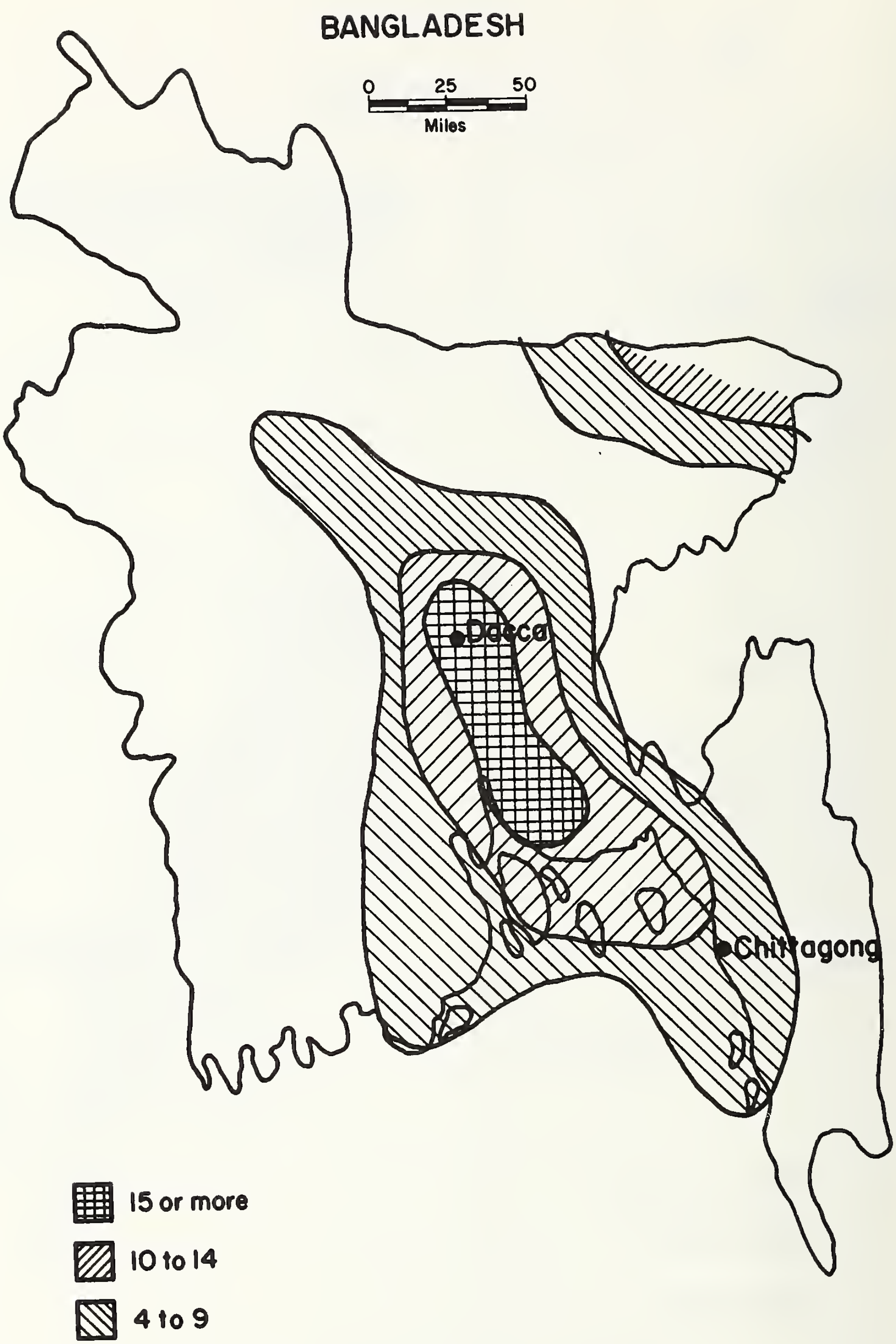


Fig. 5 Area distribution of norwester squalls (April)
(Figures indicate total no. during the period 1955-61)

Fig. 6 Area distribution of norwester squalls (May)
(Figures indicate total no. during the period 1955-61)

Fig. 7 Area distribution of norwester squalls (June)
(Figures indicate total no. during the period 1955-61)

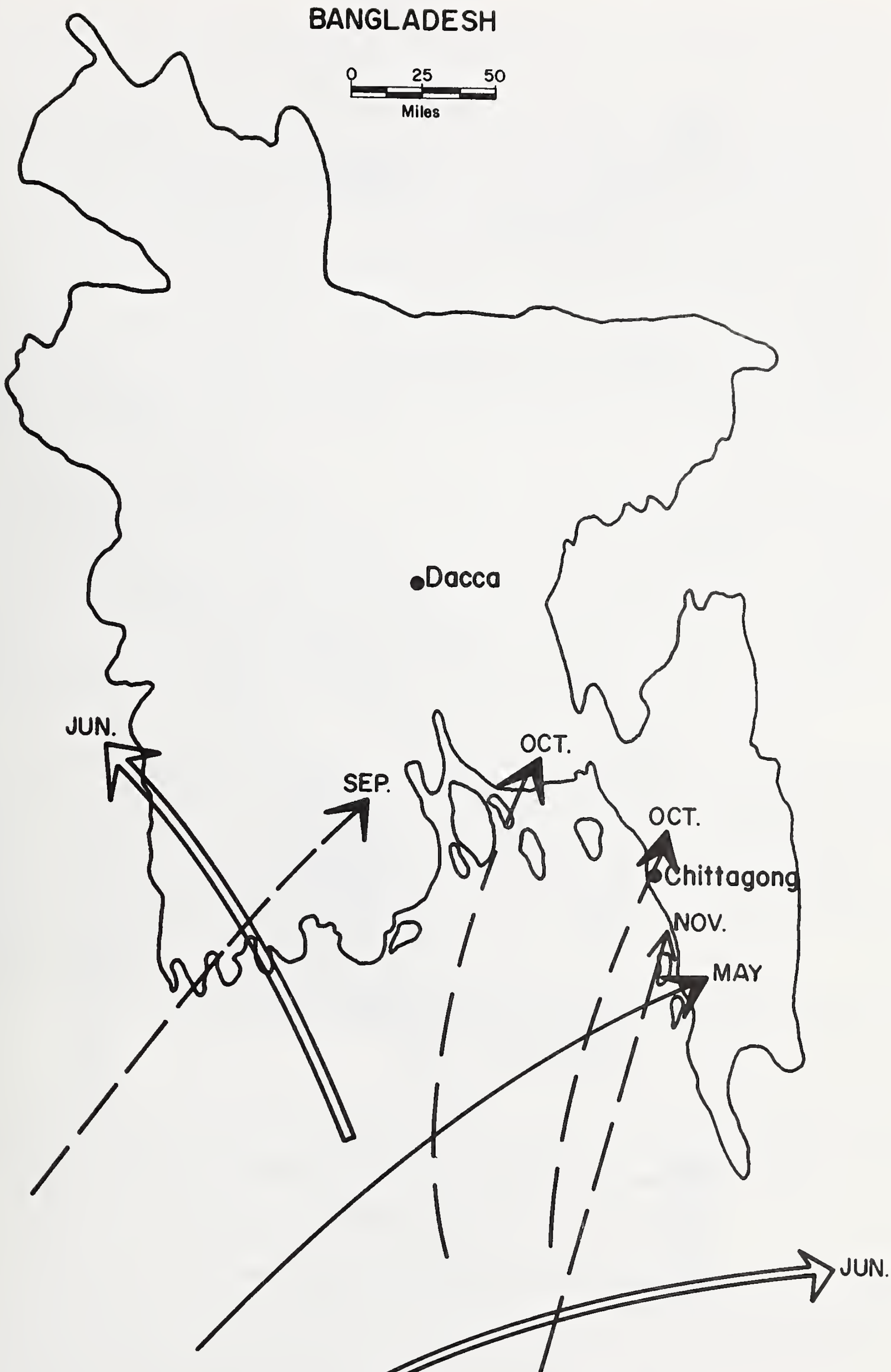


Fig. 8 Storm tracks in the Bay of Bengal Affecting Bangladesh

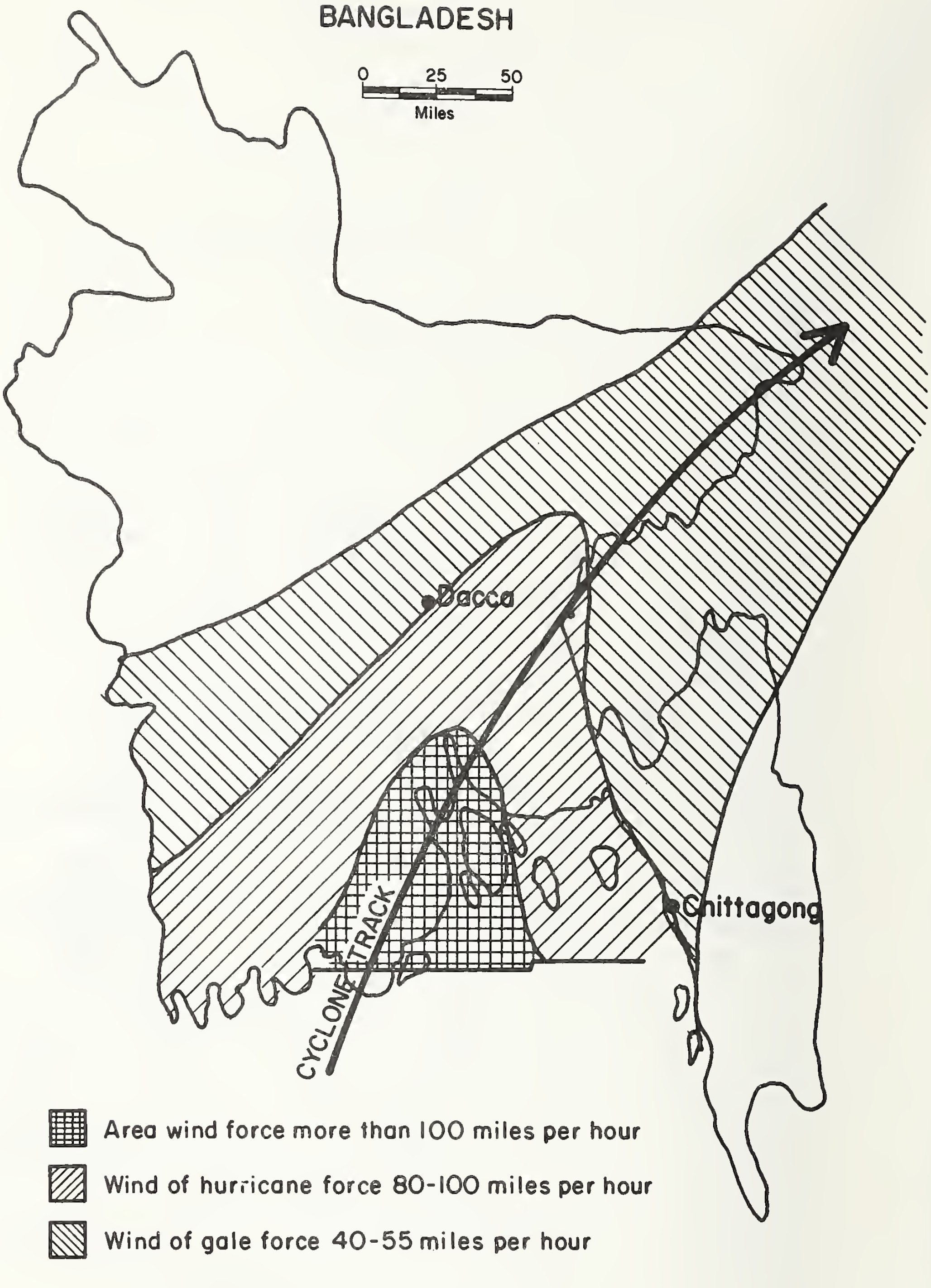


Fig. 9 Typical cyclone in Bangladesh (9th May, 1961)

REMARKS
by
William Woudenberg
CARE, Inc, Dacca, Bangladesh

Good afternoon, ladies and gentlemen. As Dr. Choudhury has mentioned I have been actively involved in housing in Bangladesh. In the past three years we have contributed approximately 15,000 units which are located mostly in the southern area of Bangladesh. Our primary interests are in certain regions in which Dr. Choudhury described as most prone to strong cyclonic conditions that prevail in the area. One thing we found is that as we proceed to other regions, the problem of building masonry houses becomes rather formidable. For that reason then, we have decided to investigate the use of other materials.

I have set up a small shop outside of Dacca where we have experiments with various approaches to this problem. Some of the disciplines involved are the availability of materials. There exists practically no stones in Bangladesh and bricks are very expensive. The supply of wood is becoming increasingly scarse and the price per cubic ft. of wood almost approaches the price of steel. In fact, in recent purchases for wood, we have to get government priority before we could buy.

So for that reason, the only material that we find easily available and we could use is jute which Bangladesh is supplying the world. I decided on a configuration of jute saturated with polyester resin. In 1971, the first four houses were built and we decided that a circular configuration would give the best resistance to violent winds. We developed that in exploring the use of these houses in the villages. The circular configuration proved to be quite unsatisfactory, however, for their social customs. They are primarily Moslems and in the villages the privacy of the women is very important and the circular area made the delineation of the living area quite difficult. For this reason, we changed to a rectangular configuration, although we still hold on to the curved shape which gave so much strength to the first prototype.

I have a few pictures here that describe the different models. This is the second house we built (Fig. 1). This is an example of a one family residence. It is 14 feet in width, 22 feet in length and it costs approximately $300 - with about 50% hard currency and 50% local currency. It is extremely light in weight. It can be transported very easily and it can be floated for ease of transport in river areas. This particular one has already withstood storms that Dr. Choudhury described and it seems that there is no ill effects on them. This particular building, because of its configuration, can lead to a lot of different shapes by adding sectional structures. This unit can be made to any length, in 3 foot increments to accommodate perhaps warehousing, etc.

This slide shows the veranda. Verandas in Bangladesh are extremely important because if a man wants to invite you to his home for tea it is very important to give you the hospitality of the house. He cannot bring you inside because you would invade the privacy of his wife.

We have a large house constructed of segments from the one shown previously (Fig. 1) and it illustrates that this material can accommodate the needs of larger buildings. This house is 33 ft in width, 44 ft in length and 22 ft high and cost approximately $1 per square foot. It can be brought to the site and assembled perhaps within one week at most.

All these materials are manufactured in Bangladesh.

We have a scale model or the building and the specimen or the insulation used. The insulation serves as a filler for the fiber glass and further strengthens the material. It serves as an insulation and its serviceability is very important. It can be used either with a foundation or without a foundation.

One very important thing I forgot to mention is that we hope to be able to deliver one unit to Manila at the early part of next year.

Thank you.

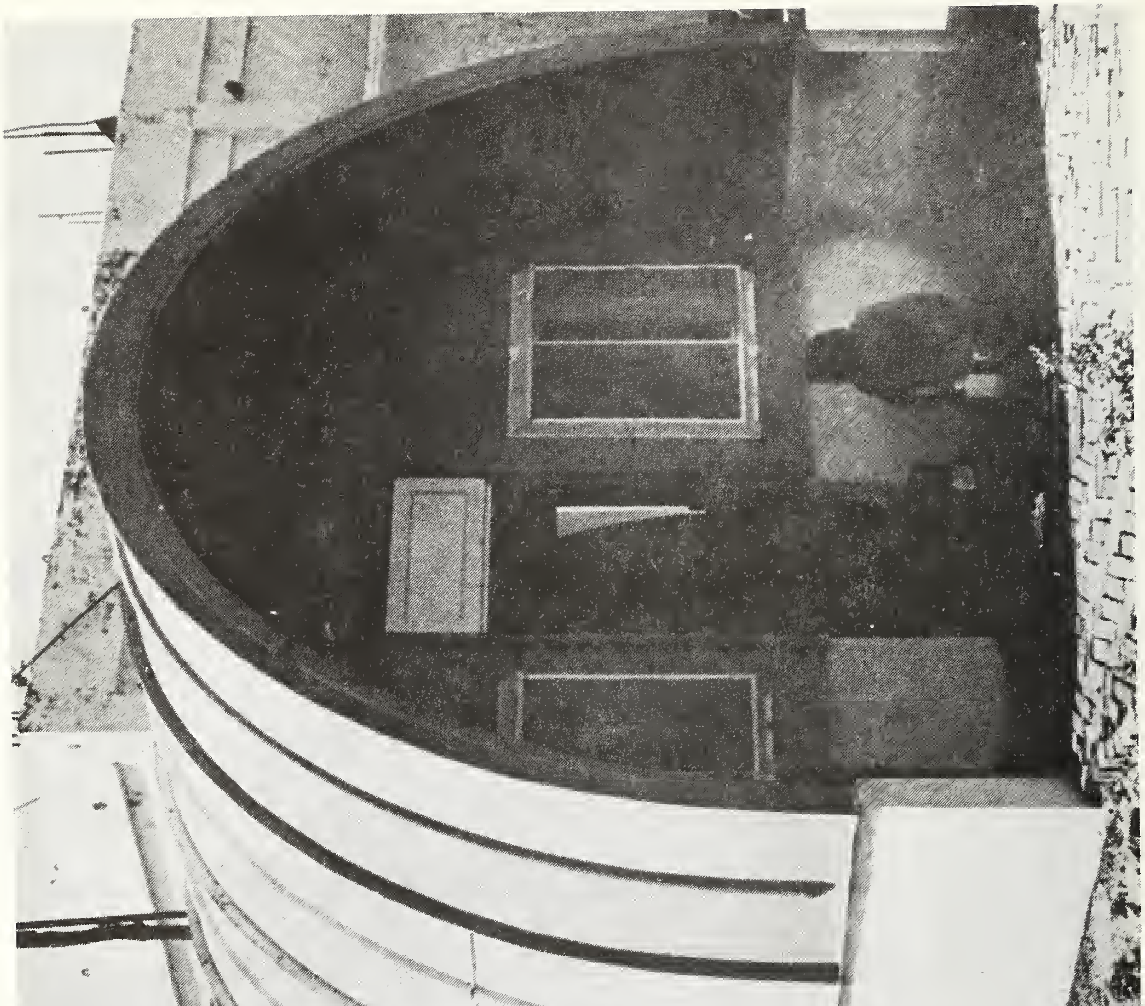


Fig. 1 CARE, Inc's Experimental Low-Cost House

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

by
A. D. Adams
Partner, Douet Brown Adams Associates,
Consulting Engineers, Kingston, Jamaica

1. Scope

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

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

2. Limitations and Assumptions

General

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

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

Data Gaps in Design and Construction

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

Socio-Economic Considerations

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

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

3. Common Low-Cost Housing Systems in Jamaica

A Look at the Past

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

> In the rural areas, most 'early low-cost' houses (say up to the 1930's) were constructed by peasant owners, using techniques described as "wattle and daub" (See Fig. 1). This consisted of

A Look at the Past.

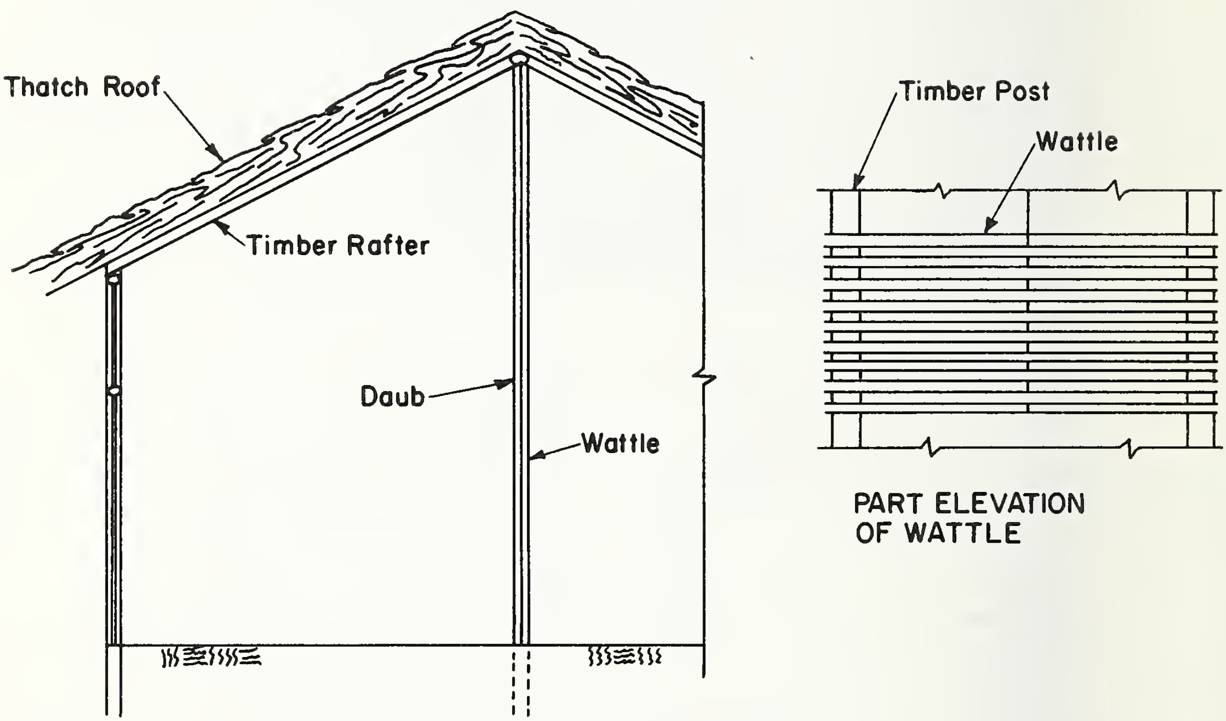


Fig. 1 WATTLE AND DAUB

Early Low-Cost Housing Construction in Jamaica a wooden skeleton frame of posts planted in the ground, tied at eaves level with wooden beams and with sticks interwoven horizontally between the posts, to form the "wattle". This "wattle" was "daubed" both inside and out with mud formed from readily available clay, to create solid walls. Roofs were of pitched wooden framing and battens. The roof covering was generally formed of 'thatch', made from bundles of dried leaves of certain plants, tied in place.

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

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

Hollow-Concrete Masonry Construction (See Fig. 4)

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

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

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

Large Panel Precast Concrete Systems (See Fig. 5)

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

In the most common local system of this type, wall and roof panels are lifted and assembled by crane and connected by welding at matching steel inserts. Overall thicknesses of wall units vary from 3" to 6" but ribbed panels are often used for the thicker units with rectangular panel thicknesses of as little as 1 1/2" between ribs.

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

Small Unit Precast Concrete Systems (See Fig. 6)

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

Timber Systems (See Fig. 7)

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

A Look at the Past

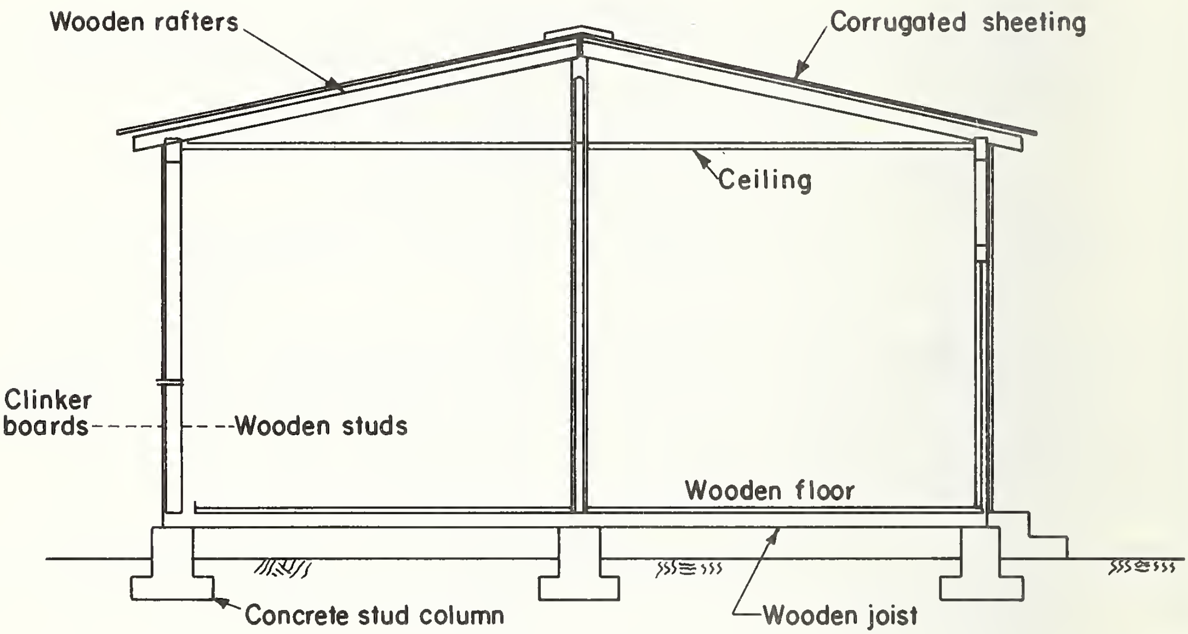


Fig. 2 TIMBER STUD AND BOARDING

Early Low Cost Housing Construction in Jamaica.

A Look at the Past

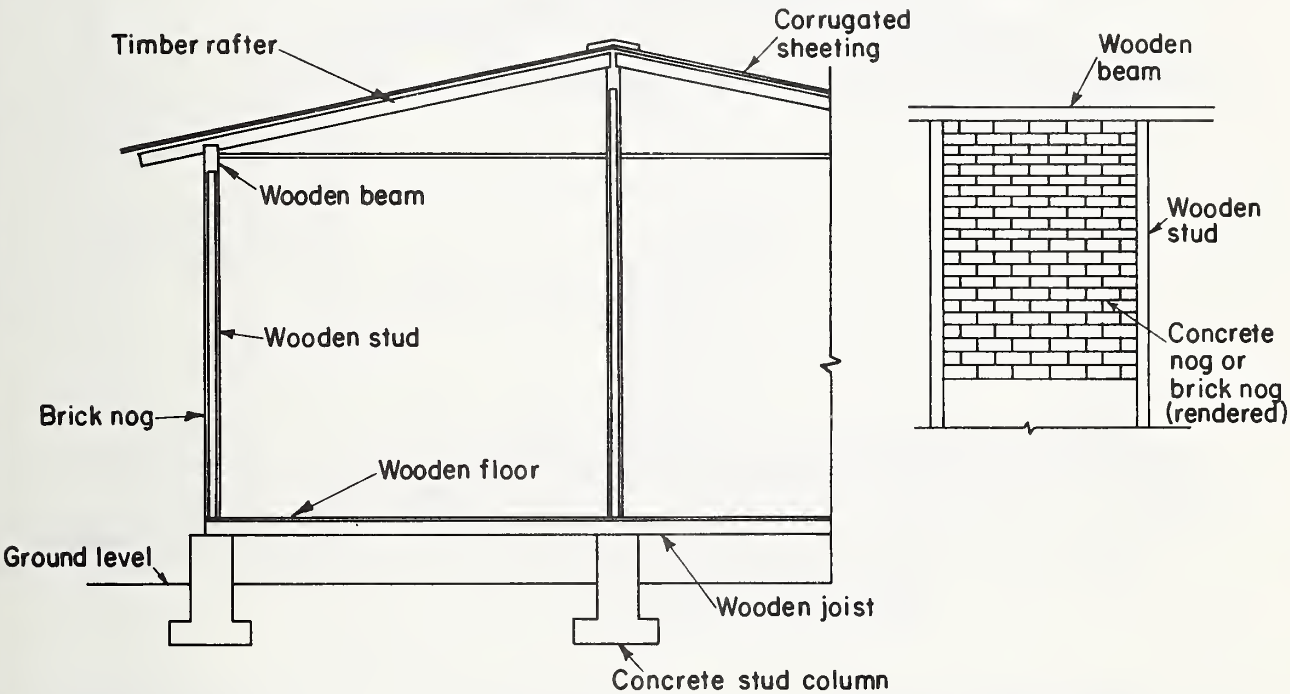
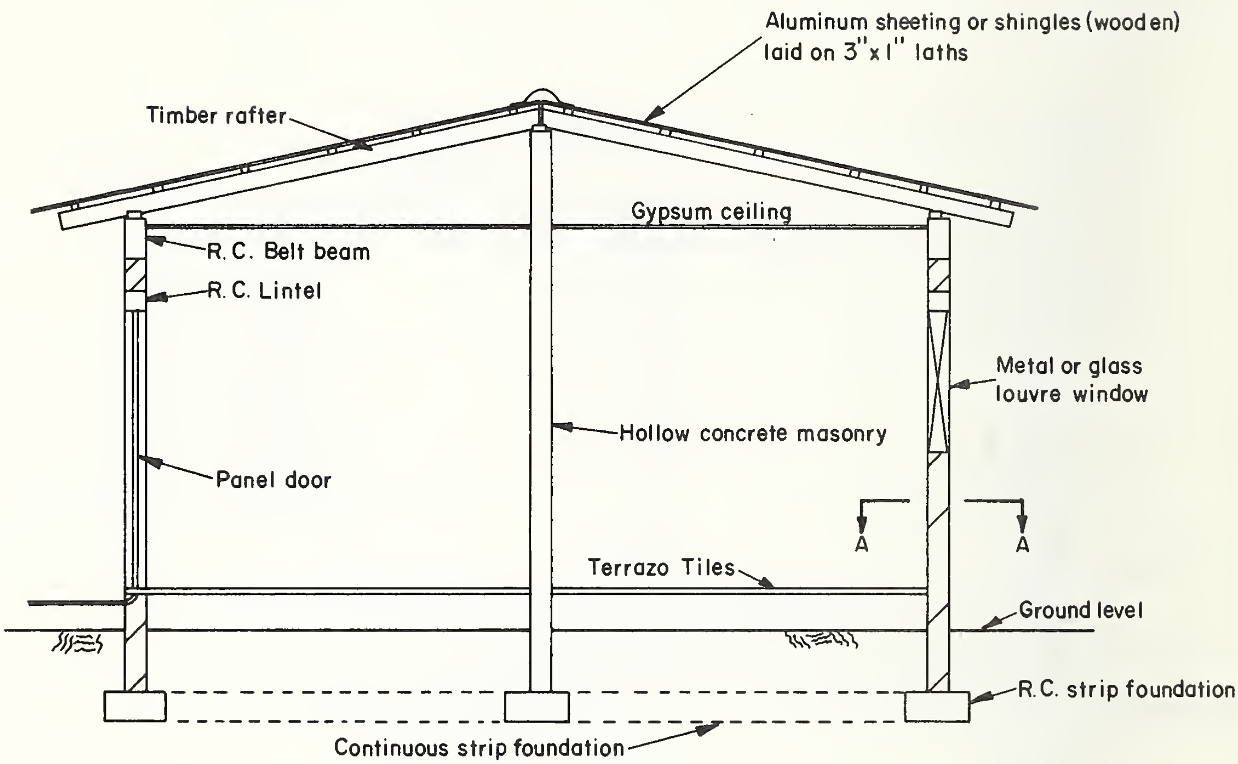
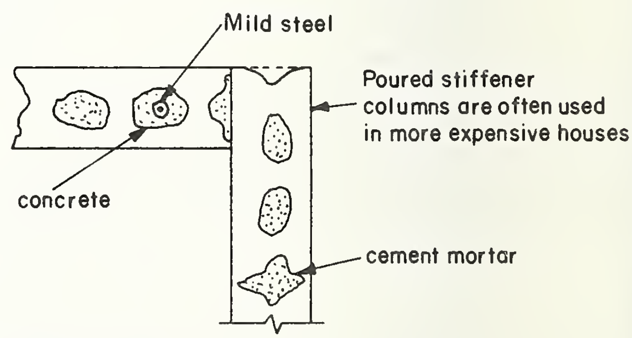


Fig. 3 BRICK NOG AND CONCRETE NOG

EARLY LOW COST HOUSING
CONSTRUCTION IN JAMAICA

Hollow-Concrete Masonry Construction





PART SECTION A-A

Fig. 4 Hollow Concrete Masonry Construction

The most common construction method in Jamaica

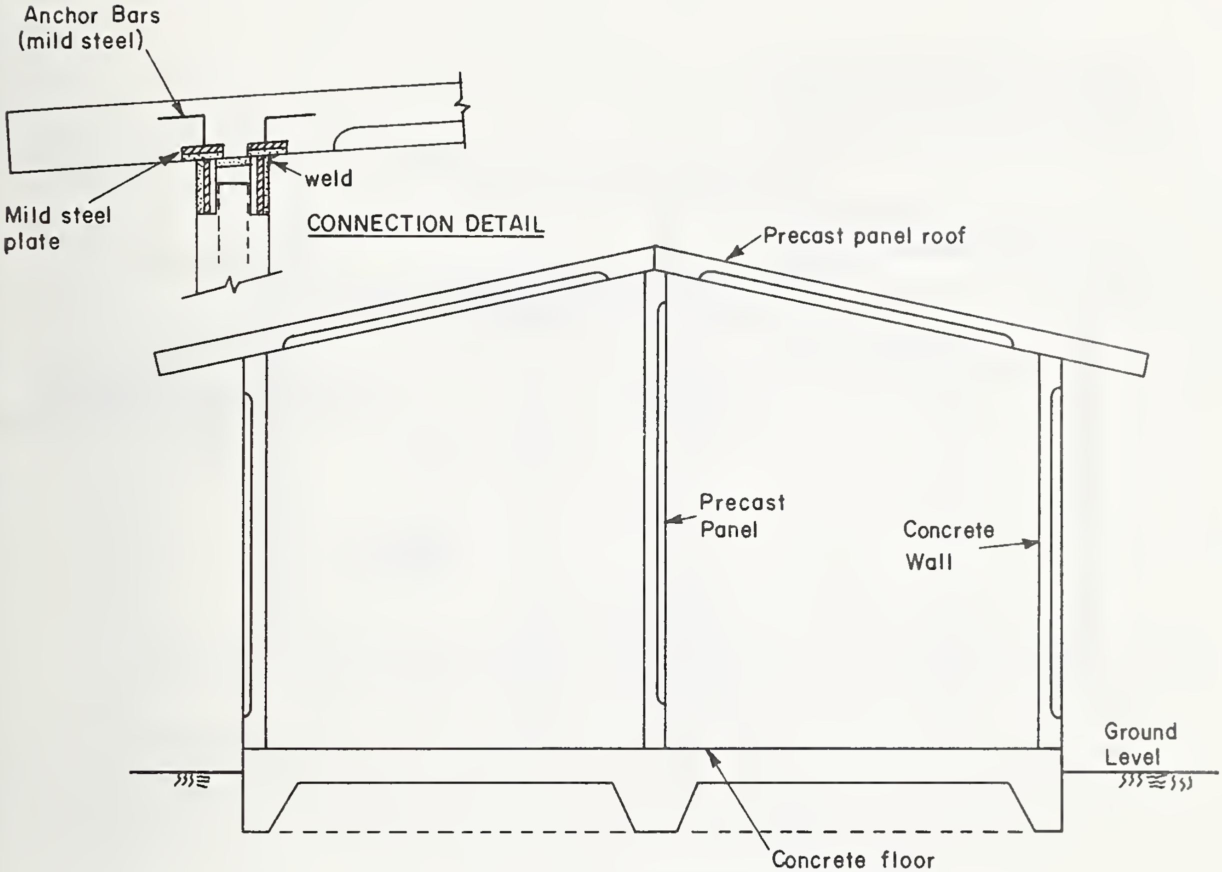


Fig. 5 LARGE PANEL PRECAST CONCRETE SYSTEM

The most established, fully prefabricated Housing System in Jamaica.

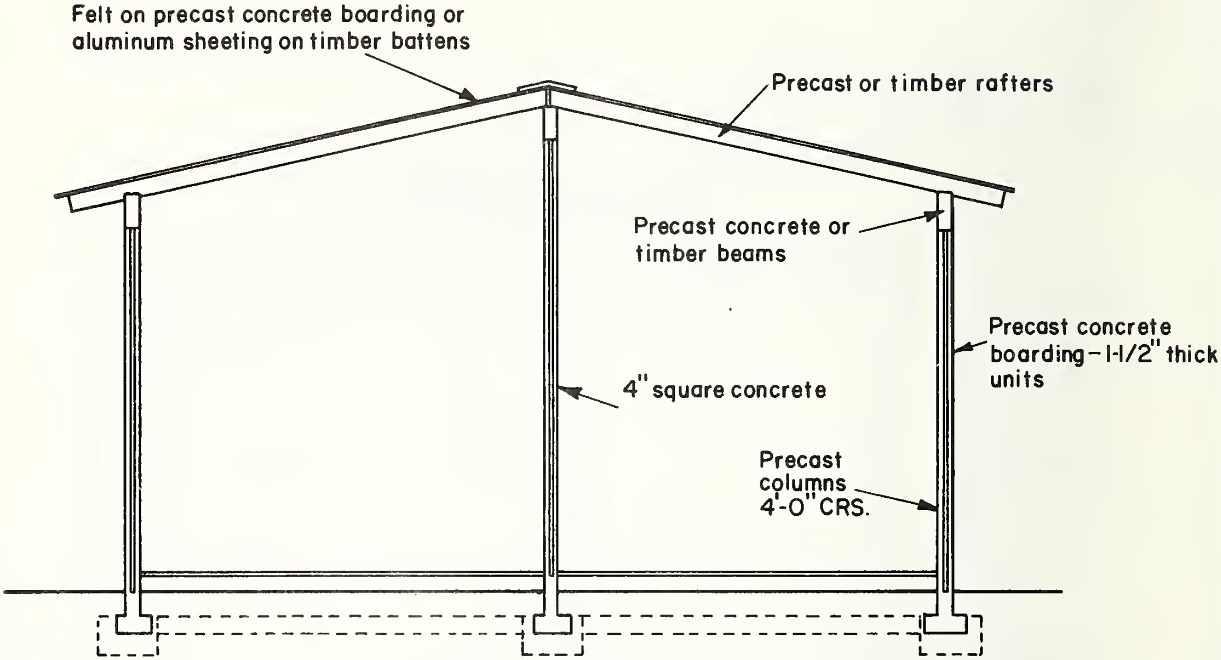


Fig. 6 SMALL UNIT PRECAST CONCRETE SYSTEM

NOTE

Government Owner occupier
Scheme Uses Timber Beams and Rafters.

Roofing are generally of timber framing with aluminum sheeting. In some cases, precast concrete joists and "boarding" are utilized with felt waterproofing.

Timber Systems

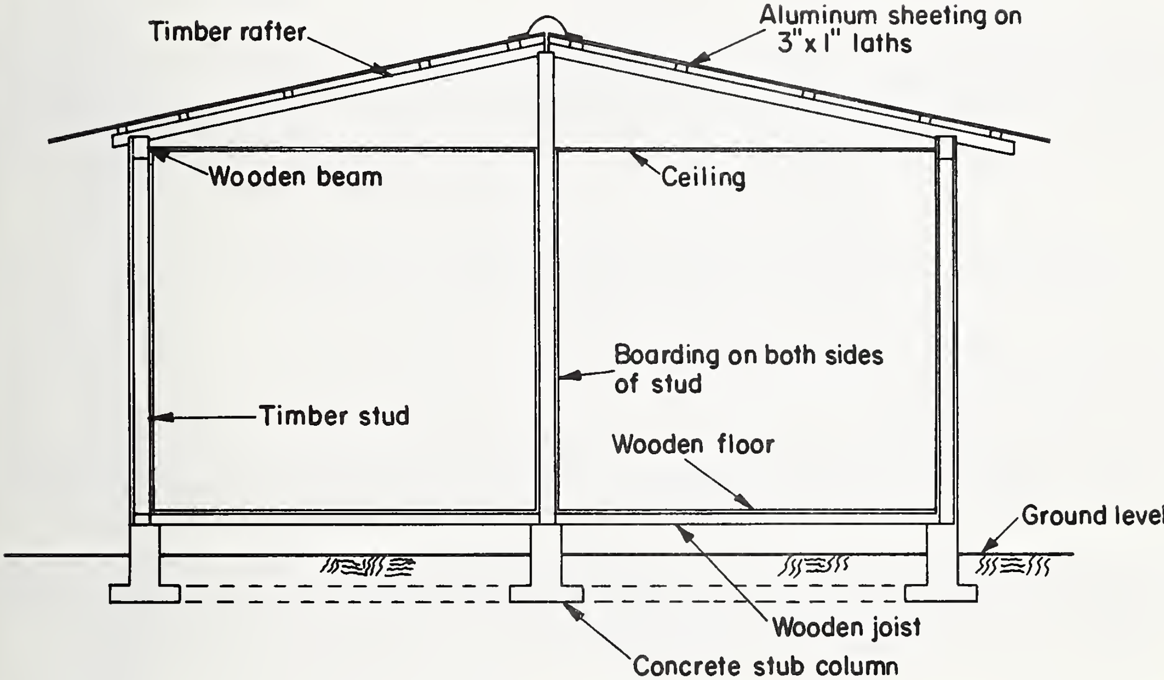


Fig. 7 TIMBER SYSTEM

STUD AND LAPPED BOARDED WALLS

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

Other Lightweight Systems

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

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

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

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

Other Low-Rise Buildings

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

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

4. Problems and Data Gaps in Design and Construction of Low-Cost Housing

Local Building Regulations

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

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

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

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

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

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

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

Structural Systems

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

Hollow-Concrete Block Masonry

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

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

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

Large Panel Precast Concrete Systems

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

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

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

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

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

Small Unit Precast Systems

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

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

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

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

Timber Systems

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

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

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

Other Lightweight Systems

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

(1) Dense surfaces

(2) Termite and rot resistance

(3) High Water repellence

(4) High screw and nail holding properties.

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

General Comments on Lightweight Roofing

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

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

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

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

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

5. Socio-Economic Considerations in Design

Definition of Low-Cost Housing

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

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

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

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

Corresponding Income Group for Low-Cost Housing

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

Annual Figures for Construction of Low-Cost Units

In the following table is some figures for low-cost housing units completed by the Ministry of Housing[5] or under Government Mortgage Insurance Scheme.

SOCIO-ECONOMIC CONSIDERATIONS IN DESIGN CONTD.

Annual Figures for Construction of Low-Cost Units

TABLE 1

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

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

Housing-Purchase Preferences in Construction Materials

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

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

6. Discussion of Extreme-Wind-Related Problems

General

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

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

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

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

Summary

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

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

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

(c) Large Panel Precast Concrete Systems:

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

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

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

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

(e) Other Lightweight Systems:

   (i) Durability

   (ii) Strength and stiffness

   (iii) Weather Resistance

   (iv) Fire Resistance

(f) Light Roofing Systems

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

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

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WIND PRESSURE PROVISIONS
OF THE NATIONAL BUILDING CODE
REPUBLIC OF THE PHILIPPINES

by
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President, Philippine Standards Association,
Consulting-Structural Engineer, Quezon City, Philippines

SYNOPSIS

The Philippines lies in an area subjected frequently to typhoons, the most severe ones usually occurring during the months of October and November. The tremendous losses of life and property due to three successive typhoons in 1970 prompted the Philippine Government to review existing regulations and formulate new ones to avoid repetition in future typhoons. The help of relevant International Institutions with facilities and expertise like UNESCO was sought by the government, so as to produce a National Building Code incorporating the best practice in design and construction of buildings and structures to withstand WIND FORCES.

1. Introduction

It was an invisible, violent lady named "YOLING" that broke her temper on November 19, 1970 and blew up the roofs of many of our low buildings, residences, schools and industrial plants, broke the window glazings and vision panels, toppled power transmission and telephone poles, television towers and signboards, disrupting communications and causing blackouts.

For more than half a century, we were contented and felt safe using the WIND PROVISIONS of the Building Ordinances of the City of Manila specifying the use of 30 pounds per square foot pressure, on a vertical plane surface for all structures, regardless of their geometrical forms, locations, ground topography and presence of vegetation and man-made improvements. But in 1970, the Philippines was the victim of three Typhoon musketeers of death:

SENING on the middle of October wrought havoc over the Bicol Area; TITANG on the last week of October smothered Mindanao and the West Visayas; YOLING hit the Greater Manila Area in November. It seemed like a well-planned military strategic attack. Add all the losses and deaths caused by these typhoons to that of the Earthquakes of April 7, 1970, and that of August 2, 1968, and you have more than One Billion Pesos worth of property. Something must be done to minimize the tremendous loss of property and human lives. One of the avenues is to review our Building Regulations and relevant aspects of direction and control.

2. Building Code Background

The oldest Building Ordinance to cover the consideration of Wind in the design of structures is that of the City of Manila which dates back to the early years of the twentieth century during the American occupation of the islands. This has been followed in other cities and the same one followed by the Bureau of Public Works.

The Code required the use of 30 pounds per square foot of wind pressure against a vertical plane surface of the structure. On inclined surfaces, the Duchemin'a Formula was the only guide which is obsolete today.

Then on November 11, 1950, pursuant to Executive Order No. 367 of the President of the Philippines, a Building Code Committee was created to prepare a "Basic Building Code" under the National Planning Commission. The Committee was composed of ranking Engineers and Architects in both the public and private sector. The final draft was sent to Malacanang for approval in 1954, but it died a natural death. However, the Code Provisions was an improvement over that of the City of Manila.

The pertinent provisions on WIND LOADS are quoted hereunder:

"Sec. 209 (c). The Wind Pressure on vertical plane surfaces shall be taken at not less than 20 pounds per square foot for the portions less than forty (40) feet above the ground and at 30 pounds per square foot for portions more than forty (40) feet above ground."

"Sec. 209 (e). Where it shall appear that an isolated building or structure may be exposed to the full force of the wind throughout its entire height and width, the pressure upon the vertical surfaces thus exposed shall be taken at not less than thirty (30) pounds per square foot."

"Sec. 209 (g). On roofs having a rise more than four (4) inches per foot of run the wind pressure normal to the surface be taken as two (2) pounds per square foot for each inch of rise on one foot when the rise exceeds twelve (12) inches per foot."

Note that nothing is mentioned about negative pressure or better understood as SUCTION, so that it is also obsolete as of now.

3. <u>The Present National Building Code</u>

Time passes on bringing with it not only changes in science and technology but also calamities and disasters that result in human misery. The August 2, 1968 Earthquake, which caused the collapse of the Ruby Tower killing more than 322 persons, injuring more than 300, and damaged more than 30 buildings, triggered the formulation of the New National Building Code through the initiative of Senators Gil J. Puyat and Helena Z. Benitez. Thirty (30) representatives of Architectural and Engineering professions, City Engineers and Fire Chiefs of the Metropolitan Manila area sat in continuing workshops to produce the National Building Code. The result is R.A. No. 6542 which establishes the purposes of the Code and the creation of a joint Building and Environmental Planning and Standards Commission to supervise the implementation.

The WIND PRESSURE provisions were formulated by making reference to the Uniform Building Code, 1967, of the U.S.A., American Society of Civil Engineers Transactions, the ALJ Structural Standards of Japan, and the Building Code of Switzerland, all of which are supposed to embody the results of the latest scientific researches and studies.

The astounding losses due to the Typhoons SENING, TITANG and YOLING, all within a period of less than two months in 1970 moved the Philippine Government to request the UNITED NATIONS EDUCATION, SCIENTIFIC AND CULTURAL ORGANIZATION (UNESCO) to send a team "to study at first-hand the nature and extent of the damage caused, in consultation with the authorities, to formulate recommendations for action designed to prevent or reduce damage to buildings and structures in the event of the future typhoons".

Accordingly, Messrs. S. Mackly, C. Finney and T. Okubo were commissioned as a team which arrived on December 1, 1970. They spent two (2) weeks for the survey and investigations with the help and guidance of our local government officials. Their report was submitted on May, 1971.

For the benefit of those who do not have access to this report, a concise excerpt of the relevant observations are given below:

"5.3 LOW-RISE DOMESTIC BUILDINGS - small houses of one or two-stories

a) Poor attention to structural and roofing details to resist wind effects, not necessarily the effect of higher velocities.

b) False economy in construction.

c) Low-pitched roofs, cantilevered to a considerable degree beyond the exterior walls to form large awnings."

"5.5 PRE-FABRICATED BUILDINGS - School Houses

The Marcos Type 1 (Post 1969) with Z-Section columns and rafters, and channel purlins as well as the Marcos Type 2 (Pre 1969) with double steel channel columns, channel rafters and purlins were damaged due to "the inadequacy of lateral bracing to withstand the racking action of wind - - - - - inadequate anchorage of the portal-frame column based into the supporting piers or footings with poor quality concrete - - - -. As a result, under the lateral wind forces, the end-portal unsupported and severely distorted portion of the roof structure resulting in longitudinal racking of the building as a whole and buckling of several portal legs along its length.

In a case of the ARMY Type (3) and (4) the nature and the amount of damage was erratic in character and depended very much on the quality of workmanship displayed in the construction - - - - . What should be inferred is that good building construction results from a combination of adequate design and good-quality workmanship."

"5.7 DAMAGE TO ROOFS

In the Philippines, the vast majority of the buildings are built with roofs having very flat slopes, with the result that the full roof area is exposed to negative pressure or suction. In view of the type and quality of roof construction generally used (light-gauge galvanized corrugated-metal sheeting, corrugated asbestos or aluminum alloy sheeting) fastened to either timber or steel purlins which are supported in turn, on timber or steel rafters, this leaves them particularly vulnerable to damages from wind attack."

"6. GENERAL CONCLUSIONS AND RECOMMENDATIONS

"6.4 EDUCATION AND TRAINING

(1) UNESCO, in collaboration with the Government of the Philippines should sponsor a National Seminar on "Design of Buildings and Structures to resist Typhoon Winds" to be held in Manila at an early date. Such seminar should be essentially practical in its outlook and should cater for the building as a whole, embracing architects, structural engineers, building inspectors, meteorologists and building contractors. Topics for discussion might include:

a) nature and characteristics of natural wind;

b) its effect on buildings and structures;

c) selection of suitable design criteria;

d) exposure factors and local sheltering effects;

e) likely damage patterns in relation to specific types of buildings and structures;

f) structural design and detailing to avoid such damage;

g) relative costs of improving design and detailing of buildings to resist wind damage; and

h) design of glazing to resist wind forces."

Acting on the above UNESCO Teams' recommendations, the UNESCO National Commission of the Philippines organized a Regional Seminar sponsored by the UNESCO Field Science Office for South East Asia in cooperation with the World Meteorological Organization.

4. Regional Seminar on "Wind Effects on Buildings and Structures"

In this Seminar, I presented a paper on "Design Methods for Wind Effects on Buildings and Structures" wherein I presented the following causes of failures as a result of my personal occular inspection of failures of various types of structures:

1. Inadequate Structural Design of members, splices, joints and anchorage.

2. Poor quality or substitution of materials.

3. Poor construction methods.

4. Lack of supervision.

5. Lack of periodic inspection and maintenance.

Lack of properly designed details for splices, joints and connections leaving the supposedly "simply" job to the Fieldman resulted in miserable failures. Substitution of rolled steel sections with built-up members with poor welding and inaccurate alignments and warping caused collapse of towers and signboards in addition to inadequate horizontal and diagonal members to resist torsion. Use of inferior grade and defective lumber as well as anchorage details without the proper analytical designs caused failure and collapse of roof trusses. Lack of supervision was revealed by uprooted members exposing crude anchorages or excessive sagging. Lack of maintenance and periodic inspection resulted in deteriorated members due to weathering. Billboards over roofs when these were not considered in the original designs caused overloads - a fault of the Owners for allowing dealers to advertise their products without the necessary professional design and responsibility to save on the expense.

Revision of the National Structural Building Code

The National Building Code was revised in its presentation by separating the Engineering Sections as a separate Volume entitled "The National Structural Code for Buildings" to which the National Building Code makes reference. In this manner, the design criteria and methods of design can be revised periodically as may be required by advances or developments of science and technology without going through the grind of legislative processes. This was made possible by the joint action of the Association of Structural Engineers of the Philippines (ASEP) and the Philippine Association of Civil Engineers (PACE).

The impact of Typhoon YOLING on its effects on various structures led to the revision of the UNIT PRESSURES due to WIND by increasing the values by 50 kilograms per square meter or 10 pounds per square foot in all areas under ZONES I, II & III.

The various Professionals who formulated the National Building Code are open-minded and receptive to valid proposals for a more realistic code justified by scientific study and research. What we have now represents our best thinking and judgment. A Building Code to serve its purpose must be dynamic.

The "National Structural Code for Buildings" was approved on June 23, 1972, while the "National Building Code of the Philippines" was enacted without Executive Signature on August 26, 1972. The Presidential Decree No. 1081 Declaring Martial Law on September 21, 1972 has affected its proper implementation.

Included herewith is a Copy of the WIND PRESSURE provisions of the National Structural Code for Buildings as approved on June 23, 1972.

Finally, let us all cooperate to bring out the best results in this Seminar where preparations were made within a short time. We look forward to a continuing session after more data are secured and analyzed and reduced to actual applications in design and construction.

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NATIONAL STRUCTURAL CODE OF THE PHILIPPINES
WIND PRESSURE

APPROVED August 26, 1972

Section 2.06 : Wind Pressure

(a) General. Buildings or structures shall be designed to withstand the minimum horizontal and uplift pressures set forth in Fig. No. 2.06-C to E and this Section allowing for wind from any direction. The wind pressure set forth in Fig. No. 2.06-C to E are minimum values and shall be adjusted by the Building Officials for areas subjected to higher wind pressures. When the form factor, as determined by wind tunnel tests or other recognized methods, indicates vertical or horizontal loads of lesser or greater severity than those produced by the loads herein specified, the structure may be designed accordingly.

(b) Horizontal Wind Pressure. For purposes of design, the wind pressure shall be taken upon the gross area of the vertical projection of that portion of the building or structure measured above the average level of the adjoining ground.

(c) Uplift Wind Pressure. Roofs of all enclosed buildings shall be designed and constructed to withstand pressures acting upward normal to the surface equal to three-fourths of the values set forth in the calculations below Fig. No. 2.06-E for the height zone under consideration. An enclosed building shall be defined as a building enclosed at the perimeter with solid exterior walls. Openings are permitted in the solid exterior wall provided they are glazed or protected with door assemblies. Roofs of unenclosed buildings, roof overhangs, architectural projections, eaves, canopies, cornices, marques, or similar structures unenclosed on one or more sides shall be designed and constructed to withstand upward pressures equal to one and one-fourth times those values set forth in the Tabulations below Fig. No. 2.06-B.

The upward pressures shall be assumed to act over the entire roof area.

(d) Anchorage Requirements. Adequate anchorage of the roof to walls and columns, and of walls and columns to the foundations to resist overturning, uplift, and sliding, shall be provided in all cases.

(e) Moment of Stability. The overturning moment calculated from the wind pressure shall in no case exceed two-thirds of the dead load resisting moment. The wieght of earth superimposed over footings may be used to calculate the dead load resisting moment.

(f) Combined Wind and Live Loads. For the purpose of determining stresses all vertical design loads except the roof live load and crane loads shall be considered as acting simultaneously with the wind pressure.

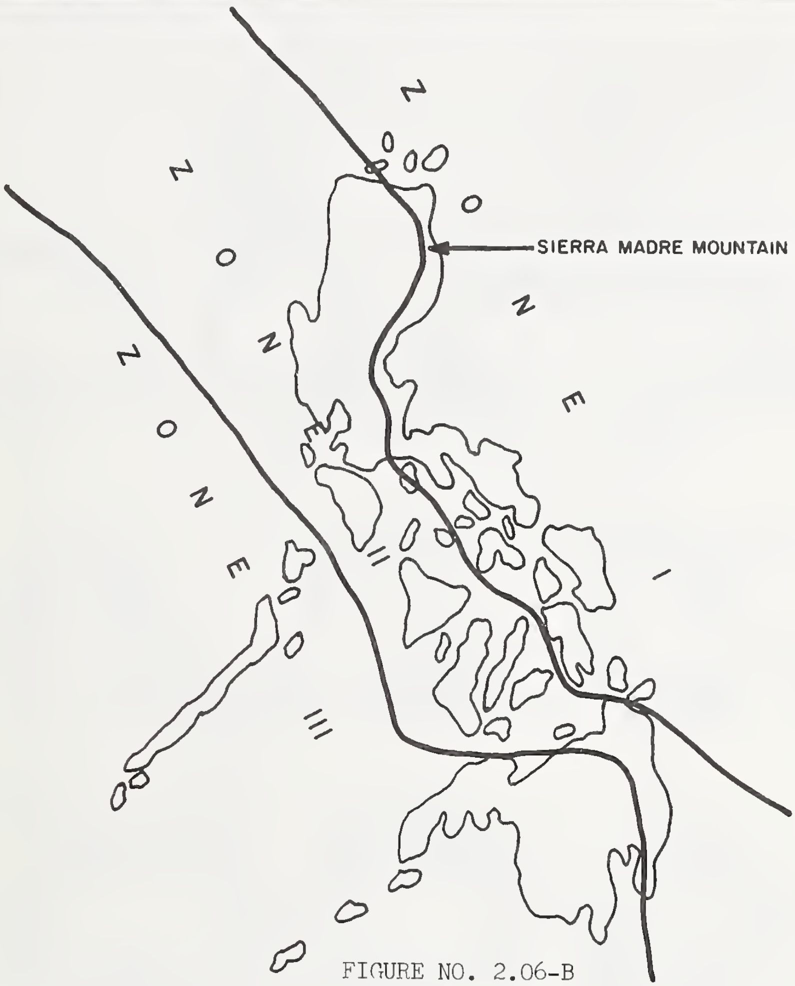


FIGURE NO. 2.06-B

ZONE I

V= 200 KPH= 125 MPH
p= 300 ksm= 60 psf, h above 100'
p= 250 ksm= 50 psf, h 30' to 100'
p= 200 ksm= 40 psf, h 0' to 30'

ZONE II

V= 175 KPH= 108' MPH
p= 250 ksm= 50 psf, h above 100'
p= 200 ksm= 40 psf, h 30' to 100'
p= 150 ksm= 30 psf, h 0' to 30'

ZONE III

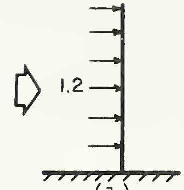
V= 153 KPH= 96 MPH
p= 200 ksm= 40 psf, h above 100'
p= 150 ksm= 30 psf, h 30' to 100'
p= 100 ksm= 20 psf, h 0' to 30'

LEGEND:

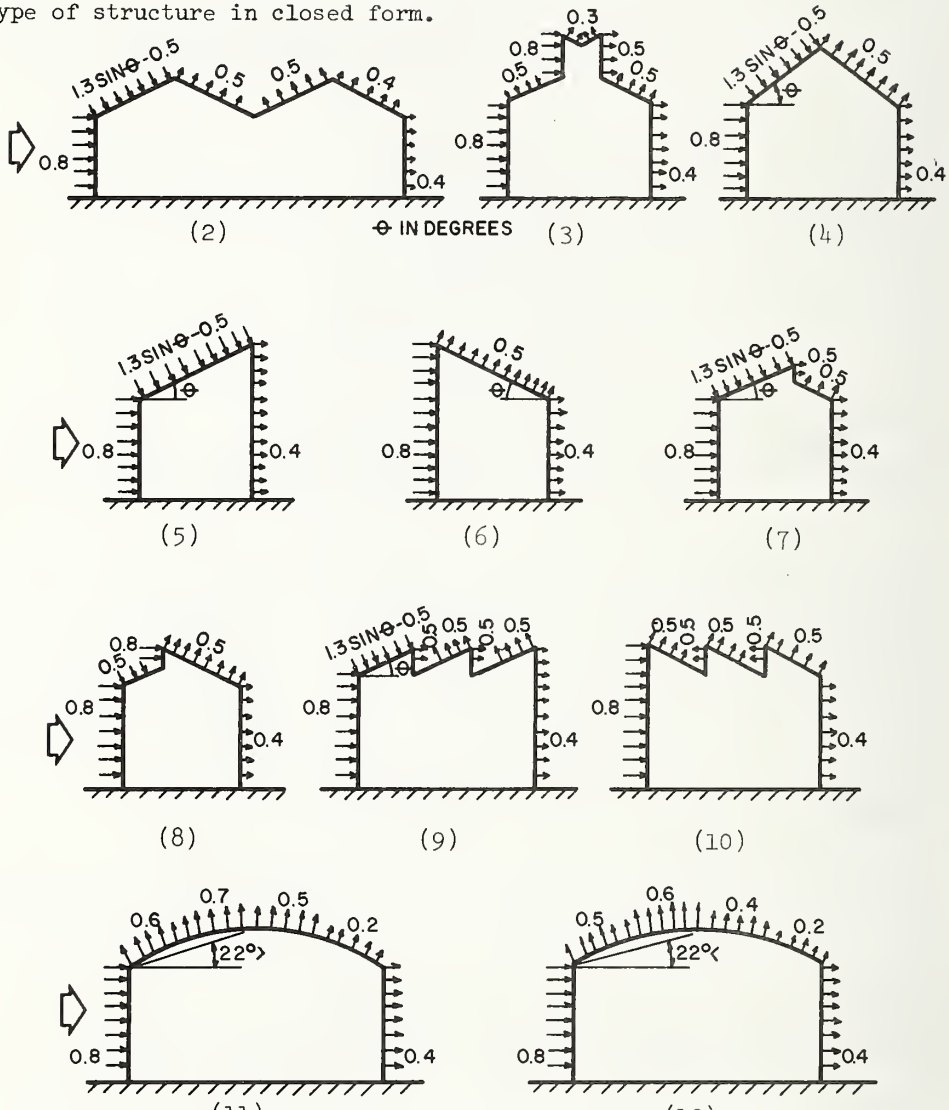
KPH= Kilometers per Hour
MPH= Miles per Hour
ksm= Kilograms per Square Meter
psf= Pounds per Square Foot

RECOMMENDED WIND PRESSURE PER SQUARE METER OR PER SQUARE FOOT OF VERTICAL PROJECTIONS

Vertical plane surfaces



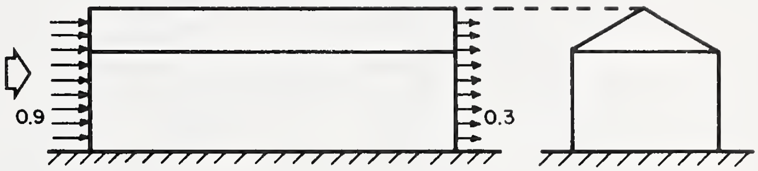
Type of structure in closed form.



In case the roof surface forms an arc, changes in pressure may be assumed at the quarter points of the arc.

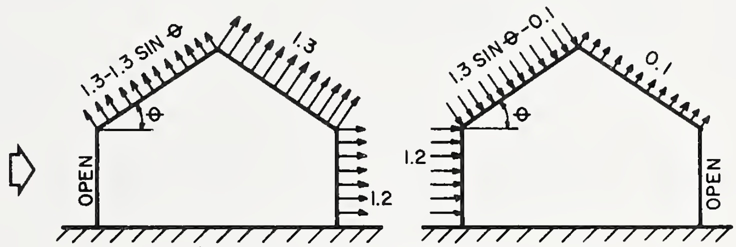
Fig. No. 2.06-C

In case of wind in direction
of side wall girders.



(13)

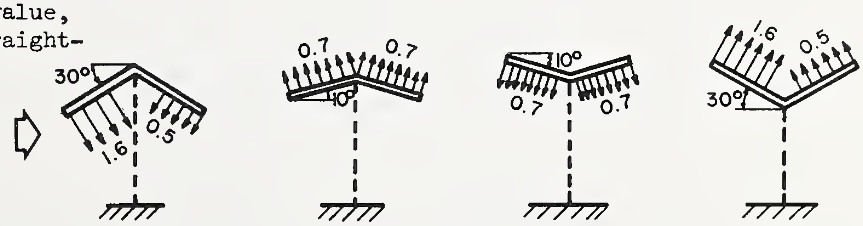
Type of structure
in open form.



(14) (15)

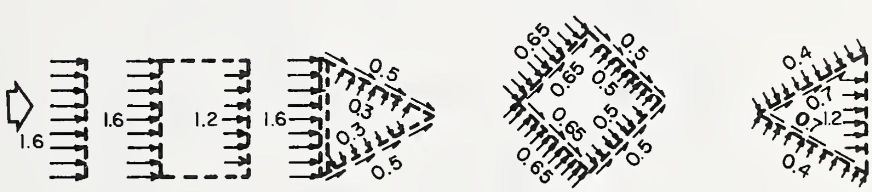
In case slope of roof
has intermediate value,
interpolate by straight-
line method.

Self-supporting
shed



(16) (17) (18) (19)

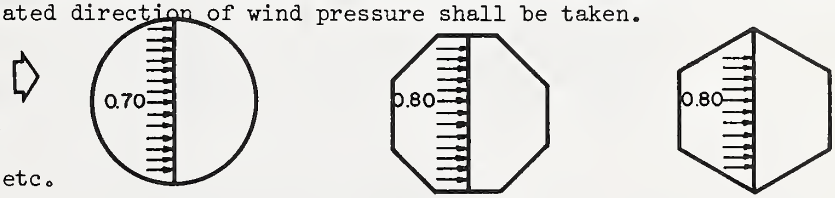
Lattice
structures.



(20) (21) (22) (23) (24)

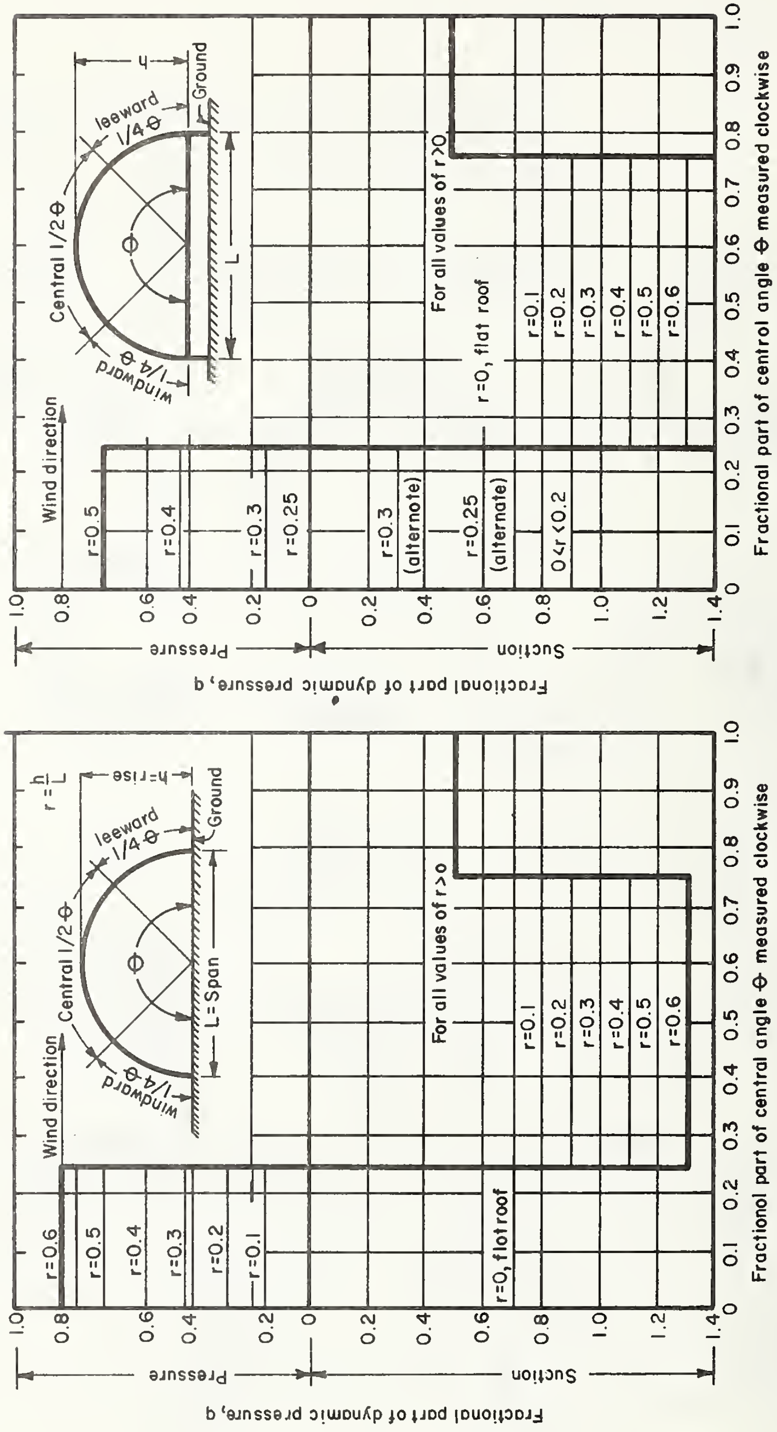
The above figures indicate cross-section of latticed beams and columns. For area acted on by wind pressure, the projected area of the latticed member on the plane normal to the indicated direction of wind pressure shall be taken.

Circular, Polygonal
structures such as
Chimney, Gas Tank, etc.



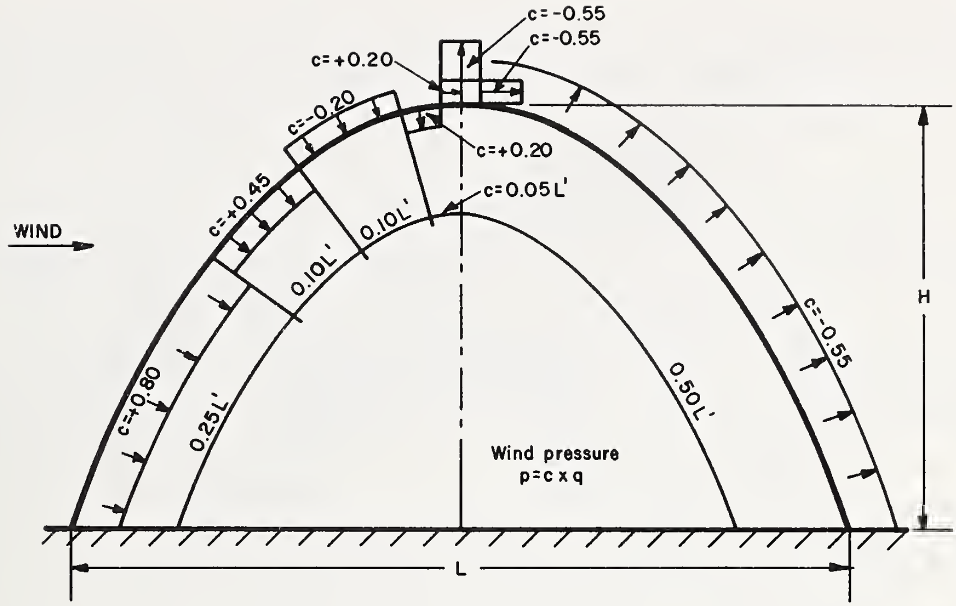
Circular (25) Octagonal (26) Hexagonal (27)

Fig. No. 2.06-D



Wind direction
windward 1/4 Φ
Central 1/2 Φ
leeward 1/4 Φ
Ground
h
L
r=0.5
r=0.4
r=0.3
r=0.25
r=0.3 (alternate)
r=0.25 (alternate)
0<r<0.2
r=0, flat roof
For all values of r>0
r=0.1
r=0.2
r=0.3
r=0.4
r=0.5
r=0.6
Pressure
Suction
Fractional part of dynamic pressure, q
Fractional part of central angle Φ measured clockwise
r = h/L
h=rise
L=Span
r=0.6
r=0.5
r=0.4
r=0.3
r=0.2
r=0.1
r=0, flat roof
For all values of r>0

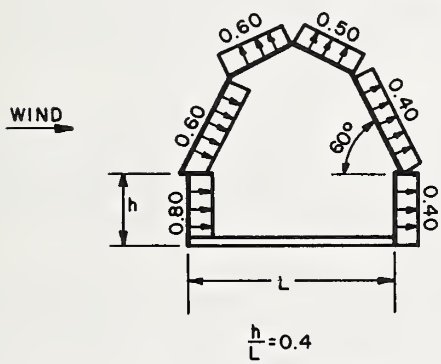
Fig. 2.06-E



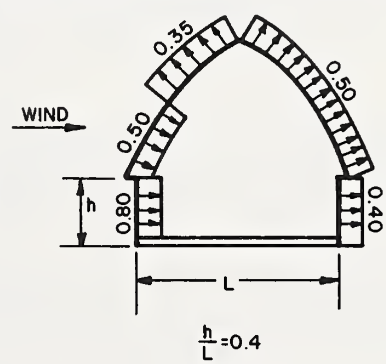
L = Length of Arch Rib

Wind Load Distribution which may be used for Parabolic Arch Ribs of $\frac{H}{b}$ Approximately 0.55

MULTIPLE GABLE ROOF BUILDING



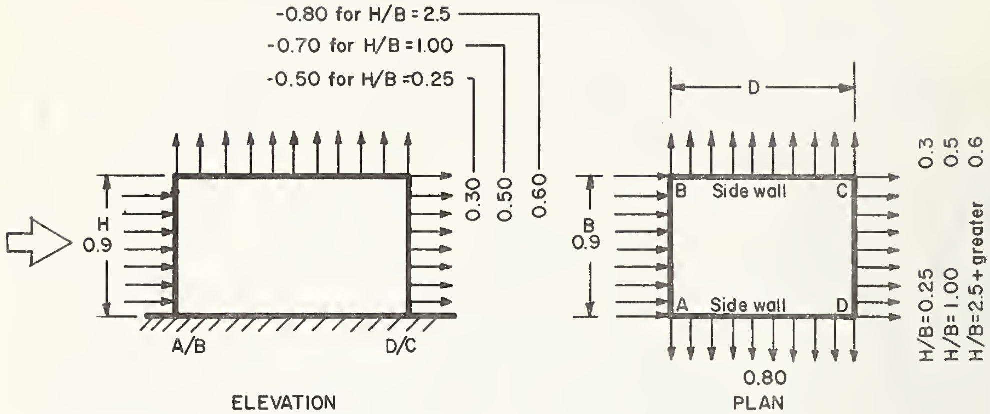
GAMBREL ROOF



GOTHIC ROOF

Fig. 2.06-F

RECTANGULAR PLAN WITH FLAT ROOF



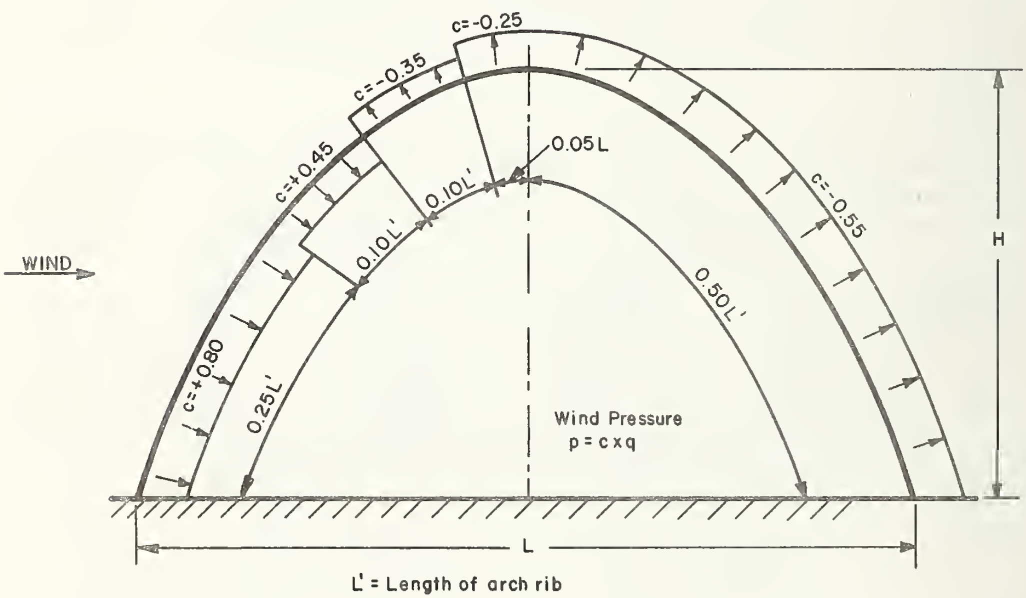


Fig. 2.06-G

Standardization in the Philippines Today
by
Ambrosio R. Flores*

Standardization of industrial products and consumer goods in the Philippines today is way behind other developed countries, like U.S., Japan and Germany. As a developing country, we still lean on them for guidance. The tremendous challenge to us, scientists and technocrats, is serious, yet how often do we hear someone say that we have one of the highest proportion of professionals per capita and that we are one of the heaviest exporters of Engineers of various disciplines, Doctors and Nurses to other countries?

There is a gap somewhere between the government institutions and the relevant private institutions as regards Standardization. Unless such link is furnished by government initiative and thereafter implemented with adequate organization and logistics, our present situation will continue to move with turtle speed.

For the proper understanding of everyone, Standardization, in general, is the act of setting up certain standards, specifications, or regulations covering dimensions, weights, proportions or compositions, characteristics or qualities to serve as models or criteria for evaluation to achieve uniformity and quality within tolerable limits of variation in raw materials or finished goods.

As early as 1901, the Bureau of Science was established and served as a states symbol in the Far East. In the same year, Great Britain started to move towards Standardization, being the first industrialized nation in the world, but it was only after the first World War when other European nations followed from 1918 to 1928, while others followed even during the Depression period after 1930. The Philippine Government created a Committee on Standardization in 1936 under the Division of Purchase and Supply of the Department of Finance with a very limited scope covering government requirements. Then on June 20, 1964, R.A. 1109, the Division of Standards under the Bureau of Commerce was converted into the present Bureau of Standards. This marked the beginning of a serious attitude towards Standardization. Its objective was to prepare standards for products used by the government, for expert and local consumption.

To develop the scientific research and technological phases, the National Science Board was erected by R.A. 1808 on August, 1956. The implementing agencies are the NIST (National Institute of Science and Technology) and the PAEC (Philippine Atomic Energy Commission). Well and good. However, the NIST and PAEC are most concerned with researches, although the Test and Standards Laboratory of the NIST accepts tests from any party. Still the arm for producing Standards and Specifications is very weak.

There are other offices which produce their own standards relevant to their own functions such as the Bureau of Supply coordination under the Department of General Services; Armed Forces of the Philippines; Forest Production Research Institutes; Food and Drug Administration under the Department of Health; Materials Testing Laboratory of the Bureau of the Public Highways; Metallurgical Laboratory Services Division of the Bureau of Mines.

Add to the above the Testing and Research Laboratories of Industrial Firms and Manufacturers. All the above offices that formulate their own specifications and standards, including PHILSA, form a heterogeneous group that should be under one Administrative Control to prevent confusion due to overlapping of activities and to expedite the production of more standards.

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* Consulting Civil - Structural Engineer, F. ASCE, NSSEEP, ASEP, PACE, PHILSA

The need for coordination is, therefore, obvious. PHILSA has for its Membership on a "voluntary basis."

Sustaining Members - - - - - - - - - - - - 3

Company Members - - - - - - - - - - - - - - -32

Associate Members - - - - - - - - - - - - -4

Individual Members - - - - - - - - - - - - 82

Life Term Members - - - - - - - - - - - - - 7

There are: 24 Technical Committees,

61 Sectional Committees, and

51 Working Groups

As of today, PHILSA has been patiently and persistently engaged itself in the formulation of Standards as reflected in the following as of 1972:

Number of Specifications Published - - - - - 35

Number of Specifications being Printed - - - 10

Number of Specifications approved by the Board for Printing - - - - - - - - - - - 11

Number of Specifications approved by the Board of Review - - - - - - - - - - - - 11

Number of Specifications under discussion by Technical Committees - - - - - - - - - 117

Considering that PHILSA was founded in 1955 by the leading technocrats then, the accomplishment seems low and the progress leaves much to be desired. However, let us look at the leading world organization for Standardization like the ISO (International Organization for Standardization). It has 70 Nation Members and the Bureau of Standards celebrated ISO's Standards day last October 17, 1972.

It has published 2,000 International Standards, 1,330 of which were published during the last four (4) years. The above data furnished by no other than Mr. Olle Stures, Secretary General of ISO, means that ISO has only prepared 1-1/8 Specifications per year per nation, against PHILSA's two (2) Specifications per year. Again, ISO has 1,200 Committees in the 70 Countries or 1.7 Committees per nation against PHILSA's 24 Technical Committees, PHILSA seems to move faster than ISO.

The scope of work is very broad and time consuming considering that there are about 150,000 Standards in the whole world that must be harmonized as to their uses and functions. And there are at present seven (7) sets of National Standards that are similar to ISO in their basic format, namely, U.S., England, Germany, France, Sweden, Japan, and Russia.

The Philippines, a comparatively new member of ISO, therefore, has a long way to go to be at par with the leading developed nations. We are trying to adopt International Standards, but modified to suit our local conditions, because of lack of logistics by way of financing, the lack of personal and national discipline to refuse and condemn substandard products and consumer goods through publicity, common action, and refusal to buy or entertain inferior commodities, the enforcement of the observation of standards will be a failure.

Standardization and quality control are the prime requisites for reducing costs to maximize production and increase exportation. If we lack those factors, the progress of the country will be consequently small. When we except substandard or inferior articles because of lower prices we are in effect subsidizing mediocrity, that will lead to less production, lack of competition to upgrade quality and finally, less gross national production.

Adoption of the Metric System

It is relevant to mention here the "Presidential Decree No. 187 prescribing the use of the Metric System of Weights and measures as the Standard measurement for all products, commodities, materials, utilities and services and in all business and legal transactions that the Metric System shall be fully adopted in all sectors throughout the Philippines by Jan. 1, 1975." To implement this he created the "Metric System Board" composed of the Top Government Officials composed of:

Sec. of Trade as Chairman
Sec. of Finance
Sec. of Agriculture and Natural Resources
Sec. of Public Works, Transportation and Communication
Sec. of Education
Sec. of Justice
Chairman, National Science and Development Board

The Department Undersecretaries and the Board Vice-Chairman concerned shall serve as alternates.

PHILSA, being a Private Organization was appointed as Member of the Advisory Board and Technical Committees.

There is also a need for an Organization, be it a Semi-Government or Government in character, to coordinate, administer, formulate or enforce such Standards prepared by the various bodies, public and private, mentioned above, with the objective of promoting and developing our national economy, similar to the practice in Japan, which make her the second best industrialized nation in the world today.

Let us hope that the New Society under the aegis of the Martial Law can change the present status from a gloomy, frustrating atmosphere to one with clear and orderly direction and implementation. PHILSA will do its best to continue the good work it has done and is ever ready to cooperate with other bodies of similar objectives.

WIND RESEARCH IN THE UNITED KINGDOM

by
Keith J. Eaton
Building Research Establishment, Department of the Environment, Gerston, Watford, United Kingdom

First of all, ladies and gentlemen, I should like to thank the Workshop for inviting me to participate here, because for sometime now we have been working on wind loads. For the last two or three years, we have been working on a joint project, with the staff of NBS, on wind loads on low-rise buildings.

When I arrived here yesterday, I was asked to talk about this subject. I have prepared some slides, and I would like to give you some idea of what we are doing in the United Kingdom.

To start with I would like to show you a short film. This will run for only about nine minutes. And I will discuss this a little bit further afterwards.

(Showing of the film.)

I would like to spend a little time on the points that were made towards the end of the film.

The gap in our knowledge was caused by the lack of information on wind pressure, on loads on low-rise buildings. In the United Kingdom in 1968 there was a great deal of controversy because we increased the loads on low-rise buildings.

We had no reliable information on which to base this and so we started full scale measurements on the estate of houses that you just saw.

I would like to show some slides and talk about these houses a little more.
(Showing of slides)

The houses on the screen are located in the Southeast of England, at Aylesbury -- the several houses in the estate there, as well as the experimental building in the field.

Here, (indicating) we have another view from the southwest; from this direction you are looking at the open field. We got the present distribution of isolated buildings in this situation.

We started constructing the experimental building. This is a steel-framed building with timber cladding. Of course, we had a trial erection back at the B.R.S. The buildings constructed were on six load cells at ground level. And, likewise, with the structure shown in this film, another six loads cells up at this level. Now you see it in its 2-story configuration. We also have the possibility of reducing this to 1-story or even adding a 3rd story. At the moment this seems a remote possibility as we have to leave this site sometime next year. There is a possibility that we might move to some other location.

In its finished configuration as you saw in the film, we have this variable pitched roof on top. This slide also shows the fixed anemometer mounts, the anemometers being at 10 meters; the other main anemometers are at 5 meters and 3 meters. In addition, we have a couple of other special anemometers in there, but they are not part of the main network.

Now I could just briefly say something about our thinking behind this change of roof pitch. What we wanted to do was get as near to a multi-geometric building, the same sort of situation that is easy to undertake in a wind tunnel -- as near to the situation as we could. We devised this roof which can vary between 5-degree and 45-degree pitch. So once the wind blows, we will take a record, say, for 20 minutes. Then it takes about five or ten minutes to change the roof pitch to any other angle we so desire. Before the wind conditions have changed appreciably, why, we essentially get the same wind speed and direction. We change the pitch, then take another record for another 20 minutes, and we carry on like that as long as the wind is blowing.

You can see we can get quite a range of aspect ratios and overall shapes of buildings, and we are already finding some completely different pressure distributions over the roof and on the walls as well with the different roof pitches. You can see the locations of the pressure transducers. They are all over the four walls and both roof surfaces. They are larger diaphragm transducers than those we saw yesterday. They are about 120 milimeters in diameter. We set these flush with the surface of the building, so that then we are measuring the pressure integrated over that area.

These were designed at the Building Research Station some 10 or 12 years ago. The idea of having a large diaphragm like that was to give a cladding load representative of the loading over that sort of size of cladding, and yet at the same time be manageable to install in buildings. There is one other feature that this slide illustrates -- and that is the slats or louvers which are on all four walls. The building is a sealed structure, but we do have a facility to open these openings to a known degree so that we can introduce various values for permeability in the walls and also in the roof of the structure. This will affect the measurement of internal pressures and, hence, the differential loading on the different parts of the structure. And from looking at some of the damage photographs this morning, it is this internal pressure which often causes us so many problems.

(Another slide) It is a very similar set up with transducers, as we said yesterday, with solenoid valves, inside the building. This is the back of the transducer. As Dick said, he copied this idea from us. We didn't patent it, unfortunately. This gives us a zero position at the beginning of each record automatically, zeroing the pressure on the outside of the transducer, with a tapping point just at the side of it.

We can't record on all 130 channels at the same time. This has cost us enough in the first place. We can accommodate 96 channels, and we have to select the channels that we are recording on. At the current time I have finished most of the work on the houses in the estate. When I say, "finished," I have the various wind directions and speeds that I am likely to get -- and I removed a lot of the transducers on the houses. I am now concentrating in much more detail on the experimental building itself.

(Another slide.) This is the recording room inside the experimental building. All these tape recorders are switched on automatically when the wind exceeds a preset level, or we can go there and switch them on manually. And this is the control panel that does all the switching, operates all the solenoid valves, puts on zero and calibration pulses, prints out the time of day. And then we have an inhibit switch down here just to give us a cooling-down period before it switches on again. We again test the strength of the wind before we would switch on.

To say a little bit more about the houses, these are pretty traditional local authority houses in the U.K. -- brick cross-wall, timber stud frames on the windward and leeward faces, built-in terraces, 22 1/2- degree pitch roofs, individual clay tiles. This is quite typical in the U.K., quite a bit heavier than other forms of roofing, but we still lose many tiles due to wind damage, particularly if they are not clipped, and most of these are just laid in place, relying on their dead weight on the battens to hold them down.

(Another slide.) This was the estate you saw modelled in the wind tunnel on the film, and one little interesting factor has come out of that straightaway. There are garden sheds in the back gardens of these houses, and in front of the houses you can see some carports.

In the first set of tests I did, I modelled all these -- and then I repeated the tests, taking these garden sheds, carports and the fences, taking these away from the model; and this had quite a tremendous difference or quite a tremendous effect on the wind loads, the pressure distribution on these windward row of houses here.

The effect is that these garden sheds are already raising the on-coming flow over this windward terrace and tending to reduce the pressures on the windward wall. In the absence of these, then the pressures on the windward wall increase considerably. And certainly, when you compare the pressure distributions going into the estate -- because you will remember we have parallel rows of houses -- it is this windward row which receives the greatest loading; and the rest of the half a dozen parallel rows, going back into the estate, in general had just a bit of turbulent suction and received very little loading.

This then raises other problems. You could possibly design sheltered houses for lower wind loads. But then if you take down that shelter sometime in the future, you will get problems.

What we have elected to do on these houses is to install our transducers in dummy roof tiles rather than put them on the outside of the house as Dick Marshall does; and we had quite a bit of water leakage here and the mastic compounds smeared all over the place. But we just took the roof tiles out and put in fiber glass tiles in place of them. We also had some troubles on these particular roofs, with grit washing down the roof from these concrete tiles and getting into that narrow gap there around the diaphragm and causing some sticking. So we had to open that annular gap so that we could wash it. We washed it out easily, and we had no trouble since then.

(Another slide.) And this is the sort of configuration in the walls of the houses where we just install the box, once the houses were being constructed, to take the transducer. This is the trouble with this sort of installation. We have to get in once the houses are being constructed -- and this poses quite a problem, knocking holes in buildings later on. And this is why there are many good points to be said for having these screw-on discs on the outside of buildings. They are certainly not restricted so much in the way where you can put them.

This house in particular is on the southwest corner of the estate and receives a lot of direct winds. So on this roof we installed 10 transducers -- I think it is six on this side and four on the other side -- and we are looking at the distribution across that roof in some detail.

You will notice that in these houses there is very little eaves overhang, compared with the other slides that you will be looking at this week -- and we copied these on the experimental building. But one thing we are going to do this winter is extend the eaves-overhang on the experimental building so that we can get some pressure measurements underneath and on top of that -- and this will give us some more results which we can compare with the work here.

Within the loft space of this house, as I have already indicated, it is important to measure the internal pressure. The underside of those clay tiles are lined with a felt roofing liner. So we have two membranes of variable permeability. And I am measuring the internal pressure in here with respect to my assigned reference pressure -- and I am also measuring the pressure at the intermediate space between the roof tiles and the under-tile felting. That is causing us some problems as well, but I won't go into that now.

The other aspect of this work is looking at wind speeds in between the houses. But going back to the code of practice, this was the big area where we had very little information. The Meteorological Office in our country -- and probably in many other countries as well -- measures wind speeds down to 10 meters or 10 meters above the level of obstructions. So if it is in the middle of a city, they would probably put an anemometer upon a mast on top of a building. They took the attitude that below that level, below the general level of obstructions, if engineers put those obstructions up, they could measure the wind speeds themselves. Hence, this wind speed unit which we now have at BRE.

We have this vehicle with a mast on it, and this can extend up to 20 meters height in total. We see it at 10 meters. In fact, in that photograph, there is one anemometer on the top there at 10 meters, another one at five meters. If you put it up to 20 meters, we in fact keep them at 5-meter intervals. So we have 20, 15, 10 and 5. And we record for about 10 minutes at a time -- and at the same time, we compare the measurements with simultaneous measurements taken with a similar mast out in the open country. So that we are getting the velocity ratio between our open country measurements -- either the same as that which the Met office provides us with or we are getting reduction factors; not always reduction factors, becuase sometimes we are getting increased speeds within the built-up area. Then we will compare these sites in between houses, in narrow gaps where we get a lot of channeling.

And in fact, since we started this work, we have increased the number of anemometers: and we have two more on the small tripods -- and we set these at 1-1/2 meters. We have taken this as a standard height for an average human being. It is sort of this height and the sort of level at which we get effects on pedestrians in built-up areas. This isn't directly relevant to loading problems; but once we have taken the measurements, we can provide information for our colleagues in the environmental division. So we get a complete idea of the velocities in built-up areas, compared to those in the open country.

All this information, as I have said -- the pressure measurements and the load measurements on the experimental building, the velocity measurements in between houses in urban areas -- will eventually provide us -- well, not too long I hope -- with information for the next revision of the British Code of Practice. Perhaps, I can just digress there and say that two or three people from various countries this week have not heard of the 1972 version of our Code of Practice. I regret to say that Bangladesh is still using the 1952 version which is very much out of date. And also, I want to put the record straight that we are entirely using SI units for the last four or five years and I think this is quite general in structrual engineering and meteorology in our country. So I hope I haven't mentioned anything unusual while I am speaking. We are revising this as I said during the next three or four years and we hope to improve the data in the next few years.

Just one other aspect of the work of the Research Establishment that I would like to mention, and this concerns the investigation of wind damage whenever we get strong winds such as tornadoes as we do get quite frequently, although not in the same experience as you get out here. We do investigate the damage to try to get some of the answers to the problems. Now, I don't have to show the slides on this because I think you have seen identical slides this morning and as I said these slides are almost identical to yours and that we have the same problems.

We have been battling on these problems for years and we run educational seminars with architects, designers, engineers and so on in our country. We hope we have been winning slowly. There are, however, some people who are not aware of the problems - students in colleges and other engineers and so on who can help in getting the message across.

BRE has produced this slide package. This consists of some 40 slides which we sell, I think, for about $15. So we put the slides in there, translate your notes on wind damage, wind flow on buildings and solar instruments. This works well in our country and we hope this will help and will find interests particularly to students where this knowledge will help in their background when they become future engineers, we hope, and will save them a lot of travel time in the future.

Thank you very much.

APPENDIX C

Units of Measure and SI Conversion Factors

This workshop proceedings describes measurements in both U.S. customary units and metric units. The United States of America, as a signatory to the General Conference of Weights and Measures (which gave official status to the metric SI system of units), recognizes the International Standard (SI) unit of measurement.

The reader should use the appropriate conversion factor (presented below) when converting from one system of units to another.

LENGTH

Metric

1 milimeter (mm) = 0.039 inch (in)
1 centimeter (cm) = 0.394 inch (in)
1 meter (m) = 3.281 feet (ft)
1 kilometer (km) = 0.622 mile (mi)

U.S.

1 inch (in) = 2.540 centimeters (cm) or 25.4 milimeters (mm)
1 foot (ft) = 0.305 meter (m)
1 mile (mi) = 1.608 kilometers (km)

AREA

Metric

1 square meter (m^2) = 10.753 square feet (ft^2)
1 square kilometer (km^2) = 0.387 square mile (mi^2)
1 hectare (ha) = 2.471 acres

U.S.

1 square foot (ft^2) = 0.093 square meter (m^2)
1 square mile (mi^2) = 2.586 square kilometers (km^2)
1 acre = 0.405 hectare (ha) or 4.046 meters^2 (m^2)

VELOCITY

Metric

1 meter per second (m/s) = 3.279 feet per second (fps)
1 kilometer per hour (k/h) = 0.278 meter per second (m/s) or 0.622 mile per hour (mph)
1 knot (kn) = 0.514 meter per second (m/s) or 1.150 miles per hour (mph)

U.S.

1 foot per second (fps) = 0.305 meter per second (m/s)
1 mile per hour (mph) = 0.447 meter per second (m/s) or 1.608 kilometers per hour (k/h)

PRESSURE

1 pound per square inch (psi) = 6895 newtons per meter^2 (N/m^2)
1 pound per square foot (psf) = 47.88 newtons per meter^2 (N/m^2)

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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.)*

An International Workshop held in Manila, Philippines, on November 14-17, 1973, addressed the state-of-the-art in mitigating building damages from winds. The workshop was jointly sponsored by the United States Agency for International Development (USAID), the Philippine Advisory Committee (formed in conjunction with this research project), and the U. S. National Bureau of Standards (NBS). This report presents the proceedings derived from the workshop. The proceedings present recommendations, the workshop program, five reports, and nine technical articles. The technical articles addressed four primary topics which were used to guide subsequent workshop discussions. The topics addressed were; wind and aerodynamics, structural related technology, socio-economic and architectural considerations, and codes and standards.

The results of the workshop will serve a twofold purpose. The first suggests improved building practices for developing countries. This was accomplished through the development of recommendations designed to upgrade to a minimum acceptable level design criteria for low-rise buildings. The second involves integrating appropriate workshop information into the overall three-year AID sponsored research project to develop improved design criteria for low-rise buildings in developing countries to better resist the effects of extreme winds.

17. Key words: Codes and standards; Information transfer; Low-rise buildings; Pressure transducers; Socio-economic; Structural design; Technology implementation; Wind effects; Wind loads.

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