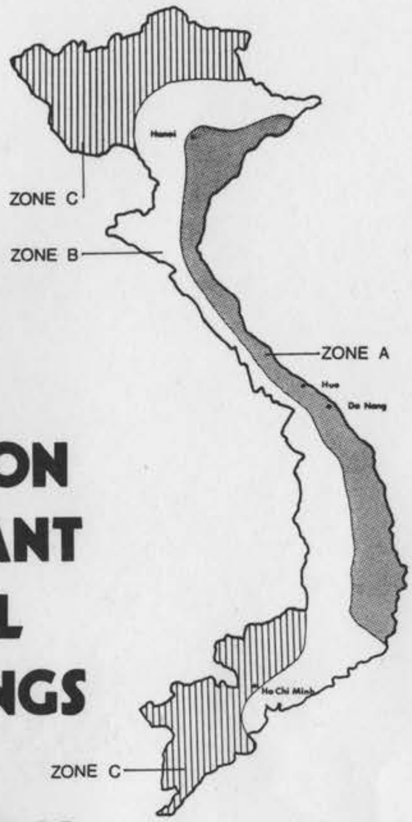


TYPHOON RESISTANT SCHOOL BUILDINGS FOR VIET NAM

by
Department of Educational Buildings
Ministry of Education
Educational Facilities Development Service
UNESCO
K.J. Macks, architect, UNESCO consultant

CONTENTS

BREB/87/D/712-300

Participants of the workshop and training course.

I. INTRODUCTION

Viet Nam is one of the Asian and Pacific countries which is frequently battered by cyclonic storms (or typhoons). The annual number of storms averages from three to five and most frequently strike the central and northern part of the country (Figures I.1, I.2, I.3). The fifth such storm in 1986 struck two provinces just south of Hanoi and for which the Ministry of Education has given the following statistics of damages.

- 1,520 classrooms destroyed
- 12,850 classroom roofs damaged
- 1,106 laboratories/workshops etc. destroyed
- 1,473 laboratories/workshops etc. roofs damaged
- 760 teachers' quarters destroyed
- 420 teachers' quarters roofs damaged

Following each major storm statistics are collected and appeals, both national and international, are made for assistance to the affected areas. Amongst the international agencies to which Viet Nam appeals for help is Unesco. Unesco, however, is not an aid giving agency and is in no position to respond to the requests for vast amounts of aid. Based on the official statistics for the 1986 storm, for example, about one square kilometer of school building roofs need to be replaced.

Being aware of this perennial problem, Unesco, Bangkok invited Viet Nam to participate in a training course on educational buildings in cyclone affected areas which took place in Manila in March 1986. The two participants were Mr. Nguyen Dinh Phung of the Ministry of Education and Mr. Le Quany Huy of the State Committee for Construction.

The Ministry of Education has decided that it would like to bring to an end this problem of annual damages and plans to do this in two phases.

Phase I : 1986 - 1987	: Undertake a design study for the development of prototype structures.
Phase II: 1988 onward	: Begin implementation of new designs in several selected districts as pilot programmes.

This experience would then be transmitted to other districts for an ever wider scale application.

In response to a request for assistance by the Ministry of Education Unesco has mobilized a limited amount of resources to support a research and development activity on typhoon resistant school buildings in Viet Nam. These funds have been taken from regular programme sources ($10,000) and from the UNESCO-AGFUND project Development of Educational Facilities in Asia and the Pacific ($14,000).

The first step in this activity has been for Unesco to carry out a mission to Viet Nam to work with Vietnamese technical personnel. Mr. Kevin J. Macks, consultant architect from Australia and Mr. John Beynon, Principal Architect, UNESCO, Bangkok, spent 14 days in the country (15-29 June). The mission was composed of three parts: i) field visits to two Districts in the affected areas, which included Tien Hai District of Thai Binh Province and Xuan Tuay District of Ha Nam Ninh Province; ii) a workshop to discuss the problems of the various provinces as well as the various solutions proposed by the Ministry of Education, Department of Educational Buildings (DEB); iii) a training course on the theory of building design in cyclone affected areas (Figures I.4, I.5).

This report covers the results achieved during the mission.

The next steps will be for the DEB to prepare preliminary designs based on the observations made during the field trip. The suggestions received during the workshop and the technical guidance made through the training course will be followed by the construction and testing of prototype schools in several of the most affected Districts along the coast.

There is every reason to believe that there is a technical answer to the problems. While the resultant designs will rely as much as possible on the use of local materials it is necessary to tie down the various building components with steel fasteners and steel reinforcement. While these are of simple design which can eventually be produced in Viet Nam, the country will require some further external assistance to be able to achieve this. This report, therefore, looks into the need for such assistance.

In view of the need for external assistance and the importance of trying the activities of this project in with those which have been initiated by other agencies or governments contacts were made with UNICEF, UNDP and the Australian Embassy.

As UNICEF is involved in various educational programmes which include the provision of teaching materials, it is necessary to ensure that buildings are secure and provide adequate protection against rain.

UNDP and the government are in the processes of finalizing a project entitled Disaster Preparedness and Rehabilitation. Binh Tri Thien Province which includes three components: improvement of the gathering of meteorological data, establishment of typhoon proof communication systems and the demonstration of disaster resistant construction techniques for local builders.

With the Australian Embassy discussions centered around the transfer of Australian technology to the conditions in Viet Nam and in particular for the fabrication of galvanized steel cyclone straps for attaching roof members to the structure. The Embassy was informed of Unesco's intention to prepare a project for external assistance which would include, in the first instance the provision of ready made materials, and for the long term the development of industrial capacity to produce these components in Viet Nam.

Particular thanks are due to the cooperation received from the Government of Viet Nam and in particular H.E. Pham Minh Hac, Minister of Education, Dr. Tran Xuan Nhi, Vice Minister of Education, Mr. Nguyen Chi Linh, Director of External Affairs (MOE) and Mr. Nguyen Dinh Phung, Acting

Director, Department of Educational Buildings (MOE).

Chapter V of this report by Mr. Kevin Macks has benefited from contributions by the following persons. Mr. David Lloyd of Blain Bremner and Williams Pty. Ltd., Consulting Engineers has checked the calculations of forces and the theory of physics. Professor George R. Walker of James Cook University and Mr. Greg F. Reardon, Technical Director of the Cyclone Testing Station and Professor Joe Minor of Texas Technical University have advised on the selected wind speeds and wind zones.

H.E. Dr. Pham Minh Hac hosted a dinner for the UNESCO team and discussed at length the work being done under this project. Dr. Tran Xuan Nhi, Vice Minister of Education, personally guided the activities of the full two-weeks and chaired or attended all sessions of the three day workshop. He has instructed those who attended the workshop and training course to implement the recommendations.

Figure I.1 **Areas of tropical cyclones and hurricanes, showing the average number of occurrences per five-degree square per year (adapted from Reference 6)**

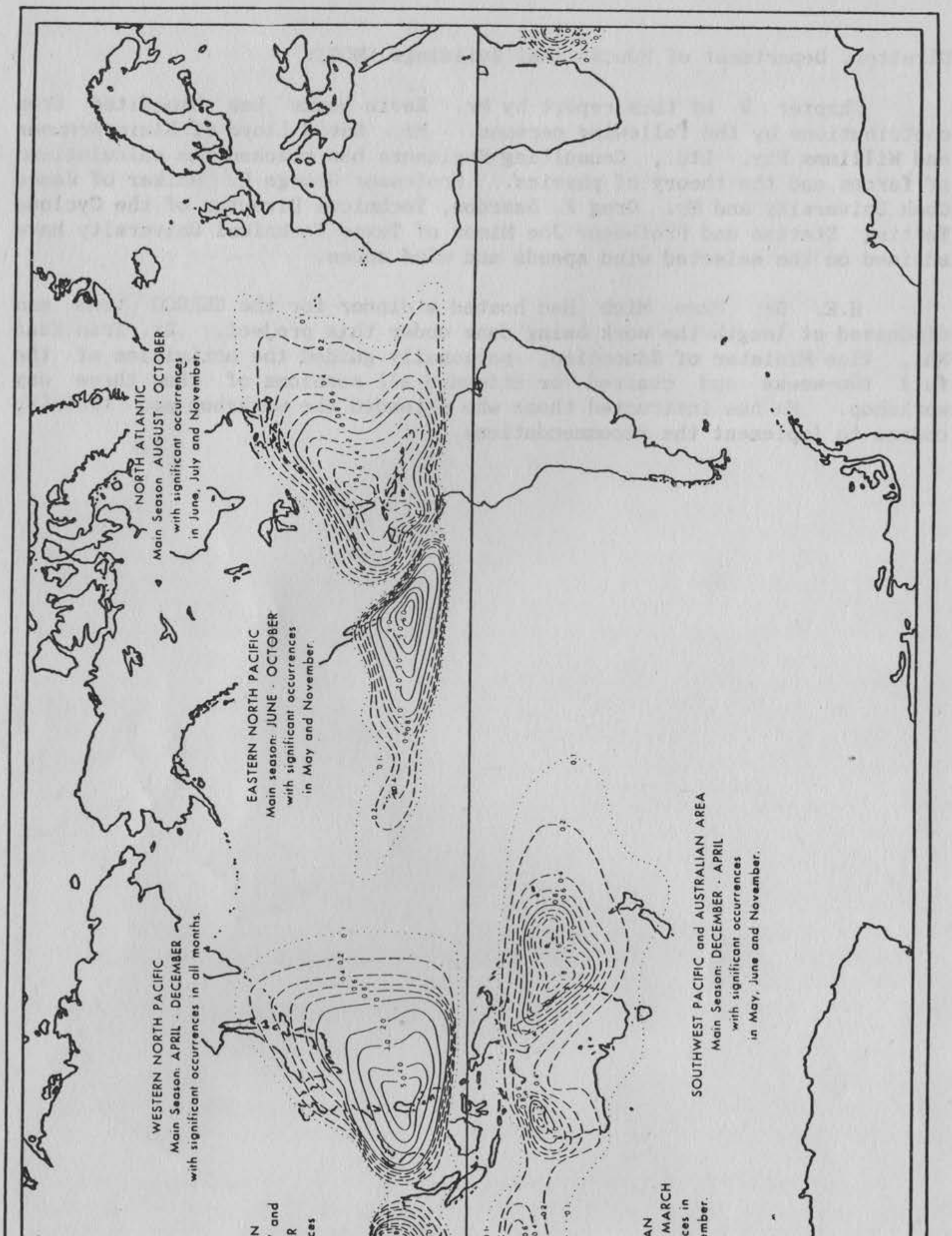


Figure I.2 MAP OF VIETNAM

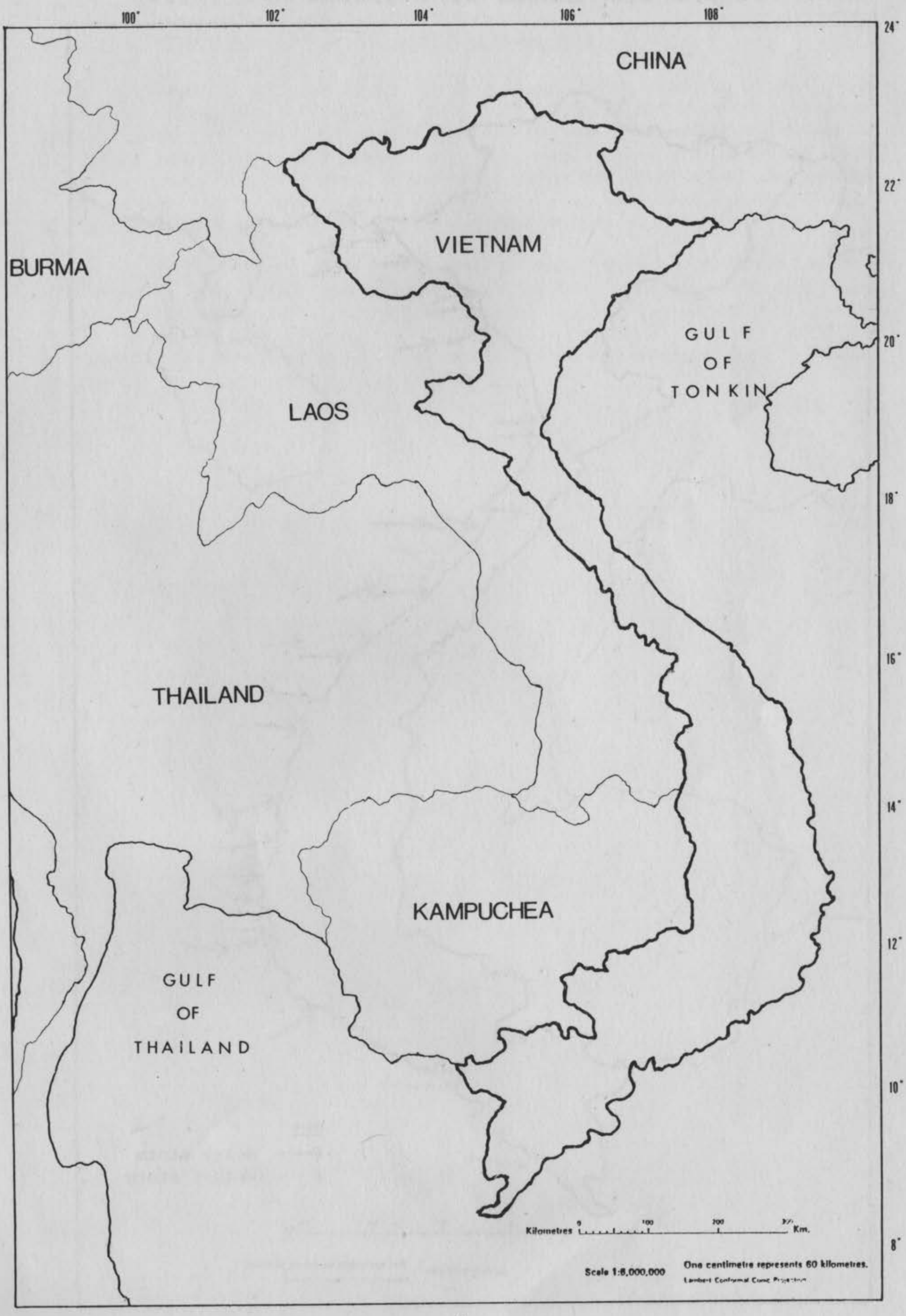


Figure I.3 TRACKS OF CYCLONES 1975-1986

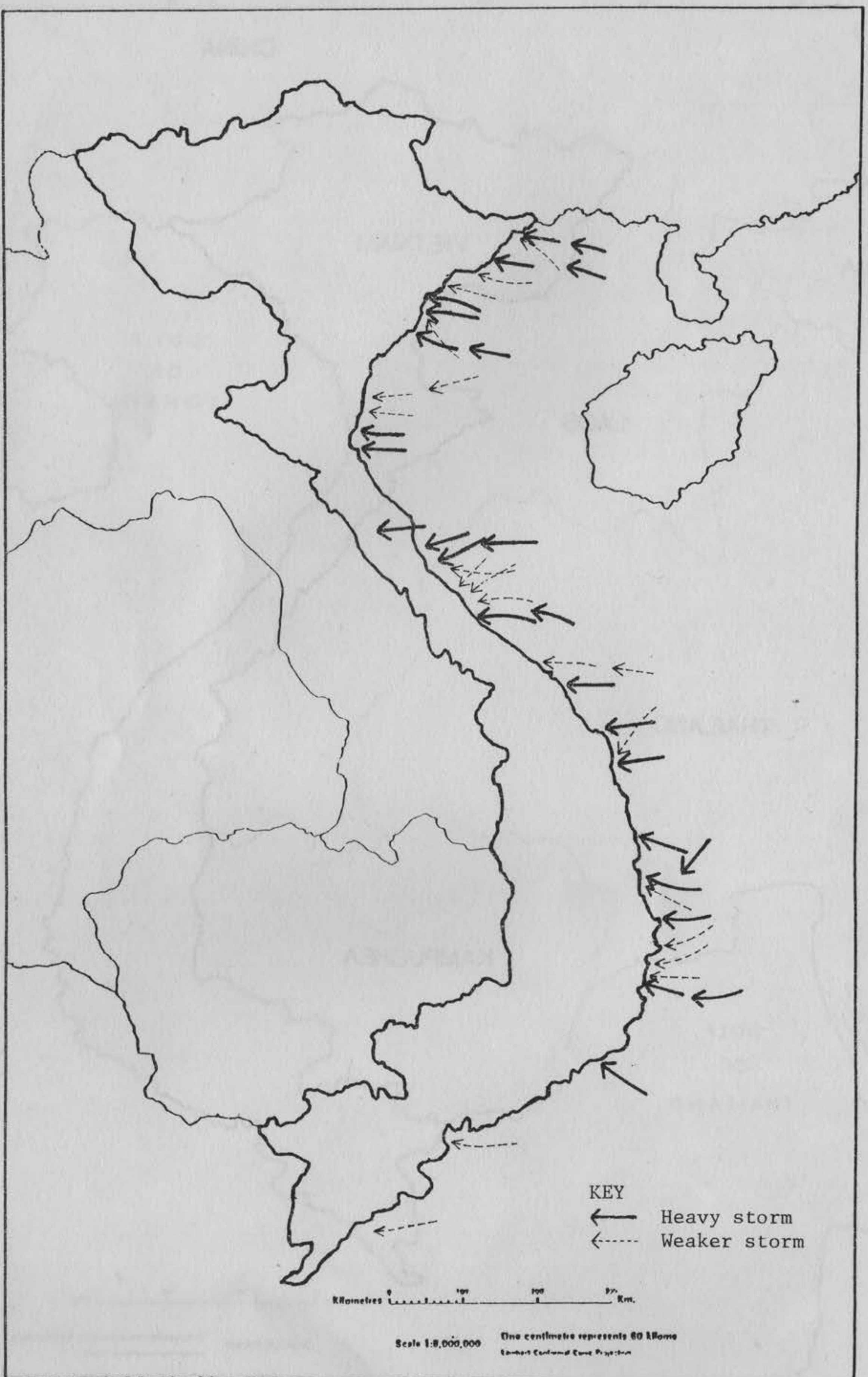
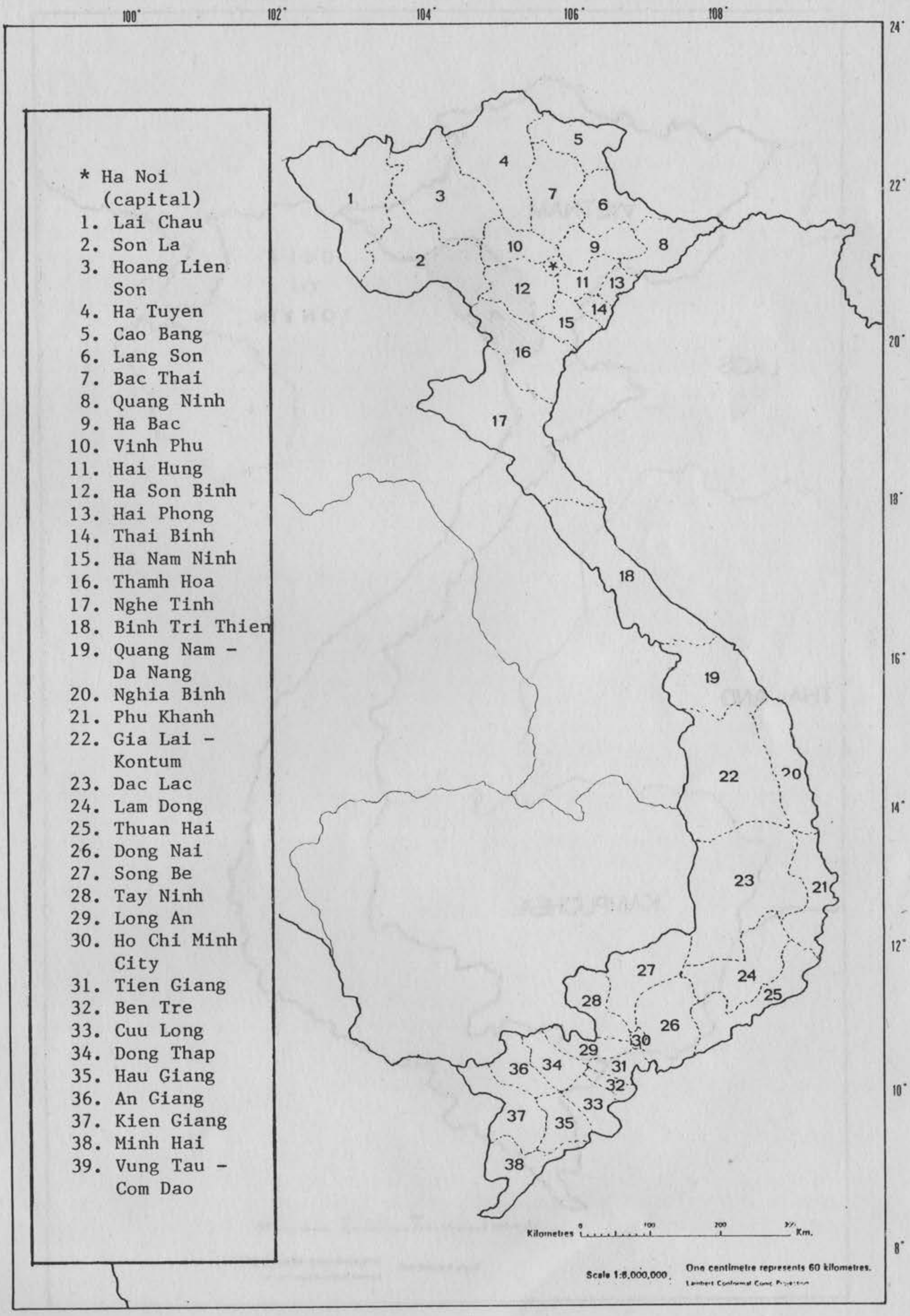
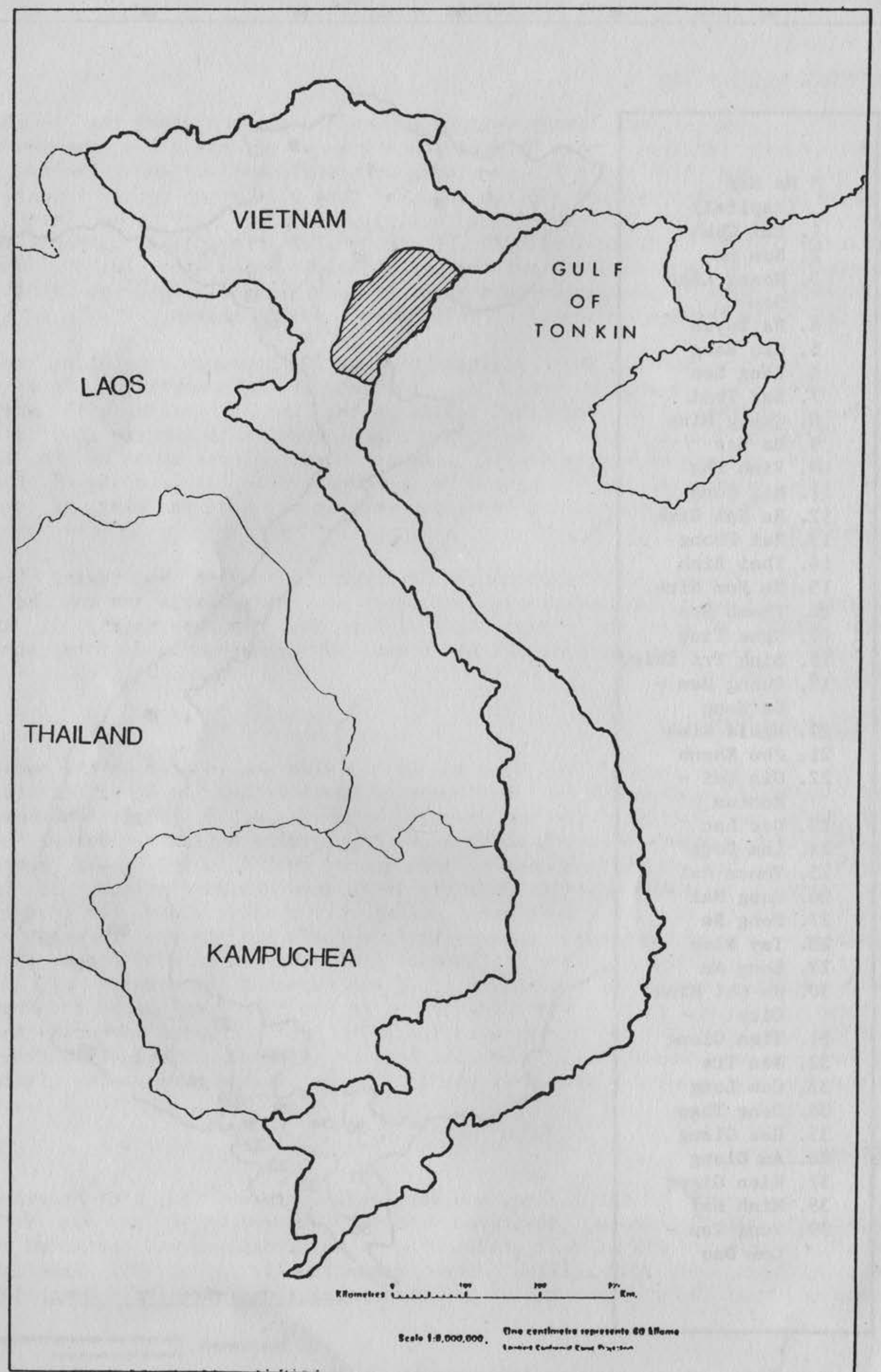


Figure I.4 VIETNAM - PROVINCES



* Ha Noi (capital)
1. Lai Chau
2. Son La
3. Hoang Lien Son
4. Ha Tuyen
5. Cao Bang
6. Lang Son
7. Bac Thai
8. Quang Ninh
9. Ha Bac
10. Vinh Phu
11. Hai Hung
12. Ha Son Binh
13. Hai Phong
14. Thai Binh
15. Ha Nam Ninh
16. Thamh Hoa
17. Nghe Tinh
18. Binh Tri Thien
19. Quang Nam - Da Nang
20. Nghia Binh
21. Phu Khanh
22. Gia Lai - Kontum
23. Dac Lac
24. Lam Dong
25. Thuan Hai
26. Dong Nai
27. Song Be
28. Tay Ninh
29. Long An
30. Ho Chi Minh City
31. Tien Giang
32. Ben Tre
33. Cuu Long
34. Dong Thap
35. Hau Giang
36. An Giang
37. Kien Giang
38. Minh Hai
39. Vung Tau - Com Dao

Figure I.5 UNESCO MISSION - JUNE 1987 - PROVINCES VISITED



II. FIELD TRIP REPORT

Educational Profile

The educational system follows a KG-5-3-3 pattern where the levels include kindergarten, Basic General Education (which covers the five years of primary and three years of lower secondary sections) and upper secondary education. Both provinces visited reported that nearly one person in three attends some kind of educational activity and that they have several primary teacher training institutions. Table II.a provides a comparative picture of the two provinces and the two districts which were visited. For the most part kindergartens and upper secondary schools work on single shifts while the Basic General Schools operate on two shifts.

Primary schools serve villages of 5 to 10 thousand population and teachers are, as much as possible, residents of the community. Primary schools average 1120 and 1325 pupils in the two districts with most operating on double shifts. Secondary school enrolments average 1000 and 900 and operate on single shifts. As secondary schools serve up to 10 villages, teachers can not always be accommodated in the locality of the school. Thus, accommodation of one room is provided for many of the teachers.

The number of classrooms can be roughly estimated by taking the number of classes in kindergarten and upper secondary levels and one half the number of sections in Basic General Schools. On this basis, it is estimated that Tien Hai District has around 800 classrooms and Xuan Tuay District 1150.

1986 Storm Number 5

The Provinces of Thai Binh and Ha Nam Ninh are located on the coast of the China Sea some 150 km. southeast of Hanoi. They lie on either side of one of the outlets of the Red River. At about 10 p.m. on 5 September 1986 storm number 5 struck these provinces causing extensive damage in both. The recorded wind speed has been quoted at 120 to 140 km per hour. As this measurement was most probably taken some distance inland, it is most probable that the speeds were considerably greater along the coast. Judging from the extensive damages to tile roofs and the over-turning of brick walls speeds well above 140 km must have occurred in many areas. The storm abated after about four hours. It was reported that the eye of the storm came inland in Xuan Thuy District of Ha Nam Ninh Province in the area of Tho Nghiep. Tien Hai District in Thai Binh province which is across the river from Xuan Thuy District was also heavily affected. Table II.b gives data on the damages suffered by the 11 schools visited during the field trip.

Storm Damages

The extent of the damages was very considerable. Thai Binh Province reported 800 classrooms destroyed and 4800 damaged while Ha Nam Ninh Province reported 413 as destroyed. The value of damages was estimated at 400 million and 1000 million dongs respectively. Tien Hai District reported that 134 of its total of 800 or so classrooms were fully destroyed

Table II.a Educational Data on Provinces and Districts visited

	Kindergarten			Basic General Schools			Upper Secondary Schools			Teacher Training		
	No. of Schools	No. of Classes	No. Enrol.	No. of Schools	No. of Classes	No. Enrol.	No. of Schools	No. of Classes	No. Enrol.	No. of Schools	No. of Classes	No. Enrol.
Thai Binh Prov.	-	-	-	300	-	-	27	-	-	4	-	-
Ha Nam Ninh Prov.	-	-	-	542	-	-	54	-	-	5	-	-
Tien Hai Dist.	32	220	6453	32	983	35800	3	57	3000	-	-	-
Xuan Tuag Dist.	41	470	12260	43	1112*	57000	4	96*	3700	-	-	-

Total	Thai Binh	450,000
	Ha Nam Ninh	670,000

Note: Figures given are rounded data supplied by provincial and district officials.

* combined equals 1208

Table II.b Data on schools visited

	Pop.	Enrol.	Cl.	CR before	CR destroyed	CR Damaged	
1. Dong Quy	–	925		14	5	11	3 shifts
2. Dong Xuyen	5,000	1,049		14	8	6	2 shifts
3. Dong Tra	–	1,354	26+10	18	18	–	2 shifts
4. Dong Hoang	–	1,150	23+9	16	6	10	2 shifts
5. Dong Lam	4,500	950	2+16+10	21	5	6	2 shifts
6. Dong Co	4,500	1,024	19+9	14	7	7	2 shifts
7. Xuan Tuay S.S.	80,000	1,000	18	20	10	8	1 shift (2 teachers rooms destroyed)
8. Huyanh Son	7,000	1,500	27+10	19	7	12	2 shifts
9. Giao Ha	–	–	–	–	3*	–	(teachers rooms destroyed)
10. Tho Nghiep	10,000	1,700	30+11	26	11	20	2 shifts
11. Xuan Vinh S.S.	90,000	780	15	15	4	8	1 shift (20 rooms for staff)
TOTALS				177	81	88	
					46%	50%	

*excluded from total since other data lacking and 400 lost their roofs. Xuan Tuay District reported that 369 classrooms were destroyed and 510 damaged out of an estimated total of 1150 classrooms. While the figures may not be exactly comparable due to differing standards for defining the damages, the point is well made that damages were substantial.

An observation of 11 schools (9 Basic General schools and 2 Upper Secondary) indicated that out of 177 classrooms which existed before the storm struck 46 per cent were destroyed to a point where both walls and roofs had to be reconstructed and 50% required extensive roof repairs. Thus only 4 per cent of the classrooms escaped serious damage.

Most buildings were constructed in a similar fashion - with 20 cm thick load bearing brick walls around the perimeter and between classrooms. Lime mortar was used in most walls. Nearly all roofs were made of clay tile. The roof trusses and tile support systems show considerable variations. Trusses were made variously of steel, timber, bamboo and composites of reinforced concrete and timber or railroad rails and timber. Purlins and battens were normally of bamboo, though some timber was also used in the better buildings. In most buildings tiles at the gable end of the walls were embedded into the brick work and sealed with mortar. In the badly damaged classrooms there were no ring beams and the trusses were not tied down either on the long walls or on the verandah columns. Lacing with light gauge wire or vegetable material was used at some schools to connect rafters to purlins.

Failures were typically at the ridges and eaves but very often the entire roof was stripped of tiles. As very few of the trusses were braced they frequently tipped over pulling the purlins out of the end walls. This seems to have led to the collapse of many end walls. Furthermore once the trusses had fallen, side walls also collapsed. In some classrooms it was noted that failure of the trusses was due to their having been severely weakened by white ants.

Very few reinforced concrete structures were found in the schools visited. One RCC structure - perhaps 20 years old - was found to be in very bad condition and on the verge of being dangerous. The reinforcing steel had rusted and broken open the verandah columns as well as the covering on the bottom side of the roof slabs. This problem can, in part, be attributed to the salt in the local sand and in water used for construction. It is also due to providing insufficient concrete cover over the steel reinforcement.

Buildings Which Survived

At one secondary school several older buildings were seen which had survived the storm nearly intact. One of these had longitudinal cross bracing between trusses which was the only example seen. The other relied on a verandah on one side and both ends to create a 45 degree corner bracing while the heavy timber used for the roof truss was firmly anchored into the side walls. Another building at the same school had a smooth finished roof made of flat tiles set into mortar. This building was some 40 years old and seemed to still be sound, though the interior spaces were not suitable for classroom teaching.

Recent Reconstructions

Two styles of reinforced concrete structures were seen which had been put up since the storm.

One of these is a flat concrete slab roof structure supported on two transversal beams. While this structure eliminates the use of roof tiles it introduces the possibility of trapping water on the roof. This in turn can easily lead to water penetrating into, and through, the roof slab. The future consequences can be the corrosion of reinforcing steel and damages to the interior surfaces.

The other was a two storey structure which used brick bearing walls with a continuous RCC lintel and ring beam. The floor was of precast hollow panels 3000 x 600 x 200. These are commonly used throughout Viet Nam and can be lifted into place with a hand operated winch. However the end support of these precast units on the concrete beams is a problem.

One damaged building had been substantially reinforced by adding a bamboo truss in between existing timber trusses thus resulting in a span for the purlins of less than two metres. The purlins were of heavy bamboo and carefully attached to the trusses with pegs and lashing. As a result the tile roof had a satisfactorily uniform appearance. While this structure may not be able to withstand a very strong hurricane, it demonstrates that if the local materials of brick, tile and bamboo are judiciously used in unison a reasonably sturdy structure can result.

Materials, Workmanship and Maintenance

Normally, a well constructed and well maintained brick school building should have a serviceable life of over 50 years. Yet many of the brick buildings in Viet Nam have collapsed within 10 years under the wind forces of the typhoons.

In the course of the field trips to three provinces and a visit to the educational equipment factory in Hanoi, it has become evident there are a number of reasons for the failures. Materials must be correctly designed, manufactured to a high quality, delivered on site when needed without being damaged, installed correctly and rigorously maintained. Problems were observed in all these steps.

It was noted that clay masonry is the basic building material in Thai Binh and Ha Nam Ninh Provinces while in Hai Phong Province there was also extensive use of blocks which used cement as a binder. While the quality of the bricks is relatively poor, they could no doubt be improved with some development work. Decorative hollow clay tiles, on the other hand are seen throughout the region and have the appearance of being very well made. Walls are often made using lime mortar which was of varying quality. In some cases where the lime and sand were pure a fairly high strength has been achieved. Walls where impurities in the mortar were evident often failed.

Clay tiles are widely produced and are used on over 80% of the buildings. The tiles tend to absorb moisture and also crack easily. During typhoons a large number of tiles are cracked, broken and removed from the roofs. A large part of the damages to buildings during typhoons are a consequence of failure of the tiles. Sheet materials are seldom used and apparently not produced in significant volume.

Timber is in relatively short supply with the consequence that villages often use other materials such as iron or bamboo in roof structures. Bamboo is almost exclusively used for the purlins, small rafters and battens in the roof. There is no treatment of the timber or bamboo with the result that they are often attacked by white ants.

Steel is in very short supply in Viet Nam and is therefore seldom used in construction. An investigation was made into the ability of the educational equipment factory to produce galvanized steel straps which could be used to give integrity to the roof structures and for firmly attaching roof trusses to walls. These elements are crucial to making buildings resistant to typhoon forces as they can take the tension forces which result from the uplift on roofs in high winds. It would seem that the educational equipment factory could produce up to 1 million units a year. It was also suggested that these straps could be produced in the provincial vocational/technical education centres possibly as a part of the programme of linking education to productive work. The ability of these factories to apply galvanization of an adequate standard is unknown. The Hanoi factory can do galvanization of 5 microns but may not have an adequate capacity to achieve the volume indicated above. The factory would need to receive the raw materials and to have three months notice to begin production.

In general the quality of construction of the damaged buildings was low. While there are problems at all stages, i.e. with the design of materials, the quality of materials produced and in construction techniques, there is a substantial scope for making local materials perform better through improving construction techniques. One major problem is the absence of tension members in the structures. Tension straps in the roofing system, ring beams at the tops of walls and vertical ties between ring beams and foundations are hardly ever used.

Once constructed buildings tend to be left unattended. Systematic repair of broken hinges and latches, patching of water leaks in roofs and walls, and painting of wooden components of buildings would contribute greatly to the longevity of the buildings.

<u>The Field Trip in Photographs</u>

A number of pictures were taken during the field trip using both black and white negative film and colored Polaroid film. The Polaroid shots were used to produce an instant record of damages which were noted in the buildings visited. These were used during the workshop and training course to illustrate various points made by the UNESCO consultant. These have been made into a book by the MOE for future reference.

Following are prints of a black and white photographs taken during the field trip. Notations are given on each to indicate the strong or weak points and to indicate where improvements might be made.

<u>TYPICAL DAMAGES</u>

Buildings with minor damages lost tiles at the edges and corners of the roofs.

Buildings with more severe damages lost not only the tiles, but the roof structure as well.

The most severely damaged buildings suffered collapse of brick walls.

CONCRETE WORK IN TYPICAL NEW CONCRETE AND BRICK CLASSROOM BUILDINGS

The roof will pond water and leak. Note lack of ventilation and unattractive design.

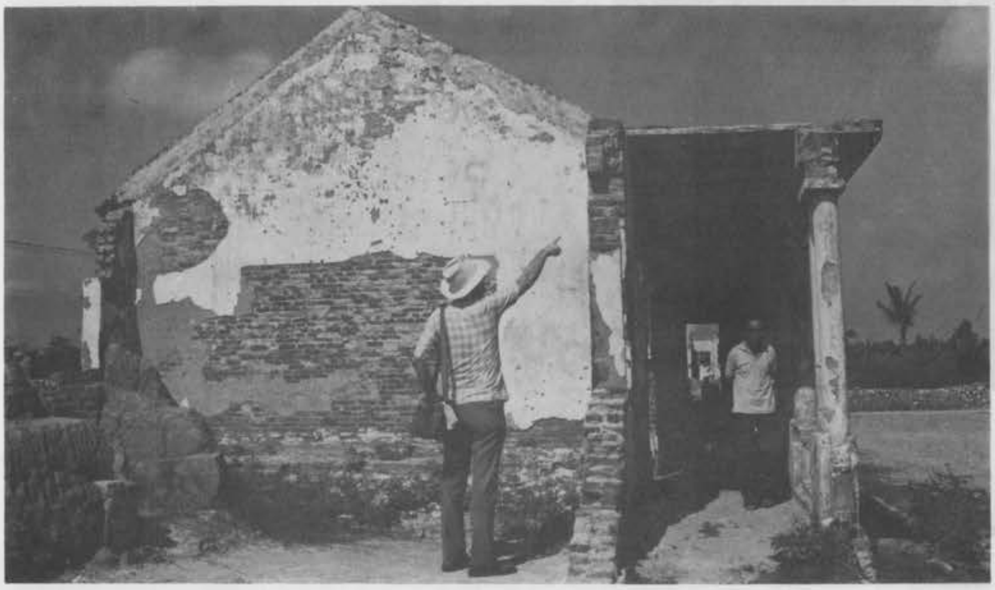
More attrative design of concrete and brick. Roof will pond water and leak.

Note crack along concrete beam which weakens support. This is the start of "concrete cancer". Concrete work demands excellent workmanship and design and control of materials quality.

Thin RCC slab. There is no cover to protect reinforcement rods. Thus rust attack has led to expansion of the rods and cracking of the concrete. See also below.

Precast columns or slabs removed from building because they were attacked by concrete cancer. Materials must be free of impurities such as salt which causes steel to rust.

EXAMPLES OF "CONCRETE CANCER"

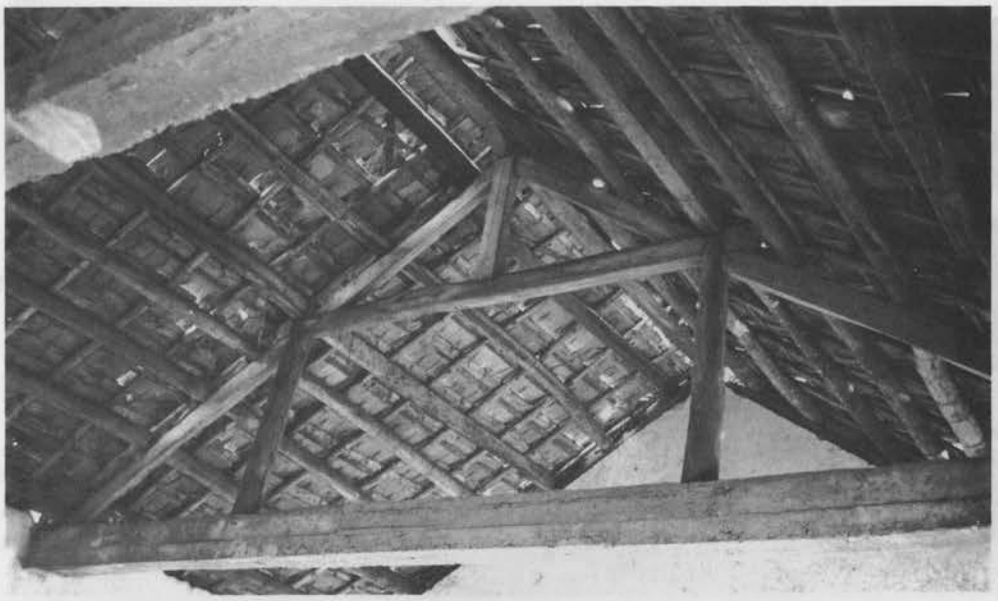


Note insufficient 40 mm thickness of slab. Steel should have a concrete cover of at least 25 mm. Steel should not be covered with materials which absorb moisture, such as brick.

ROOF FRAMING

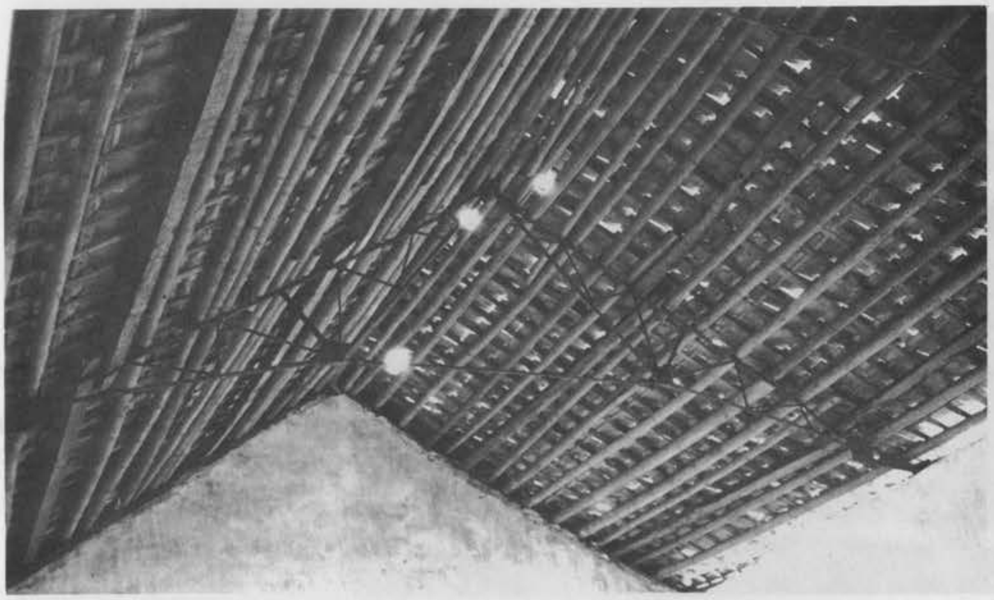
This roof lifted off due to absence of fixing. The truss fell over due to lack of cross bracing and attachment to walls. Walls remained intact as they were not called on to transfer any load. However, note crack at the window. All elements of the roof frame should be tied together to create an integral, rigid structure.

This truss failed due to white ant attack and lack of maintenance action. Timber needs to be treated and if white ants do attack a structural member, it should be immediately replaced.

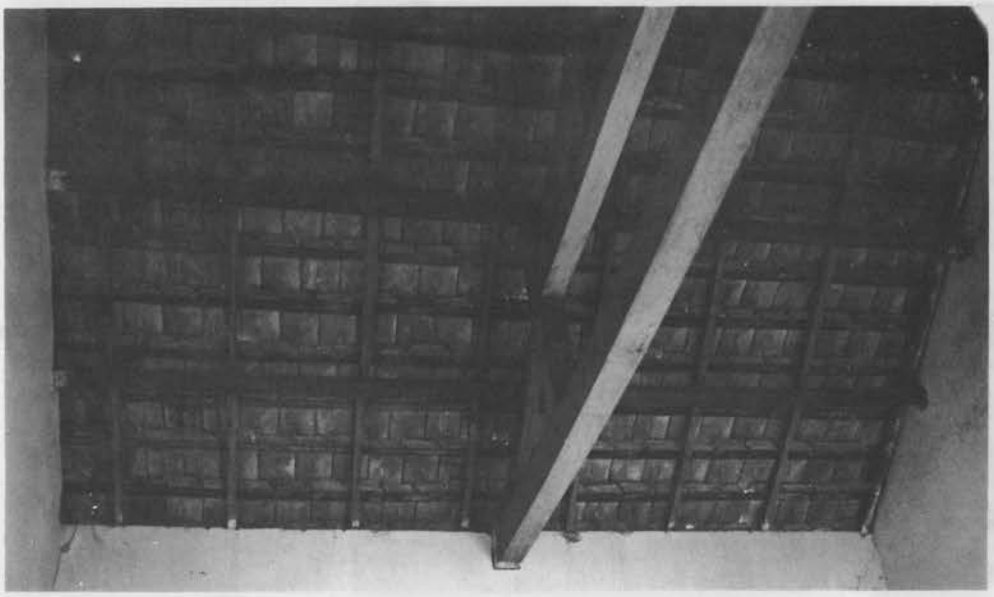


ROOF FRAMING AND TRUSSES

Note truss with concrete bottom chord and absence of fixing to timber struts. It will fail in the next storm. Tie all members of a truss together.

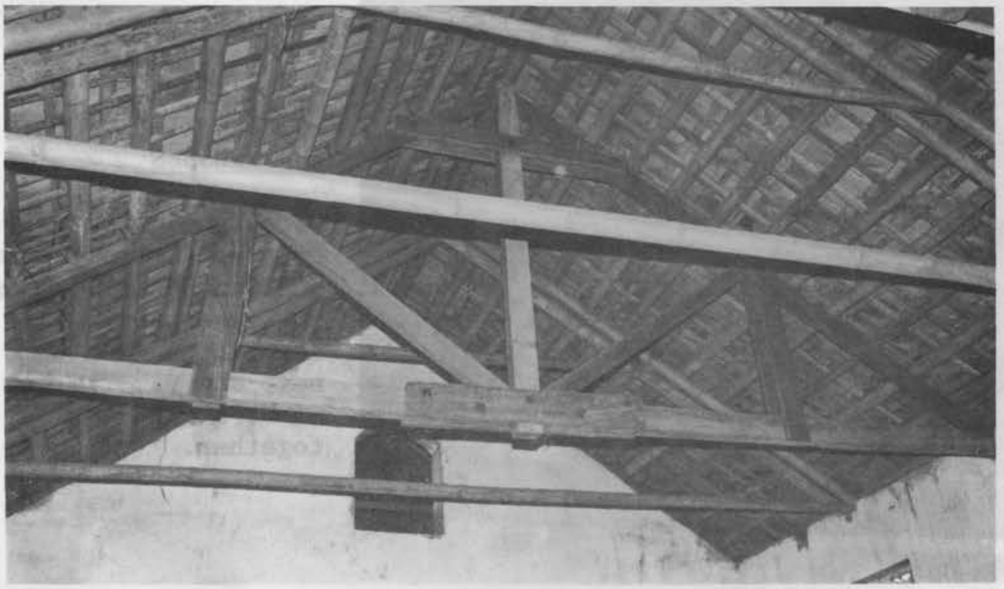


The close spacing of purlins is excellent. This truss is too slender to carry the heavy forces on it. It will fail in the next storm. Note lack of longitudinal bracing and tie down to walls.

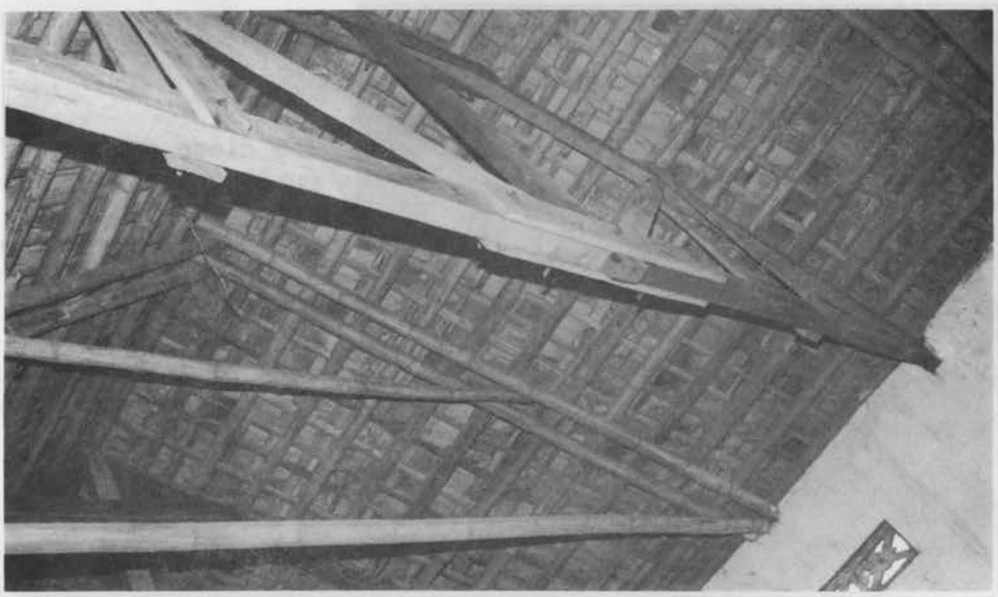


A well made roof. However the truss needs to rest on a good ring beam and be tied down to walls.

ROOF TRUSSES AND FRAMINING



A well made timber truss with an intermediate truss of bamboo which needs additional struts. Bracing between trusses is required. Purlin spacing and fixing is good. Roof frame should be tied to foundations via a ring beam.



The same roof as above. The intermediate truss of bamboo installed after the roof was lost has resulted in an even roof without sagging.

When roof loads are transferred to a masonry wall, the wall may fail and crack. There is need for a bond beam and tie down. Such suspended cracked brick work is not safe.

ROOF FRAMING

This roof shows the work of a good tradesman. However there is no tie down between the trusses and columns. Note bamboo truss which has been added between timber trusses. A horizontal beam should be placed between piers to support bamboo truss. Trusses should be tied to the beam, and the beam tied to brick column and brick wall. A tension tie should be fit on the face of the column fixed to beam above and carried down to the foundation.

This tradesman understands that roofs need tieing down. However the joints are not tight and pins too small for wind loads.
Note the bamboo as an over-batten. This detail demonstrate good intentions and theory but needs a little guidance to be made effective.

ROOF FRAMING AND CLADDING

Note stiffness provided by timber braces and struts. Note longitudinal beam over columns. Note large size of rafters and close spacing of purlins. Very good workmanship. To further improve resistance against strong winds the beams need to be tied down to the foundations and the timber members need to be well connected to each other.

See same building below.

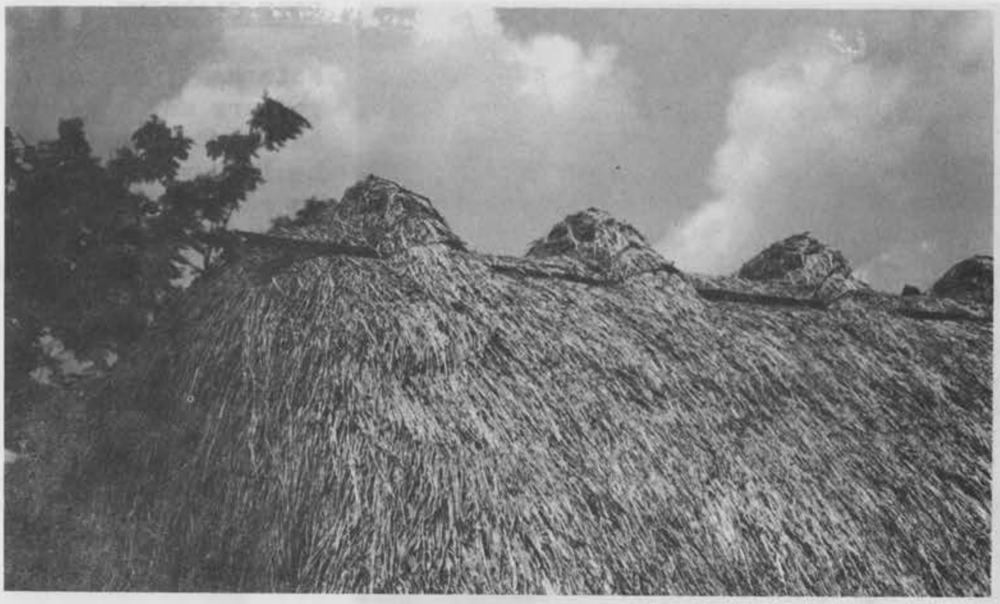
Well built school. Note shape of dutch gable end which provides bracing. Note attempt to fix over rafters of brick on top of roof.

See detail of corner above

ROOF CLADDING

Note small battens rafters and edge beam. Battens must be larger and fixed to rafter which should be securely fixed to purlin which in turn, must be fixed to truss.

High pressure at perimeter removed roof tiles.
Tiles not tied down.



ROOF CLADDING

Detail showing good workmanship in traditional roof.

Traditional houses in Tien Hai District. The local tradesmen have understood need to have a strong roof ridge.

III. EDUCATIONAL BUILDINGS IN THE TYPHOON AFFECTED AREAS OF VIET NAM

by Department of Educational Buildings, Ministry of Education

PART 1. TYPHOONS AND CYCLONES IN VIETNAM: THEIR DAMAGES TO EDUCATIONAL BUILDINGS

1. GEOGRAPHIC AND CLIMATIC FEATURES IN VIETNAM

1.1 Geography

The country of Viet Nam, S-shaped, stretches between latitude 8° 30 North and latitude 23° 22 North, and between longitude 102° 10 East and longitude 109° 30 East. Situated in the East of Indochinese peninsula, the country faces the Eastern Sea, a closed and large sea with an average depth of over 1,000 metres. The total sea area is 3,447,000 square kilometres.

Geographically, the country gradually gets higher and higher from east to west with heights and plateaux about 1,000 metres above sea level; the highest peak being 3,143 metres.

1.2 Climate

Viet Nam has a tropical climate with monsoons. It is hot and humid with 2 seasons yearly. From May to October is the hot and rainy season the South East and South West winds prevail. From November to April, is the cold and dry season with North East and North West wind which is dominant.

The yearly average temperature ranges from 21,6 C in Lang Son to 26,9 C in Ho Chi Minh City.

The climate is frequently dominated by the monsoons. The winter monsoon (North East) blows in spells from November to April. In coastal areas from Quang Ninh to Binh Tri Thien wind force reaches to 5 or 6 (nearly 14 metres a second). The summer monsoon blows from May to October with the direction of South West in the South to the direction of South in Central Viet Nam and the direction of South East in the North with the force of 3 and 4 (Figure III.1).

Typhoons frequently attack coastal areas in Viet Nam usually from June to November. As the year draws to its end cyclonic storms batter the more Southern coastal areas. These typhoons often form themselves in the West Pacific within latitude 10 to 20 North, longitude 123 to 130 East, or right in the Eastern Sea between latitudes 7 to 20 North and longitudes 112 to 120 East.

The average quantity of rain every year is roughly 2,000 mm.

2. DAMAGES CAUSED TO EDUCATIONAL BUILDINGS BY TYPHOONS

2.1 Typhoons and storms in Viet Nam

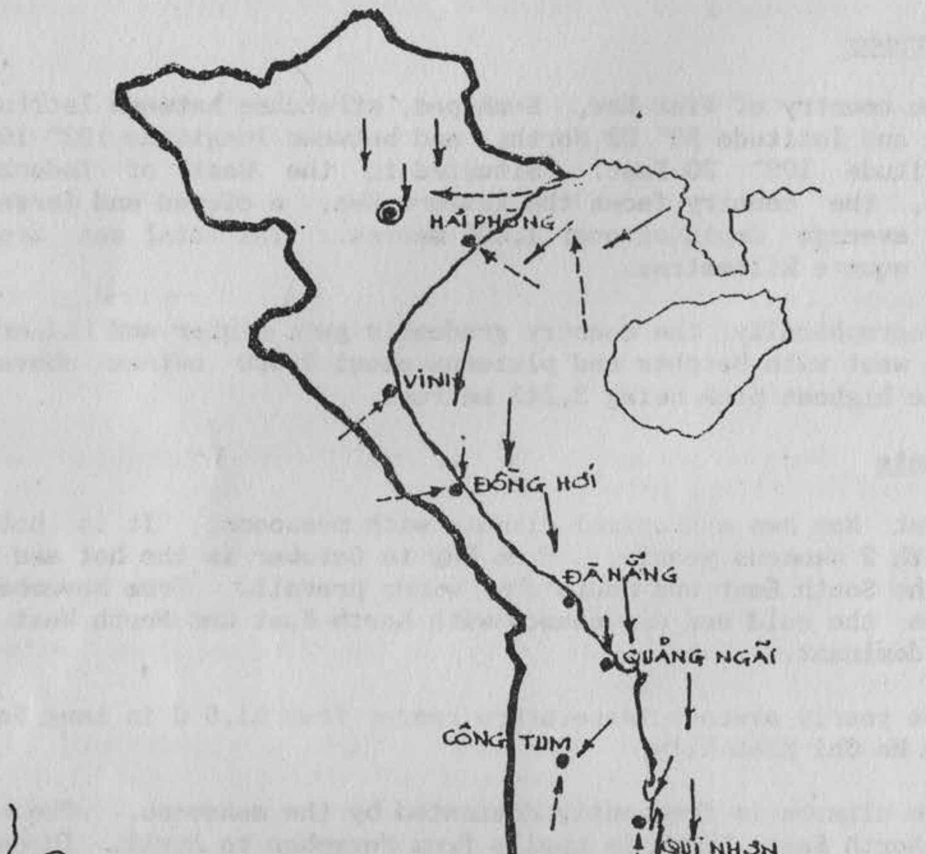


Fig. III.1 Monsoons in Viet Nam.

According to statistics collected over the past many years the annual number of storms averages 3,9 and most frequently strike coastal areas of Viet Nam. It sometimes happens that there are years with either no storms at all or 7 to 8 storms. If low tropical atmospheric pressures are included (LTAP) the annual number of storms averages 7,2 and sometimes there are 12 to 13 storms striking a year. (LTAP means propitious whirlwind with wind force of 6 or 7).

Some 44% of storms that strike Viet Nam have wind force of 10 to 12, that is wind speeds of 30 metres a second to 42 metres a second (see also Part 4).

Storms usually move at the speed of from 10 km/h to 20 km/h, therefore in places where the storm centres pass by there is strong wind changing its direction and blowing hard for 3 to 4 hours running. Besides, there are storms, moving very slowly, which strike the land with strong wind blowing for 10 to 12 hours running.

Storms carry heavy rain with them. Each storm brings to the places it strikes about 10% to 15% of the annual rain amount. In some cases, a storm can bring about 1,200 mm of rain i.e. 50% of the annual rain amount in that locality.

Heavy damages are caused to the localities struck by storms with forceful whirlwinds and protracted rains.

Statistics show that nearly 75% of storms that strike Viet Nam mostly affect coastal areas in the North from Quang Ninh to Binh Tri Thien, while only 25% of them hit coastal areas in the South, from Quang Nam - Da Nang southwards. Especially, in the Cuu Long River Delta there are practically no hurricanes.

Besides, there are cyclones. These cyclones with violent whirlwind limited in time and scope of activities have got high speed, no less strong than storms and affect an area, hundreds of metres wide and a few kilometres long. Within dozens of minutes, such cyclones can level to the ground hundreds of houses and even electric poles. The difference of cyclones from storms is that instead of forming themselves in Eastern sea in Northern hemisphere or in West Pacific cyclones often form themselves almost anywhere in coastal areas in the Delta, the midlands and mountainous regions west of Viet Nam. Cyclones and whirlwinds most frequently occur in North Viet Nam.

2.2 Scope of Damages caused by storms

Forming itself on the Sea, a storm moves from east to west, then strikes land. Its usual direction is Eastward, South Eastward to Westward, North Westward, then changing over to the direction of East - West and finally East, North East to West, South West.

Sometimes, a storm moves very swiftly in almost a straight line, from the Sea to land, then dissipates within 2 to 3 days. Yet, there are some storms that move very slowly in complex circles or trajectories, with directions changing many times and that last for 2 to 3 weeks.

A few storms form themselves and dissipate right on the sea, but most of them hit land before their disappearance.

In Viet Nam, statistics and observations show that in the North storms often weaken and disappear in the Midlands, and in the Central part in mountain areas and Western plateaux (Figure III.2).

In North Viet Nam, the average number of storms accounts for nearly 75% of the total number of storms that strike Viet Nam. Following are the 11 localities often suffer from damages by typhoons: Quang Ninh, Hai Phong, Hai Hung, Ha Bac, Thai Binh, Ha Nam Ninh, Hanoi, Ha Son Binh, Thanh Hoa, Nghe Tinh, Binh Tri Thien. In the South, affected areas are Quang Nam - Da Nang, Nghia Binh, Phu Khanh, Thuan Hai.

2.3 Damages caused to educational buildings

Following is the number of school buildings and classrooms as well as the number of students in typhoon affected areas (Tables III.a-d).

In provinces that are frequently struck by typhoons there are 11092 kindergarten schools, general education schools and secondary education schools with 131,113 classrooms and 7,566,071 students accounting for 54.8% of the total number of classrooms and 51.2% of the students throughout the country.

School buildings and classrooms in these areas can be divided according to quality of construction as follows:

- Strongly constructed buildings in reinforced concrete	15.5%
- Buildings, with brick walls, tile roofs, etc.	58.0%
- Thatched roofs, bamboo structure, classrooms	26.5%

This shows that the number of schools and classrooms vulnerable to typhoon damages amounts to 84.5%.

Destruction and damages caused by typhoons are extremely great. In many areas, schools and classrooms were destroyed or damaged for they had to suffer from one storm after another with no time for repair in between.

2.4 Causes of damages

A typhoon is a natural phenomenon with strong wind and heavy rain that can cause terrible destruction and damages in a large area hundreds of kilometres in width along its path. Up to now, with his knowledge, man is in a position to subdue to a certain extent typhoon damages. This depends on many factors both subjective and objective. In Viet Nam, the damage and destruction are due to the following.

2.4.1 Social and economic causes

The highly affected areas are exactly those suffering from heavy war damages and destruction over the past decades. Many towns and

Fig. III.2 Typhoon affected areas in Viet Nam.

villages were completely destroyed. Since the restoration of peace, people have returned to their naive land, therefore, a lot of houses and other kinds of construction need to be built at once to meet the immediate requirements. Within 10 years after National liberation hundreds of classrooms have been temporarily built with various kinds of materials for the children to go on with their learning.

These makeshift classrooms are not up to modern standards desired by Ministry of Education, and are liable to damages caused by time and nature. Due to limited resources, Ministry of Education has aimed to improve the learning conditions for our pupils. As a result, throughout the country there are about 75% of schools and classrooms are made of bricks and tiles.

Table III.a Schools in typhoon affected areas
1986 - 1987 school year

Names of provinces	Number of Schools			Total
	Kindergarten	General Education	Secondary Education	
Highly typhoon affected				
Quang Ninh	89	236	22	347
Hai Phong	180	221	27	428
Hai Hung	427	429	45	891
Ha Bac	118	347	28	493
Thai Binh	290	300	27	617
Ha Nam Ninh	474	526	52	1,052
Hanoi	378	447	57	882
Ha Son Binh	168	443	44	655
Thanh Hoa	512	622	45	1,179
Nghe Tinh	635	818	68	1,521
Binh Tri Thien	295	487	33	815
Total				8,880
Less typhoon affected				
Quang Nam - Da Nang	205	389	30	624
Nghia Binh	272	410	33	715
Phu Khanh	160	282	28	470
Thuan Hai	146	246	11	403
Total				2,212

Table III.b Classrooms in typhoon affected areas
1986 - 1987 school year

Names of provinces	Number of Classrooms			
	Kindergarten	General Education	Secondary Education	Total
Highly typhoon affected				
Quang Ninh	757	2,695	239	3,694
Hai Phong	1,545	3,213	336	5,094
Hai Hung	3,075	6,178	669	9,922
Ha Bac	2,204	5,624	482	8,310
Thai Binh	2,160	3,905	444	6,509
Ha Nam Ninh	4,459	8,168	865	13,492
Hanoi	2,976	6,842	816	10,634
Ha Son Binh	1,890	6,121	527	8,538
Thanh Hoa	3,311	8,388	797	12,496
Nghe Tinh	5,147	11,930	1,301	18,368
Binh Tri Thien	2,072	5,542	424	8,038
Total				105,092
Less typhoon affected				
Quang Nam - Da Nang	1,934	5,550	386	7,870
Nghia Binh	1,905	6,700	493	9,098
Phu Khanh	1,357	4,137	293	5,787
Thuan Hai	621	2,479	166	3,266
Total				26,021

Table III.c Students in typhoon affected areas
1986 - 1987 school year

Names of provinces	Number of Students			Total
	Kindergarten	General Education	Secondary Education	
Highly typhoon affected				
Quang Ninh	19,901	145,104	19,065	184,070
Hai Phong	49,019	247,090	32,067	328,176
Hai Hung	97,329	444,214	44,262	585,805
Ha Bac	66,658	383,796	27,491	477,945
Thai Binh	65,487	303,684	27,066	396,237
Ha Nam Ninh	119,962	544,707	48,597	713,266
Hanoi	98,107	545,401	62,868	706,376
Ha Son Binh	55,682	330,359	37,968	424,009
Thanh Hoa	120,665	533,374	50,140	704,179
Nghe Tinh	147,143	692,914	66,616	906,673
Binh Tri Thien	62,722	358,698	25,411	446,731
Total				5,873,467
Less typhoon affected				
Quang Nam - Da Nang	55,638	358,099	31,826	445,563
Nghia Binh	85,775	507,950	32,721	626,446
Phu Khanh	52,003	304,346	22,564	378,913
Thuan Hai	29,212	202,899	9,571	241,682
Total				1,692,604

Table III.d Damages caused by typhoons from 1977 to 1985

Kind of area	Classrooms		Destroyed Educational Equipment	
	Destroyed	Damaged	Desks (sets)	Books
Highly typhoon affected	22,635	27,838	107,227	3,443,000
Less typhoon affected	3,198	4,497	18,371	515,000
Total	25,833	32,335	125,598	3,958,000

Furthermore, over the past years, educational development has exceeded economic development. There has been a decrease in investment for educational buildings as well as in the supply of basic building materials. Many schools, built by local people do not follow any recommended design as the Ministry of Education does not monitor or give any guidance to design and development of individual schools. Consequently, this leads to random school development. Many schools have been built at high costs but with low qualities.

In brief, the number of schools that can resist typhoons without any damage only account for 15.5%, thus destruction and damages are unavoidable.

2.4.2 Technical causes

(a) Planning. Due to the pressing needs for construction, planning for the building of many schools was not done or poorly carried out and consequently they suffered from heavy damages when struck by storms. In this case, the choice of location is wrong.

There are a few examples.

Schools are built in open areas, exposing themselves to wind, so natural damages are likely to happen. (Figure III.3)

Schools are located in high places or hills in the full force of wind.

Schools are positioned in places full of draughts. (Figure III.4)

Many schools have got good places for construction, but general site planning is wrong so heavy damages are likely to occur. Here are some instances.

Rooms are arranged in line creating a wall against the wind. (Figure III.5)

Rooms are arranged in the shape of H forming a bag full of wind. (Figure III.6)

Trees are planted in wrong positions not leaving enough safe space so when there is a typhoon trees are broken and fall levelling houses to the ground.

(b) Design and structure. Among the causes that lead to the collapse of many constructions there are two main ones.

- Classrooms are too large in size. Most of the classrooms that have been constructed have the dimensions of 6 m x 9 m. The unsupported walls are too long to be strong enough to resist typhoons. (Figure III.7) (see also Part 4)

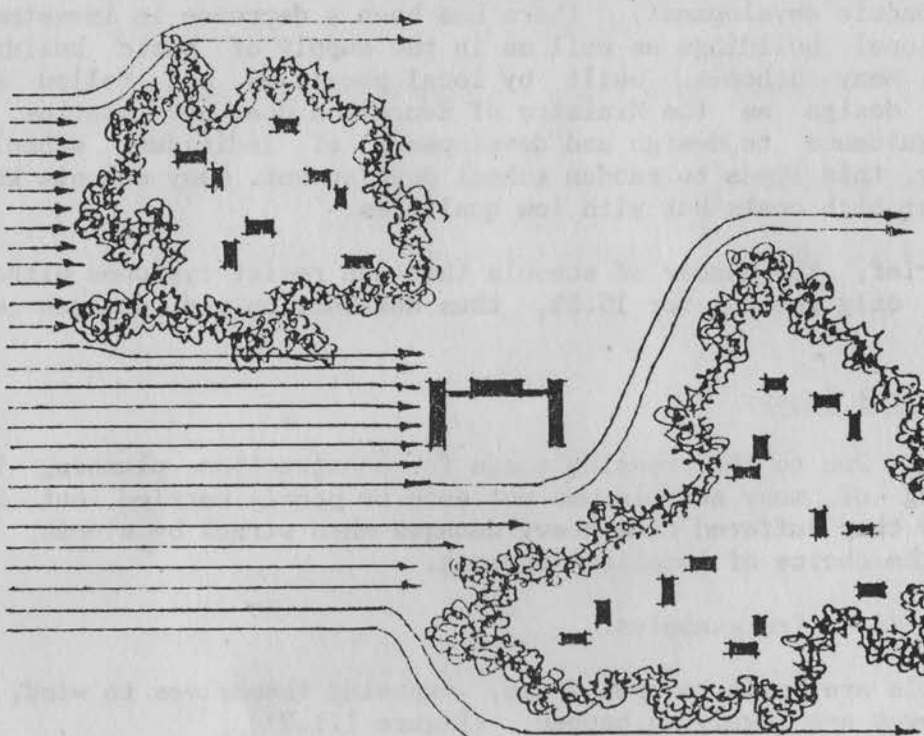


Fig. III.3 Schools positioned in open places.
Villages surrounded by bamboos.

Fig. III.4 Schools placed in a valley full draught.

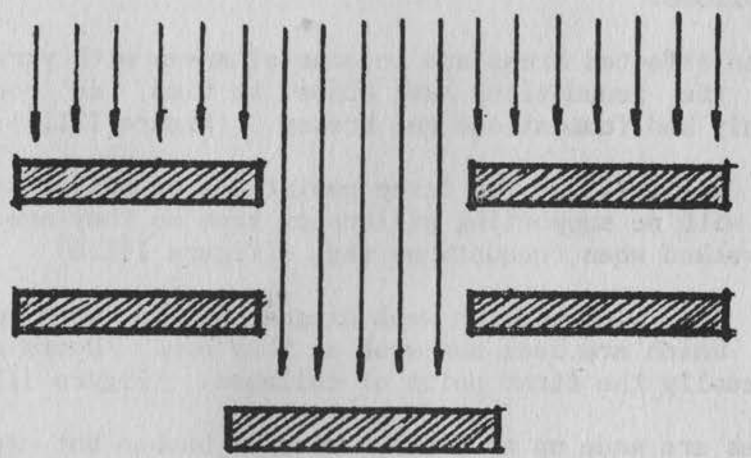


Fig. III.5 Houses arranged in walls standing against the wind.

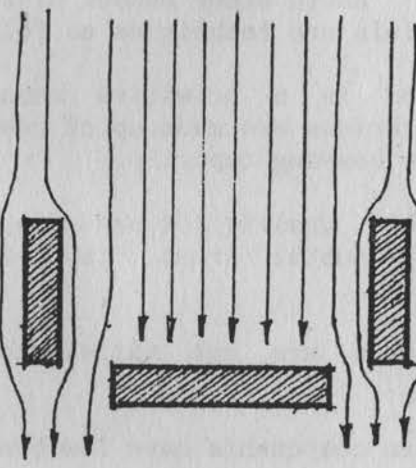


Fig. III.6 Schools arranged in ├──┤ shape forming a bag full of strong wind.

- Most of the classrooms are built without taking into consideration the force and pressure of the wind created by typhoons. They are only based on experience.

There are other shortcomings concerning components of the construction as follows.

- Typhoon affected areas are in coastal areas with very soft soil while the foundations have almost to ties, so rooms settle unevenly and foundations get broken. (Figure III.8)

- Walls built either for force resistance or protection are very thin with no supporting pillars or ties so they are likely to get cracked when foundations sag. (Figure III.8)

- Doors and windows with weak hinges all the more weaken the walls which are long and weak as they are. Doors and windows are usually the first point of collapse. (Figure III.9)

- Trusses are made up of steel, wood or bamboo but are not bound together nor bound to the walls. Roof sheets are not tied tightly to rafters and roofs have no ceilings, thus they are easily get blown away. (Figures III.10, III.11, III.12, III.13, III.14)

In general, every component has weak points, and all the components are not joined together into a solid block, so when the rooms are struck by typhoons they collapse in this order, doors and windows, then roofs and finally walls. (see also Part 4)

(c) Building techniques. Among other causes of failure there are some concerning building materials and techniques as follows:

- Bricks are baked in a primitive manner. They have low strength. Some bricks are made up of coal waste, not baked, and they have low bearing capacity.

- Mortar is of bad quality for sand is mixed with organic substances. In coastal areas, sand is mixed with saline matter.

- Building techniques are not satisfactory. Bonding lines coincide.

- The joints between components have low bonding capacity.

- Bonding lines are not filled up with mortar.

(d) Repair and maintenance. Repair and maintenance work is not regularly done, consequently the resistance of the construction declines. Sometimes, serious damages occur, such as:

- Doors and windows are lost or damaged, wind blows off roofs. This leads to other damages.

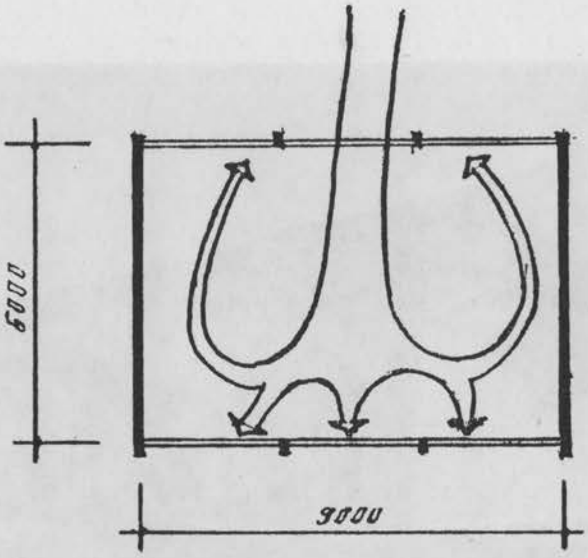


Fig. III.7 Classrooms too large in size.

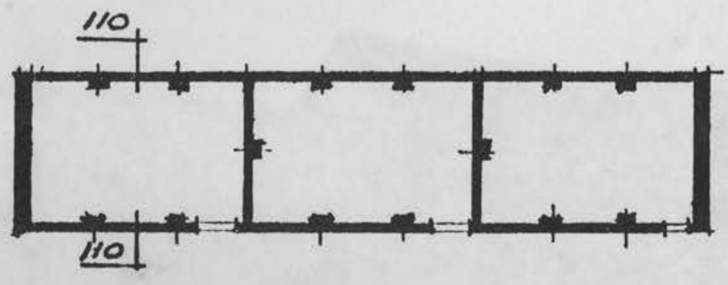
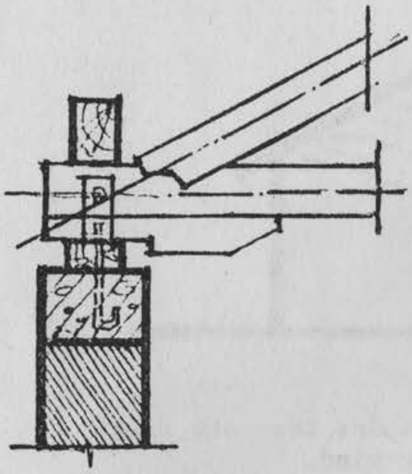


Fig. III.8 Classrooms with walls 110 mm thick, supporting pillars not strong enough to resist typhoons.

Fig. III.9 Doors and windows with hinges attached to walls, unable to resist strong wind.

Fig. III.10 Rafters just placed on walls.
Inverted trusses visible through windows.



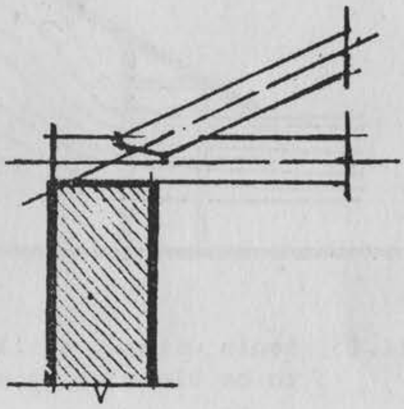


Fig. III.11 Ends of rafters bolted to cushion unable to resist typhoons.

Rafter ends placed on pillars unable to resist typhoons.

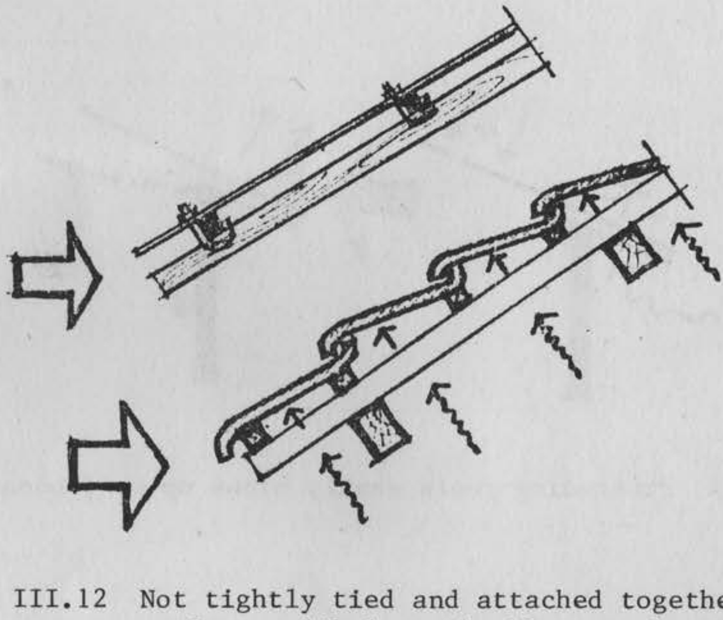


Fig. III.12 Not tightly tied and attached together, roofs are likely to be blown up by typhoons.

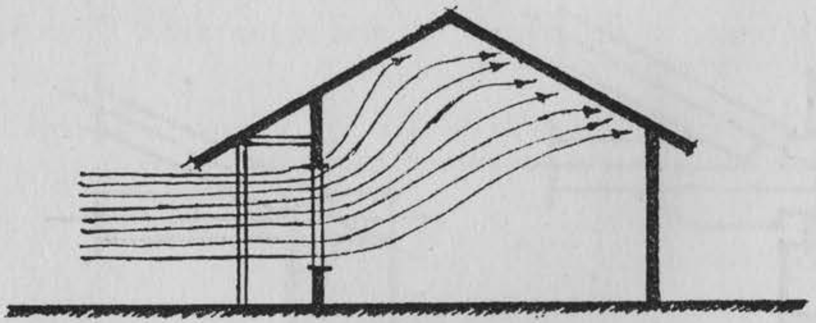


Fig. III.13 Roofs without ceilings under them are likely to be blown up by strong wind.

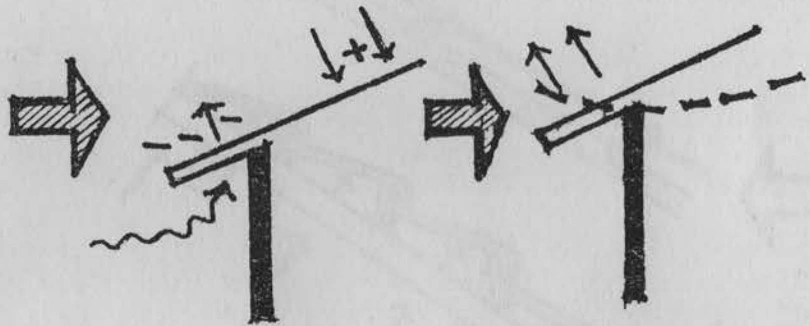


Fig. III.14 Protruding roofs easily blown up by typhoons.

- The mortar coat gets swollen and cracked, or the lime paint layer is not applied regularly, so the rain gets into walls. This lessens the bearing capacity of the walls.

3. LESSONS AND EXPERIENCES

From an analysis of the causes of damages mentioned above we can draw the following conclusions:

- The construction of educational buildings over the past years is only aimed at quantity rather than at quality.

- Unplanned development of schools does not correspond to economic management.

The work of monitoring and guidance is neglected, norms and standards are not sufficiently defined. Research work and design work have not received close attention. Guidance and inspection work is neglected. No exchanges of experience have taken place.

PART 2. MEASURES AGAINST TYPHOON DAMAGES

On the basis of an understanding of the causes of typhoon damages we can propose the following measures:

1. PLANNING MEASURES

1.1 Choice of location for school construction

Along with economic and technical reasons, the choice of location for construction should take into account the advantage of the geographical situation that can reduce or prevent the effects of typhoons. In concrete terms, this should be:

- that schools should be built in places with advantageous geographical location that can provide protection from typhoons. It is necessary to take advantage of the existing houses, buildings, trees, bamboos, etc. that can act as shields for schools. (Figure III.15)

- that schools should be built on foot of hills, mounds, the height of these hills or mounds can bar the wind and its damages. (Figure III.16) (see also Part 4)

1.2 Surface planning

What should be done are as follows:

- Choice of proper sizes for classrooms; avoidance of long blocks.

- Rational arrangement of buildings in geographical locations that can reduce or prevent typhoons.

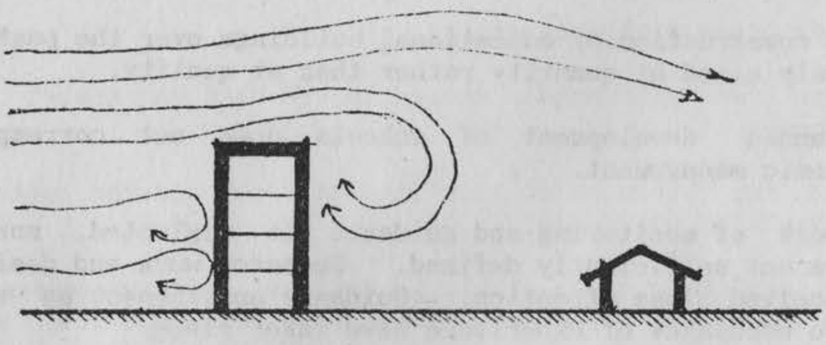


Fig. III.15 Classrooms situated behind tall buildings.

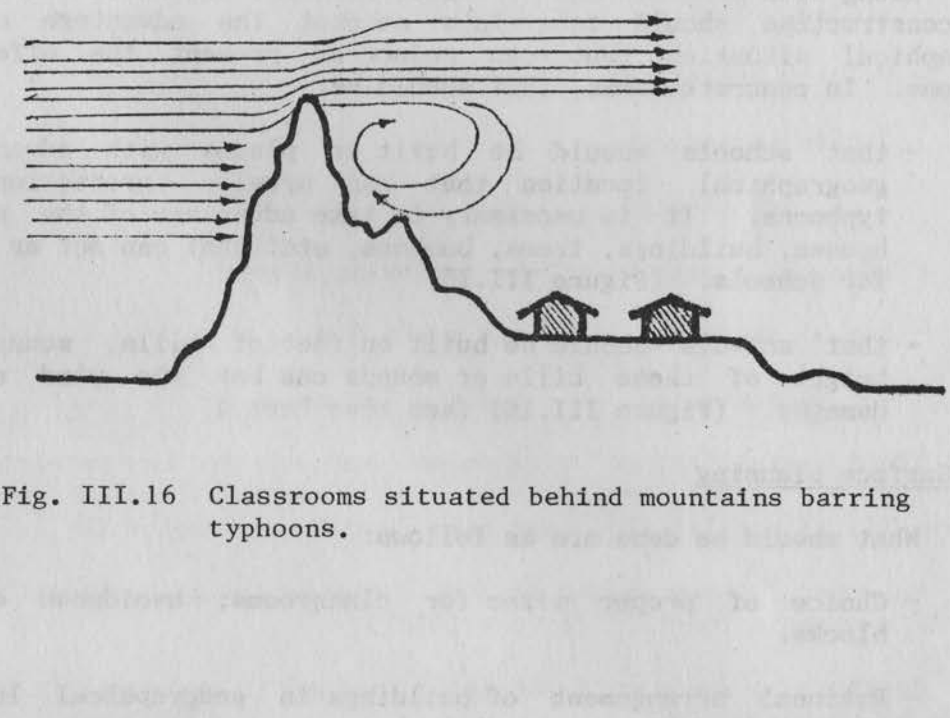


Fig. III.16 Classrooms situated behind mountains barring typhoons.

1.3 Planting trees for protection

Beside taking advantage of the existing village buildings, bamboos and lines or blocks of trees, we should locate new trees for shade or for surrounding the school properly in lines so as to provide protection. In doing this, it is necessary to:

- choose trees that can grow fast;
- choose trees with deep roots;
- choose trees with needle shaped leaves that can resist cyclones;
- decide the thickness of each line of trees and the intervals on the basis of windforce;
- make sure that there should be rational distance between trees and classrooms so that in case they fall down they will not strike the rooms.

2. TECHNICAL MEASURES

2.1 Concerning structure

Statistics show that in typhoon affected areas small sized classrooms can be built. Each classroom can provide 1 m2 a student. Following are some statistics for reference.

The average number of students per class:

- Kindergarten:	25 - 30
- Primary education:	30 - 35
- Junior Secondary:	35 - 40
- Secondary (Senior):	40 - 45

Classrooms should be of the following sizes:

- For 30 students:	5,4 m x 6,6 m
- For 40 students:	5,4 m x 7,2 m

These small sized classrooms can easily be repaired and maintained to resist typhoons at the time of limited resources. (Figures III.17 and III.18) (see also Part 4 and Chapter IV)

Moreover, there should be 2 or 3 classrooms joined together only 20 to 22 metres in length. (Figure III.19)

Overhanging components should be avoided in order not to be blown upwards by strong winds.

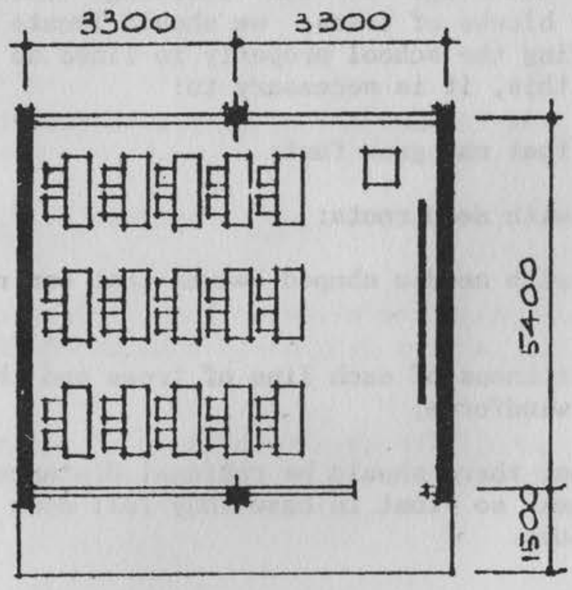


Fig. III.17 Small-sized classrooms (30 seats) restricting typhoon damages.

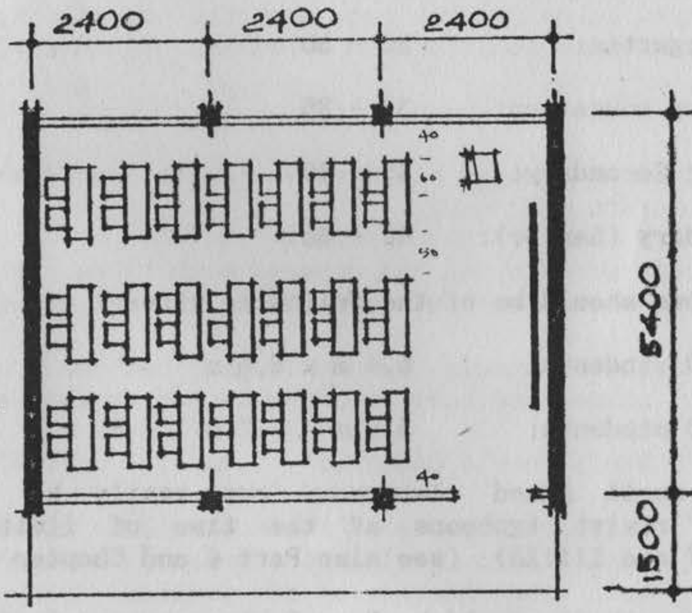


Fig. III.18 Small-sized classrooms (40-42 seats) restricting typhoon damages.

It is necessary to take into account wind force while a typhoon is raging. Each component of the construction must meet the following requirements:

Foundations:

- Foundations should be strong enough to resist all kinds of forces affecting them.

- There should be foundation ties to prevent cracks of walls when the earth settles.

- There should be joints allowing for differential settlement when the site is in geologically complex or foundations are long.

- Foundations should be in virgin layer of earth at the depth required by accepted norms.

Walls:

- Walls should be strong enough to resist all kinds of force.

- There should be ties inside them.

Doors and windows:

- To ensure the connection between doors and windows to resist typhoons, doors and windows should be of 2 kinds: Door frames fastened to walls with hook anchors; or sliding doors close to walls with moulds fastened to walls. (Figure III.20)

Roofs:

- If there are enough building materials, roofs should be made up of concrete and steel.

- If roofs are sloping and covered with tiles, fibre-cement, or aluminium sheets, they should meet the following requirements.

    : There should be ceilings, best made up of lath and plaster to keep cool and to resist rain and wind;

    : Roofs should be of 30° (see also Part 4).

    : Different parts of roofs should be closely fastened to each other, purlins to trusses, trusses to walls, in both the horizontal and vertical planes. Beams and other parts should also fastened to trusses and to roof sheets.

    : Trusses should be fastened to walls with steel hooks.

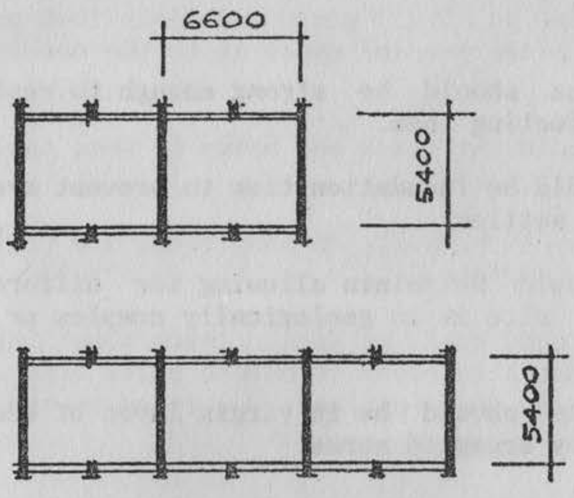


Fig. III.19 Classrooms should be in lines of 2 or 3 classrooms only.

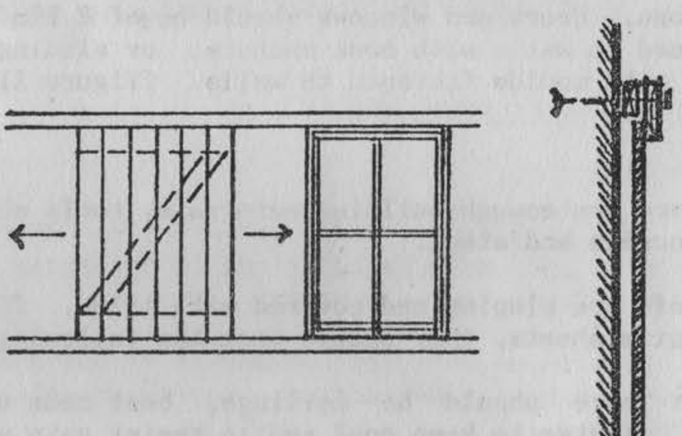


Fig. III.20 A kind of sliding windows resistant to typhoons.

Application of traditional experience

Vietnamese folk and traditional architecture reflected in Buddhist temples that have been standing firm against typhoons for centuries shows that we should study and learn from past experience of the traditional architecture and apply it to the construction of typhoon resistant schools.

- Roofs should be thick and heavy to keep cool and to resist typhoons.

- Houses should be built on wood frame and pillars firmly fixed on a floor surface.

- With thatched roofs we should learn something from the bamboo net attached to roofs or bamboo poles attached downward from top of roofs (over-battens) and fixed to the ground around the house.

3. ADMINISTRATIVE MEASURES

3.1 Design and construction

It is necessary to:

- Revise the existing standards and regulations, and if necessary, develop certain standards and regulations for design and construction of schools in typhoon affected areas.

- Develop regulations for strict examination and inspection of designs.

3.2 Model designs and research work

It is necessary to:

- Carry out studies in order to establish diagrams of force resistance and make calculations to determine the shapes and dimension of all the components;

- Carry out studies on types and models of building materials to be used in school construction, paying attention to the use of materials available in each locality.

- Carry out studies and prepare prototype designs for classrooms of different sizes.

- Study measurements of general planning for schools of different sizes in typhoon affected areas.

- Study details of doors, rafters and other forms of joinery.

- Study and select the kind of trees to be planted for protection, distance and density of lines of trees against typhoons.

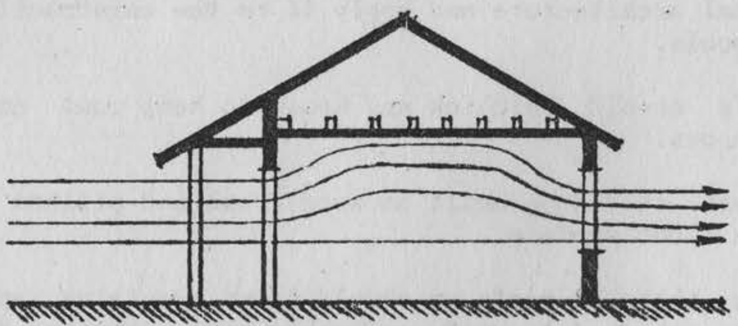


Fig. III.21 Classrooms with ceilings under them as hard surface restricting typhoons from blowing up roofs.

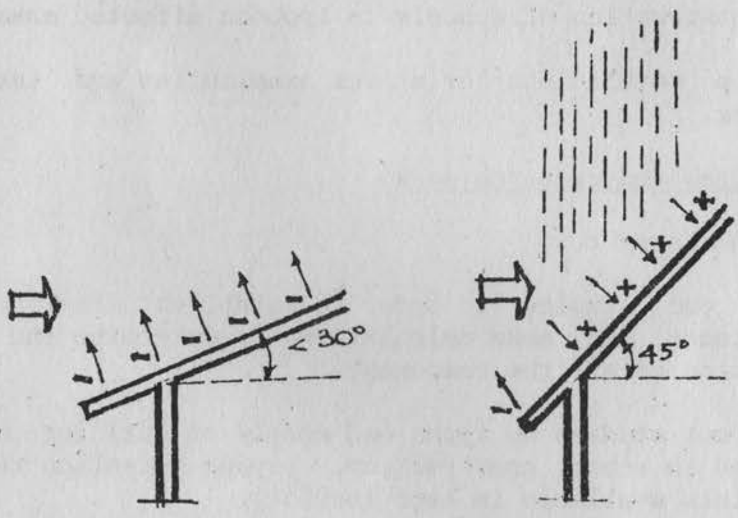


Fig. III.22 Roofs of 30 degree slope likely to be blown upwards by typhoons.

Roofs of 45 degree slope preventing them from being blown up by typhoons and leakage due to heavy rain and strong wind.

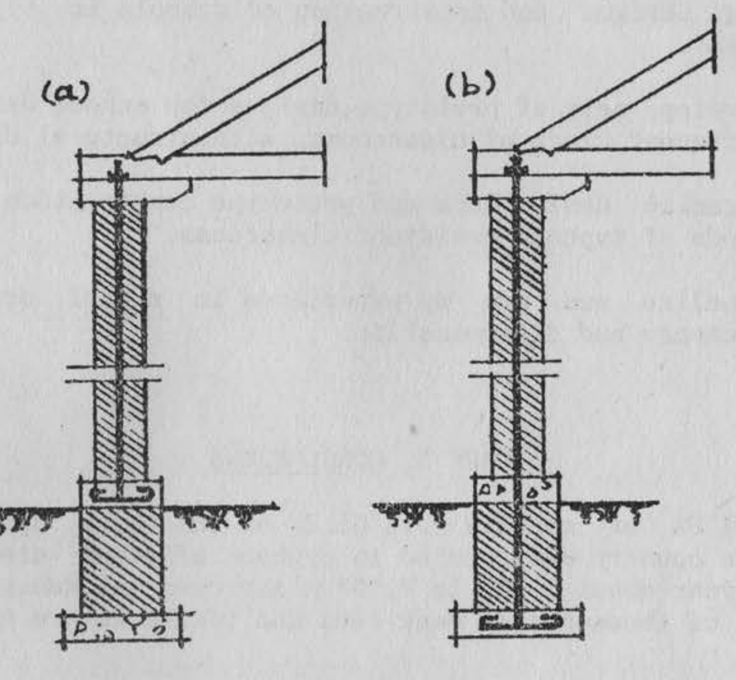


Fig. III.23 Steel anchor fixed from rafter end to foundation.

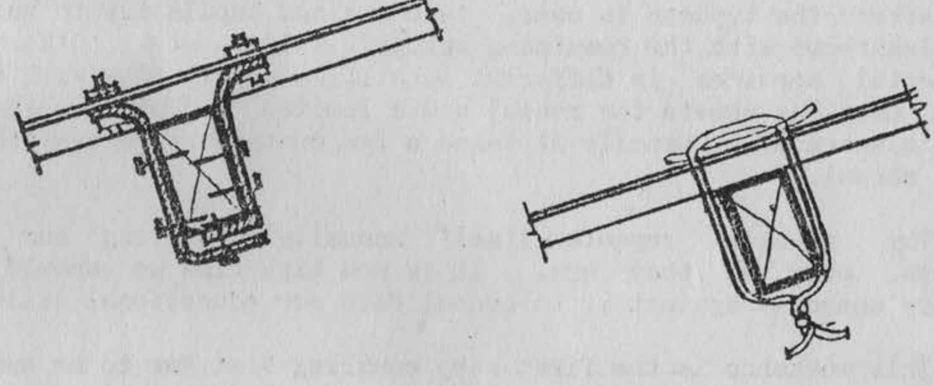


Fig. III.24 Linkage from roofing materials with roof frames to restrict damages by typhoons.

3.3 Administrative work

It is necessary to:

- Develop regulations on administrative responsibilities concerning designs and construction of schools in typhoon affected areas.

- Develop sets of prototype designs for school development, for different kinds of classrooms, with structural details.

- Organize design work and prototype construction of different kinds of typhoon resistant classrooms.

- Finalize and sum up experience in school construction for exchange and dissemination.

PART 3. CONCLUSIONS

Some 54.8% of schools with 51.2% of the total number of pupils throughout the country are located in typhoon affected areas. In these areas, every year about 6,000 to 7,000 classrooms get damaged or destroyed and hundreds of thousands of desk sets and textbooks are spoiled due to typhoons.

The serious thing is that beside the considerable material losses, millions of pupils have no classrooms and have to learn in 3 or 4 shifts in makeshift classrooms, in offices or local people's houses. This situation lasts for months, badly affecting teaching, learning qualities and pupils' health.

So far, we have only come up with passive and temporary solutions to the problem when a typhoon comes.

After the typhoon is over, teachers and pupils try to build again their classrooms with the remaining bricks, tiles, etc. Other concerned governmental services in different localities supply them with tar paper (to be used as sheets for roofs) and a limited budget to restore the damaged classrooms. Usually it takes a few months before everything comes back to normal.

The problem repeats itself annually depleting our material resources, poor as they are. It is now high time we should take up necessary measures against it to consolidate our educational buildings.

This workshop is the first step enabling Viet Nam to be aware of the problem, to evaluate the causes of damages and destruction in the past years as well as measures to be taken against the problem in the near future. This also is a change for educational builders and managers to master some theoretical aspects and technical experience concerning typhoon resistant schools development from other countries in Asia and the Pacific. On that basis we should renovate our ways of thinking and action.

It is necessary to implement the recommendations approved at this Seminar step by step.

The problem should be solved on an economic and technical basis. In recent years, SRV Ministry of Education has been given both technical and financial assistance from UNESCO-PROAP. This workshop is an example. It is our great hope that over the next years, UNESCO-PROAP will continue their support and assistance for our Project on typhoon resistant schools development as already agreed upon.

PART 4. COMMENTS ON REPORT BY K.J. MACKS

PART ONE : Wind speeds

Meteorological data on wind speeds and pressures may be inaccurate due to location of anemometers at some distance from coast and their inability to survive storms without breaking. Actual 5 second gusts on the coastal areas may have exceed 50 m/s (180 km/hr).

Para 2.4.2(b) - Classroom size

The comment is made that classrooms are too large and cannot resist typhoon forces. In fact the problem is that the walls are not stable enough to resist the forces. Therefore action to make the walls stronger would be a better policy than making rooms smaller.

Para 2.4.2(b) - Continuity of correction

The causes of failure are correctly identified:

- Trusses not tied together
- Trusses not tied to walls
- Walls unable to transfer loads (no ring beam at top)
- Walls not tied to foundations
- Lack of vertical tension component in walls
- Lack of bracing in roof framing
- Lack of bracing in wall panels
- Lack of reinforcing in foundations
- Door and window hinges weak and poorly fixed
- Inadequate design input to schools
- Too much use of poor materials
- Inadequate workmanship and supervision
- Poor or no maintenance of completed buildings

PART TWO

Figure 15, para 1.1

Where schools are located behind high buildings in order to get their protection they should not be sited too close to the protecting building otherwise they will be affected by higher wind forces caused by turbulence as the wind passes around the corners of the high building. It is suggested that a distance of from 80 - 100 m be a minimum space between the high building and the school.

Para 1.3 Tree protection

Tree protection and other landscape techniques are good but only if the trees are capable of withstanding the wind forces and are not easily broken. Research in this area is needed.

Para 2.1 Classroom size

Reducing the size of the classroom will not avoid problems of poor design and construction in wall and roof areas.

Para 2.1 Roof slopes

Wind forces on roofs change from suction on slopes of less than 25-27° to pressure on roof slopes pitched at 30-40°.

Steep slopes on roofs cause special problems as the ridge is affected by high turbulence and this creates pressure. The result is that the high roof has to transfer a large wind load which tends to overturn the building.

IV. GENERAL PRINCIPLES OF EDUCATIONAL BUILDING DESIGN WHICH HAVE RELEVANCE TO TYPHOON AFFECTED AREAS

by John Beynon
Principal Architect, UNESCO, Bangkok

Educators often complain that their requirements as school building users go unheeded by architects; architects complain that engineers insist on structural solutions which interfere with architectural concepts; and engineers are often baffled as to why such a dialogue need to take place at all. This short paper is intended to review some of the principles of educational buildings (in particular teaching spaces) in such a way as to show how solutions can be found which will meet the desires of all three professional groups. As the subject of the training course is educational buildings in cyclone affected areas, this paper looks particularly at the special needs of these schools. Cyclone areas, it is worth noting, are all located in the tropical zones of the globe.

1. Optimal Learning Environments

Lighting. Light levels in classrooms must be relatively high - from 100 to 300 lux - and should be obtained through daylighting. This requires large wall openings of 15 to 45% of the floor area. It is also preferable to have bilateral lighting which makes seeing easier for learners.

These two requirements mean that schools must have large window openings. This can pose problems for the architects and engineers who need to brace these buildings well. (Figures IV.1, IV.2)

Ventilation. It is the seated children who need to be made comfortable. Therefore, ventilation openings should be placed in walls at a height corresponding to the seated children. It is also important to reduce radiant heating from the roof surfaces which are normally exposed to the sun. It is essential therefore, that teaching spaces have ceilings located well below the roof and that the space between roof and ceiling be well ventilated to take away the hot air which builds up between them.

Providing permanent ventilation openings on either side of a classroom has the advantage of lowering internal pressures during strong winds. The installation of of a ceiling can benefit the design because if it is made of solid material it can provide diaphragm action. (Figures IV.3, IV.4)

Buildings need to be oriented so as to catch the prevailing winds. This can create problems for designers as it may also be the orientation which is most liable to cause damage by cyclones. (Figure IV.5)

Sun Control. The windows of teaching spaces should be oriented to the North and the South to permit the best control of the direct rays of the sun. Again, this may result in bad orientation as regards cyclone and their associated wave surges. (Figure IV.1, IV.5)

Acoustic. It is difficult for most teachers' voices to be easily heard for more than seven meters. This means that classroom should not be more than about eight meters long. (Figure IV.6)

2. Optimal Teaching Environments

Classroom size. The basic determinants of classroom size are the number of students to be taught in a class and the amount of space which is to be given to each student as well as to the lecturing space and group work activities at the front and rear of the room. The research which has been done indicates that if students are provided with double desks having adequate space to write while referring to an open textbook desk tops should be 1100 mm x 450 mm for primary school students and 1100 mm x 450 mm for secondary school students. Aisle space should be at least 45 cm while 2 meters should be provided between the chalkboard and the first desk and 600 mm is needed to provide access to a tack board at the rear of the room. Figures IV.7 and IV.8 give the basic data which can be applied to classroom design at primary and secondary level.

For reasons of acoustics and sight lines, it is recommended to have seven rows of pupils or less. The table below shows the minimum area per place in which students can comfortably work.

		CR capacity with 7 rows	CR size (mm)	Area (m2) per place
Primary	6 per rank	42	4200 x 9040	0.90
	8 per rank	56	5750 x 9040	0.92
Secondary	6 per rank	42	5100 x 9040	1.10
	8 per rank	56	6950 x 9040	1.12

Flexible space. Class sizes are usually not the same which means that if equal size classes are provided some rooms will be over-utilized and others under-utilized. In these cases, there is a need for a variety of sizes of spaces in any educational institution. In many countries a long open hall school building which can be divided into spaces of variable sizes will be most efficient. (Figure IV.9)

This means that it is preferable to separate classrooms with partitions that can be moved. They should not, therefore, be structural. On the other hand, cross walls provided excellent diaphragm action and on very long buildings may have to be provided every second or third classroom.

Chalkboards and other visual aids. Chalkboards need to be located so that there is a minimum of glare. When chalkboards are placed between windows the light contrast is so great that it is difficult to read the writing on the board.

To increase visibility, a curved "panoramic" board can be used and the solid sections of the walls should have at least one meter of solid wall projecting in front of the chalkboard location. Chalkboards may be mounted on light partitions which separate classes. (Fig. IV.10)

Display surfaces. Good schools have places to display the work of students and also to present supplementary learning materials such as posters. Since many of these materials are prepared with dark printing on light surfaces these can effectively be located between windows on the side walls, or on either side of the chalkboard. They may also be mounted on the walls at the rear of the classroom. (Figure IV.10)

Storage. All classrooms need a place to store teaching and learning materials. These can be provided as built-in units located next to the end walls and integrally surrounding intermediate columns. These can provide substantial stiffening if they are incorporated into the structural design. (Figure IV.11)

3. Protection from the Weather

Roofs. The width of classrooms is such that they are most easily spanned by trusses. If flat roofs are required and reinforced concrete beams are used these beams may have a very deep section; if they are kept shallow the costs rise substantially.

The use of trusses which give sloping roofs can result in a roof shape which performs well in strong winds. The use of reinforced concrete beams has the advantage that they can be cast integrally with a reinforced concrete ring beam. Flat roofs have the advantage in some countries that they make it easier to expand the building vertically. (Figure IV.4) However they collect water and are usually susceptible to leaking and to corrosion of reinforcement bars.

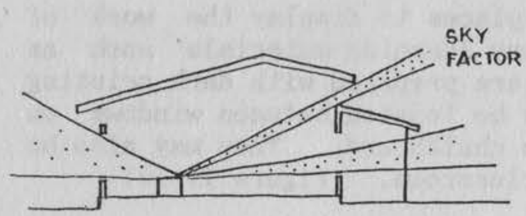
In many countries, it is desired that a verandah be provided along one side of the classroom. In all countries affected by cyclone it is desirable to have a substantial roof overhang to keep rain off the exterior walls.

Verandahs and large roof overhangs are among the parts of a building which are most vulnerable in strong winds. (Figure IV.1)

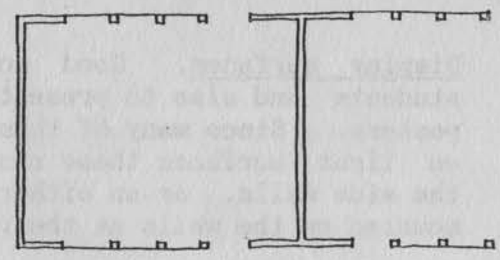
Walls. Exterior walls are required for reasons of security, to provide tackboard space and to keep out horizontally driven rain. They need corner bracing if they are to be kept rigid. In many countries, it is not yet feasible to use glass in the windows and they must, therefore, rely on wooden or steel shutters.

Walls, as well as roofs, must be designed to resist wind loads. Creative solutions may be required so that walls will meet the needs for strength as well as to provide satisfactory wall openings. (Figures IV.11, IV.12)

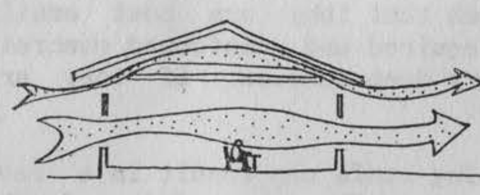
Floors. In many localities where there is flooding, one common architectural solution is to raise the building above the ground on stilts. Raising the building introduces additional costs and requires the engineers to find solutions which are structurally sound yet economical. Architects can take advantage of these raised buildings to provide covered play space or temporary classroom space. (Figure IV.13)



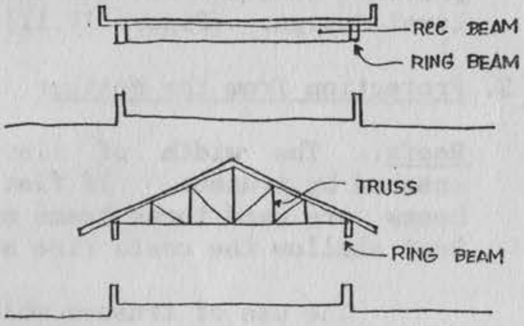
IV.1 DAYLIGHT · ILLUMINATION



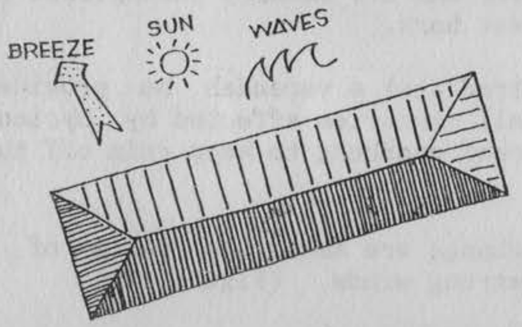
IV.2 MAXIMUM OPENINGS



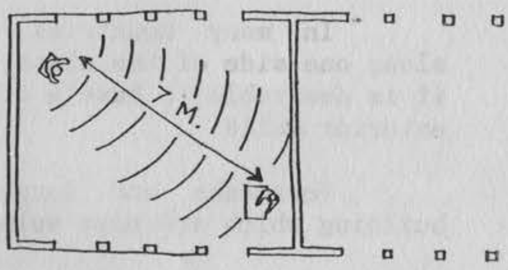
IV.3 NATURAL VENTILATION



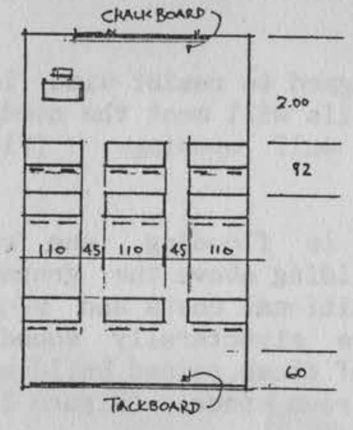
IV.4 STRUCTURE



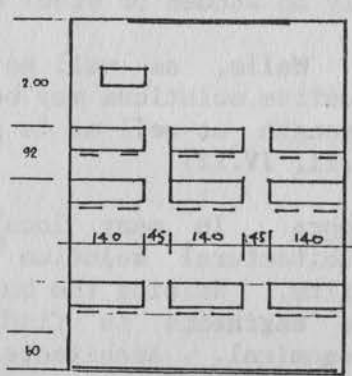
IV.5 ORIENTATION



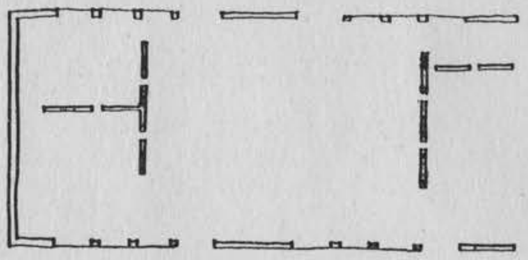
IV.6 ACOUSTICS



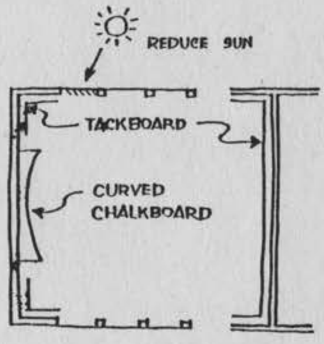
IV.7 PRIMARY LEVEL



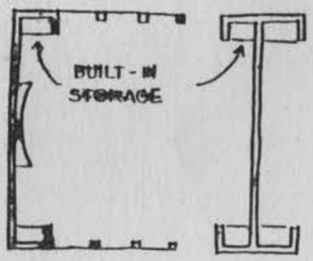
IV.8 SECONDARY LEVEL



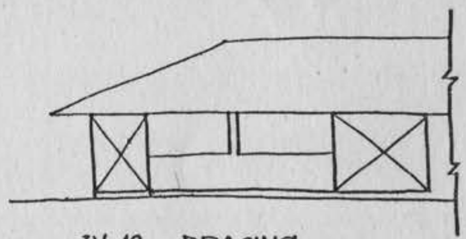
IV. 9 FLEXIBLE SPACE



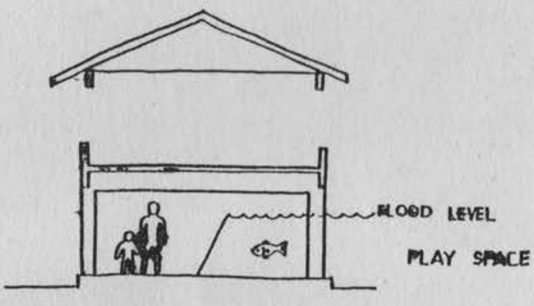
IV. 10 CHALKBOARDS / TACKBOARDS



IV. 11 STORAGE AS BRACING



IV. 12. BRACING



IV. 13 BUILDING ON STILTS

V. CONSIDERATIONS FOR THE DESIGN OF TYPHOON RESISTANT BUILDINGS IN VIET NAM

1. BRIEF COMMENTARY ON WIND FORCE EFFECTS

Windspeed. The wind moves over the ground at a certain speed normally referred to in metres per second (m/sec), kilometers per hour (km/hr) or miles per hour (miles/hr). In a cyclone or typhoon as in all wind environments the wind fluctuates and changes speed rapidly so that in a period of one hour, the forward wind speed is less than the maximum wind speeds which are achieved over periods of a few seconds only. The fastest design wind speed, which is the windspeed used in cyclone wind design, is that which occurs in a three second wind gust. This is referred to as the design wind velocity speed (V). Design windspeeds are normally those which occur at a height of 10m above the ground on an open, inland terrain (category 2) and are based on a 50 year return of the wind event.

Height. The wind speed and wind gust varies with height, being slower near ground level where the wind is slowed down by the roughness of the ground, and faster at high altitudes where there is less interference to the wind's forward speed. This effect can be measured at altitude intervals of 10 meters and thus taller buildings are subjected to higher wind speeds than are low buildings. A design factor for different building heights has been established.

Wind Zone. Due to various geographical features cyclonic storms occur with predictable frequency in different locations. Cyclones are at their strongest over water and once they have travelled up to 50 km inland lose a substantial part of their force. By reviewing meteorological data of a country subjected to cyclones it is possible to define the zones which will get the strongest winds, strong winds and less strong winds. These wind zones are labelled A for wind gusts of up to 60 m/s, B for wind gusts up to 50 m/s and C for winds up to 40 m/s. Wind zones for Viet Nam are shown in Figure V.1.

Terrain Category. The smoother the ground surface the less friction there is for the wind and therefore faster wind speeds result at building height levels. Ground roughness characteristics known as terrain categories have been defined. In general these can be ranked as follows from fastest wind speeds to slowest: flat sea coast areas, exposed hills, level open ground, built-up suburban regions, forested areas and densely built-up city areas. A design factor for terrain categories have been developed and is given in Fig. V.2.

Wind Pressure. The wind speed can be converted into the pressures exerted on a plane surface normal to the wind. Table V.A covers all commonly used units of measure for both wind speed and free stream dynamic pressure. This table may be used for conversion of wind speed into pressures.

Structural Wind Loads. Winds create both positive and negative pressures on buildings. The windward planes which are tending to be pushed toward the inside of the building are considered to be positive external pressures. Those pressures which are caused by the airfoil effects of

Table V.A CONVERSION OF WIND SPEED TO FREE STREAM DYNAMIC PRESSURE TABLE

SPEED				FREE STREAM DYNAMIC PRESSURE			
m/sec	Knots	miles/hr	km/hr	lbf/ft^2	kgf/m^2	N/m^2 Pa	kPa
0.278	0.540	0.621	1.000	0.001	0.005	0.047	0.00005
0.447	0.868	1.000	1.609	0.003	0.012	0.122	0.0001
0.514	1.000	1.150	1.850	0.003	0.016	0.162	0.0002
1.000	1.942	2.237	3.600	0.013	0.063	0.613	0.0006
1.277	2.480	2.856	4.597	0.021	0.102	1.000	0.001
4.000	7.770	8.947	14.40	0.205	1.000	9.808	0.010
8.835	17.162	19.762	31.81	1.000	4.883	47.85	0.048
10.000	19.425	22.368	36.00	1.282	6.255	61.30	0.061
20.0	38.85	44.74	72.02	5.124	25.02	245.2	0.245
30.0	58.28	67.10	108.0	11.53	56.29	551.7	0.552
35.0	67.98	78.29	128.0	15.69	76.63	750.9	0.751
40.0	77.70	89.47	144.0	20.50	100.0	980.8	0.981
40.3	78.28	90.14	145.1	20.81	102.1	1000.	1.000
45.0	87.41	100.66	162.0	25.94	126.7	1241.	1.241
50.0	97.12	111.84	180.0	32.03	156.4	1532.	1.532
55.0	106.84	123.02	198.0	38.75	189.2	1854.	1.854
60.0	116.55	134.21	216.0	46.12	225.2	2207.	2.207
65.0	126.26	145.39	234.0	54.13	264.3	2589.	2.589
70.0	135.98	156.57	252.0	62.73	306.5	3004.	3.004
75.0	145.69	167.76	270.0	72.06	351.8	3448.	3.448
80.0	155.40	178.94	288.0	81.99	400.3	3923.	3.923
85.0	165.11	190.13	306.0	92.55	451.9	4429.	4.429
90.0	174.83	201.31	324.0	103.80	506.7	4965.	4.965
95.0	184.54	212.50	342.0	115.60	564.5	5532.	5.532
100.0	194.25	223.68	360.0	128.10	625.5	6130.	6.130

Formulae:

$P = 0.613V^2$ N/m^2 (Pa) for V in m/sec

$P = 0.0625V^2$ kgf/m^2 for V in m/sec

$P = 0.00256V^2$ lbf/ft^2 for V in miles/hr wind blowing around the walls or over the roofs create an external vacuum or a net negative (suction) external pressure which causes the various building planes to be pushed outward. It is the resultant sum of the positive and negative pressures which determines the total force on any plane of a buildings exterior.

As well as these external effects, a building can be pressurized with internal pressure (or vacuum) if openings occur in the building envelope.

As the external suction forces can become very strong, in high winds buildings tend to "explode". These outward forces are particularly strong on roofs where positive and negative forces combine and under some circumstances create a force stronger than the wind force itself. The Tables on Figures V.3a and V.3b indicate just how important this factor can be.

Roofs with less than 20° pitch are subjected to stronger external suctions than are roofs of greater pitch. Buildings which have an opening one side only are subjected to stronger positive pressures than buildings which are securely closed or which are open on both sides. Figure V.3a gives the pressure coefficients for buildings with openings on one side only while V.3b gives the pressures for buildings open on both sides.

As the wind passes over or around objects such as trees, ridges, fences, buildings, cliffs and valley, the wind becomes turbulent and causes local increases in air speed and wind pressure. The effect of these air pressures on the edges and perimeters of these obstructions can become much more severe than the normal wind pressure. These effects are catered for by allowing a local pressure factor "K" for critical areas of buildings. Figure V.4 shows the affected local areas of a building and gives the "K" factors. These loads are applied only in calculation of the forces on the cladding.

Other Effects on Wind Speed. The wind speed is also affected by atmospheric pressure, the ambient temperature and air density. However, for this paper, these effects are not taken into account and the factor used is 1.0.

Return Periods. Selective increases can be made to the design wind forces to cater for the expected life of a building or to give a building a greater factor of safety.

If a building is to remain intact for a once in 100 year event, it should be expected to resist the worst wind speed that could occur in a 100 year period. This wind speed would be higher than the worst wind speed expected in a period of 50 years. Therefore, the 50 year wind and 100 year wind can be referred to as specific events. Since this wind could arrive at any time, it would damage all buildings designed for a lesser event.

A 500 year or 1,000 year event would be described as catastrophic and, since meaningful records are not known for these periods, assumptions of their forces can only be assessed.

<u>Post Disaster Functions</u>. Important buildings, such as hospitals, police stations, post and telecommunication buildings, electricity generation and control buildings and refuge shelters (such as schools) should be expected to survive severe events such as cyclones so that they are able to serve their "post disaster function" during the recovery period.

Whilst most buildings should be designed for a 50 year event, most post disaster buildings should be designed for a 100 year event. The increase in design loads for the 100 year event is approximately 20%.

<u>Cyclonic Overload Position</u>. In considering the ability of building materials and their fixings that resist the cylone wind loads, it is important to remember that the materials have to resist the maximum design forces only for very short periods of approximately 3-5 seconds. These short term loads may occur many times over the duration of a storm.

Some materials are able to accept short term overload situations with enough flexibility to recover to their normal strength. As timber will flex and recover, an overload allowance of 100% is allowed in the design of timber members for 3-5 second wind gusts. Steel members are permitted on overload factor of 33%. Brickwork, on the other hand, will not recover after cracking.

2. <u>PROCEDURE TO DETERMINE WIND LOADS</u>

The following procedure may be followed to design a building which will be safe from damages in high winds.

Step 1: Collect the facts
- (a) Identify national wind zone
- (b) Identify wind speed
- (c) Identify terrain category
- (d) Identify height of building
- (e) Determine design pressure

Step 2: Determine the wind forces
- (a) Identify building dimensions, length, height, width
- (b) Determine co-efficients for wall and roof loads
- (c) Calculate structural loads - on walls
  - on roof
  - on windows

Step 3: Determine wind loads
- (a) Work out actual loads
- (b) Determine structural lines of forces
- (c) Decide on lines of resistance - in wall plane
  - in roof plane
  - in floor plane
  - in roof framing

Step 4: Design construction details and connections
(a) Decide on details
(b) Design resistance members
(c) Design fixing details
(d) Decide on materials to be used
(e) Specify workmenship required
(f) Check load areas and overturning moments

Some of the important points to be kept in mind as one works their way through this procedure are spelled out below.

1. The design wind applies to the wind speed at a height of 10m on a terrain category 2 site (e.g. at 10m on an airfield) and is based on a 50 year return wind.

2. If the site is more exposed (beside the sea) the design wind is higher. If the site is more protected (in city areas) the design wind is less.

3. If the building is higher than 10m the design wind is higher. If the building is lower than 10m the design wind is lower.

4. The design wind is to be converted to free stream dynamic pressure (e.g. kgf/m2, or pounds per sq.ft. or kilopascals). This pressure becomes the design pressure.

5. This design pressure is increased or decreased by co-efficients which provide the actual pressure applied to various parts of the building's walls and roof areas and depends on the wind direction, the disposition of openings in the building and the roof slope.

6. This pressure or suction force resulting from the design wind and the building shape is to be added to the internal pressure generated inside the building which tends to push the walls and roof outwards. The resulting total pressure is the force to be resisted by the structure of the building and is referred to as the "Structural Load".

7. In addition, the cladding materials (roof sheeting and wall materials) are subjected to local pressures tending to pull off the cladding. These forces effect the cladding only and do not affect the structure.

8. The cladding of the central wall and roof areas carry the same loads as the actual pressure. However, perimeters of walls and roof areas carry a greater suction (50% greater). While the corners of the roof and sharp ridges and projections carry an even greater suction (100% greater). These forces or pressures affect the fixing of the claddings to their immediate supporting members and are referred to as "Cladding Load".

Table V.B gives a listing of the force of airfoil affect at different wind speeds.

Table V.B AIRFOIL AFFECT : WHEN ROOFS FLY

Velocity	Typical movement
0.00 m/sec	Dead calm - Birds fly
0.23 m/sec	Leaf moves
0.50 m/sec	Leaf flys
0.75 m/sec	Paper flys
0 - 5 m/sec	
5 - 10 m/sec	Loose aluminium sheets fly
10 - 15 m/sec	Loose galvanised iron sheets fly
15 - 20 m/sec	Loose fibre cement sheets fly
20 - 25 m/sec	
25 - 30 m/sec	Loose concrete and clay files fly
30 - 35 m/sec	Roof sheets fixed to battens fly
35 - 40 m/sec	DC3 aircraft take off speed
40 - 45 m/sec	Roof tiles nailed to battens fly
45 - 50 m/sec	Garden walls blow over
50 - 55 m/sec	
55 - 60 m/sec	
60 - 65 m/sec	100 mm thick concrete slabs fly
65 - 70 m/sec	
70 - 75 m/sec	150 mm thick concrete slabs fly
75 - 80 m/sec	
80 - 85 m/sec	
85 - 90 m/sec	
90 - 95 m/sec	
95 -100 m/sec	250 thick concrete slabs fly

3. COMPARISON OF INTERNATIONAL WIND CODES

To compare the wind codes of various countries, the wind forces created by a 50 m/sec wind at 10m above ground in Site Category 2 on a 50 year return period have been calculated in these codes as follows:

Viet Nam	112.9	kgf/m2
Sri Lanka	141.6	kgf/m2
Australia	153.4	kgf/m2
USA	156.0	kgf/m2
Britain	156.25	kgf/m2

It appears that from a comparison with other National codes, the Viet Nam wind code formula generates design loads between 20 to 27% less than those from the other comparative codes.

The large variation that results from using the Viet Nam code is called to the readers' attention. On the basis of this comparison it is suggested that the Viet Nam wind code be reviewed with an eye to updating.

For reference, the formulas of the various codes used are given below along with the calculations which led to the above results.

COMPARISON OF INTERNATIONAL WIND CODES

Calculations at 50 m/sec Velocity (111.84 miles/hr)

Viet Nam

$$q_o = \frac{(av)^2}{16}\ \text{kgf/m}^2 = \frac{0.85 \times 50^2}{16} = 112.9\ \text{kgf/m}^2$$

where:
$a = 0.75 + \frac{5}{v}$
v = wind speed in m/sec

United States of America

$$Q_{30} = 0.00256\ V^2_{30}\ \text{lb/ft}^2 = 32\ \text{lbf/ft}^2 = 156\ \text{kgf/m}^2$$

where:
Q_{30} = wind pressure at 30 ft
V_{30} = wind speed at 30 ft

Australia

$$Q_z = 0.6\ V^2_z \times 10\text{-}3\ \text{kpa} = 1.5\ \text{kpa} = 153.4\ \text{kgf/m}^2$$

where:
V_z = wind speed at 10.0 m
Q_z = wind pressure kpa

Sri Lanka

$$q = KV^{\circ 2}_2\ \text{lbf/ft}^2 = 0.00232 \times 111.84^2\ \text{lb/ft}^2 = 29\ \text{lb/ft}^2 = 141.6\ \text{kgf/m}^2$$

where:
V_2 = design wind speed
K = constant, zone 1-0.00232
q = dynamic pressure

British Standards

$$q = KV^2_s = 0.0625 \times 50^2\ \text{kgf/m}^2 = 156.25\ \text{kgf/m}^2$$

where:
V_s = wind speed
K = 0.00256 lb/ft^2
K = 0.0625 kgf/m^2

4. WIND PRESSURE TABLES FOR VIET NAM

Taking into account the above factors it is possible to generate tables which are suited for a specific country. This has been done for Viet Nam. Table V.C gives the design pressures for different wind zones in the country and with adjustments for each of the four terrain categories. Table V.D to V.I give Design Loads on roofs for each terrain category in the three zones. Separate tables are provided for roofs under 20° pitch and those over 20°.

Table V.C PROPOSED WIND PRESSURES (Q_Z) VIET NAM
DYNAMIC WIND PRESSURE - FOR SITE AND HEIGHT

Return period 50 years - 3 sec. gust in cyclone wind.
$P = 0.0625V^2$ kgf/m² for V in m/sec.
Assessed adjustments made to wind speed to suit site roughness and height.

Terrain Category (Site roughness)	Height (meters)	Velocity Multiplier	Q_Z - kgf/m² Wind Speed (m/sec)			Q_Z - kgf/m² Free Stream Dynamic Pressure		
			Zone A	Zone B	Zone C	Zone A	Zone B	Zone C
1. Seaside	10	1.09	65.4	54.5	43.6	267	186	119
	5	1.02	61.2	51.0	40.8	234	162	104
2. Rural open	10	1.00	60.0	50.0	40.0	225	156	100
	5	0.93	55.8	46.2	37.2	195	135	87
3. Urban	10	0.85	51.0	42.5	34.0	162	113	72
	5	0.79	47.4	39.5	31.6	140	98	62
4. City	10	0.70	42.0	35.0	28.0	110	76	49
	5	0.65	39.0	32.5	26.0	95	66	42

Notes: Most sites in Viet Nam fall in Terrain Categories 2 and 3.
For post disaster buildings which should survive to serve the community immediately after a disaster (e.g. hospitals, police station, telecommunication buildings and perhaps schools if used as refuge centres), add 20% to all forces.

5. FORMULAE AND COEFFICIENTS FOR CALCULATING WIND FORCES

For easy reference by the reader, the formulae and the coefficients used in this chapter are summarized and presented together.

1. To convert wind speed to dynamic pressure

$Q_z = C\,V_z^2$

Q_z = Dynamic wind pressure
C = Coefficient
V_z = Dynamic wind velocity

$Q_z = 0.613V^2$ N/m² (pascals) for V in m/sec
$Q_z = 0.0625V^2$ kgf/m² for V in m/sec
$Q_z = 0.00256V^2$ lbf/ft² for V in miles/hr

---

2. Design wind pressure on a surface

$P_z = C_p\,Q_z$

P_z = Design wind pressure
C_p = Coefficient of pressure

The coefficient varies according to location of the surface and direction of wind.

---

3. Coefficient for height

The datum of 1.00 refers to a height of 10m on terrain category 2. Coefficients for other heights are:

0 - 5 m high	-	0.93
5 - 10 m high	-	1.00 - datum
10 - 15 m high	-	1.03

---

4. Coefficients for terrain categories

Refer also to diagrams for degree of site exposure to wind. The datum is 1.00 at a height of 10m on terrain category 2.

Terrain Category 1	-	1.09	e.g. - at seaside
Terrain Category 2	-	1.00 - datum	- open country
Terrain Category 3	-	0.85	- urban
Terrain Category 4	-	0.30	- city centre

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5. Local pressure factors to walls and roofs (K)

Refer to diagrams for typical areas affected.

General surface areas	A -	1.0
Perimeter areas	B -	1.5
Corners and gable ends	C -	2.0

The local pressure factor is multiplied by the external suction on a roof or wall and affects the cladding and its supporting framework and fittings only. It must not be used to determine total forces on a building.

Table V.D DESIGN LOADS - ZONE A - PITCH $<20°$

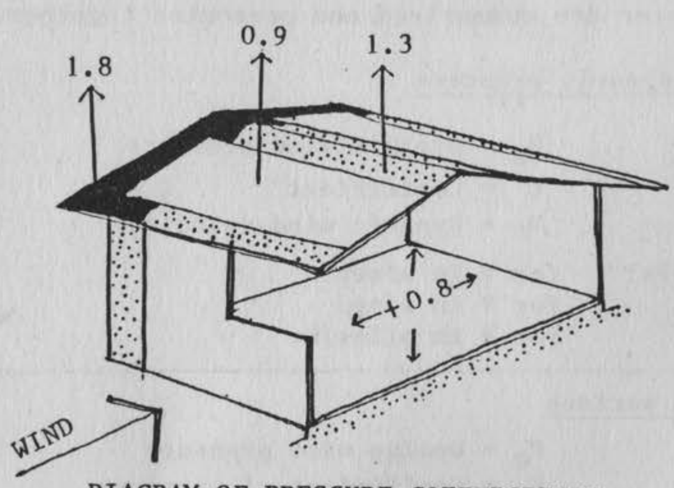


DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_z)

AREA A - $P_s + P_I$
AREA B - $1.5P_s + P_I$
AREA C - $2.0P_s + P_I$

Q_z = STATIC WIND PRESSURE
P_z = DESIGN PRESSURE
P_I = INTERNAL PRESSURE
P_s = EXTERNAL SUCTION

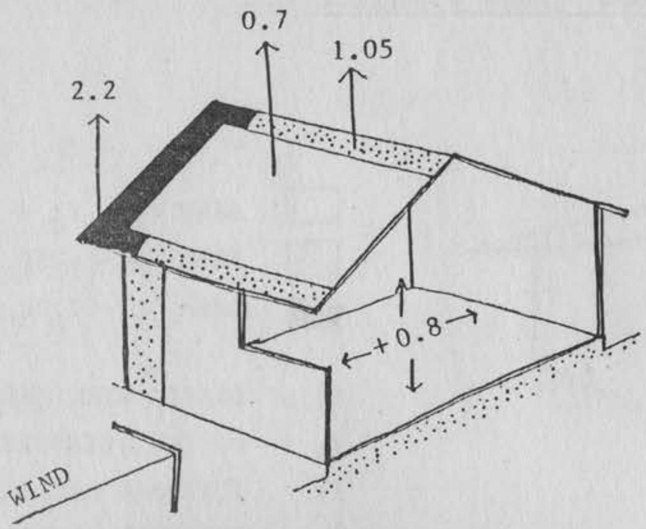
STRUCTURAL LOAD $P_z = Q_z\ (P_I + P_s)$
CLADDING LOADS $P_z = Q_z\ (K \times P_s + P_I)$

			DESIGN LOADS - Kgf/m²			
TERRAIN CATEGORY	HEIGHT	PRESSURE Q_z	AREA A $1.7 \times Q_z$	AREA B $2.15 \times Q_z$	AREA C $2.6 \times Q_z$	WIND SPEED m/sec
1	10 m.	267	454	574	694	65.4
	5 m.	234	398	503	608	61.2
2	10 m.	225	383	484	585	60.0
	5 m.	195	332	419	507	55.8
3	10 m.	162	275	348	421	51.0
	5 m.	140	238	301	364	47.4
4	10 m.	110	187	237	286	42.0
	5 m.	95	162	204	247	39.0
			STRUCTURAL LOAD	CLADDING LOADS*		

ROOF LOADS - DOMINANT OPENING IN WINDWARD WALL

* Local pressure factors must not be used in the determination of the total forces on a structure or a surface such as a wall or roof.

Table V.E DESIGN LOADS - ZONE A - PITCH >20°



AREA A - $P_s + P_I$

AREA B - $1.5P_s + P_I$

AREA C - $2.0P_s + P_I$

Q_z = STATIC WIND PRESSURE

P_z = DESIGN PRESSURE

P_I = INTERNAL PRESSURE

P_s = EXTERNAL SUCTION

DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_z)

STRUCTURAL LOAD $P_z = Q_z (P_I + P_s)$

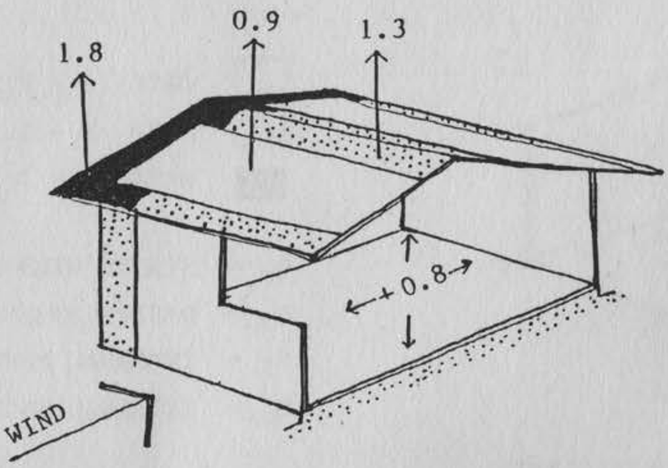
CLADDING LOADS $P_z = Q_z (K \times P_s + P_I)$

			DESIGN LOADS - Kgf/m²			
TERRAIN CATEGORY	HEIGHT	PRESSURE Q_z	AREA A $1.5 \times Q_z$	AREA B $1.85 \times Q_z$	AREA C $2.2 \times Q_z$	WIND SPEED m/sec
1	10 m.	267	400	494	587	65.4
	5 m.	234	351	433	515	61.2
2	10 m.	225	338	416	495	60.0
	5 m.	195	293	360	429	55.8
3	10 m.	162	243	300	356	51.0
	5 m.	140	210	259	308	47.4
4	10 m.	110	165	204	242	42.0
	5 m.	95	143	176	209	39.0
			STRUCTURAL LOAD	CLADDING LOADS*		

ROOF LOADS - DOMINANT OPENING IN WINDWARD WALL

* Local pressure factors must not be used in the determination of the total forces on a structure or a surface such as a wall or roof.

Table V.F DESIGN LOADS - ZONE B - PITCH <20°



AREA A - $P_s + P_I$

AREA B - $1.5P_s + P_I$

AREA C - $2.0P_s + P_I$

Q_z = STATIC WIND PRESSURE

P_z = DESIGN PRESSURE

P_I = INTERNAL PRESSURE

P_s = EXTERNAL SUCTION

DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_z)

STRUCTURAL LOAD $P_z = Q_z (P_I + P_s)$

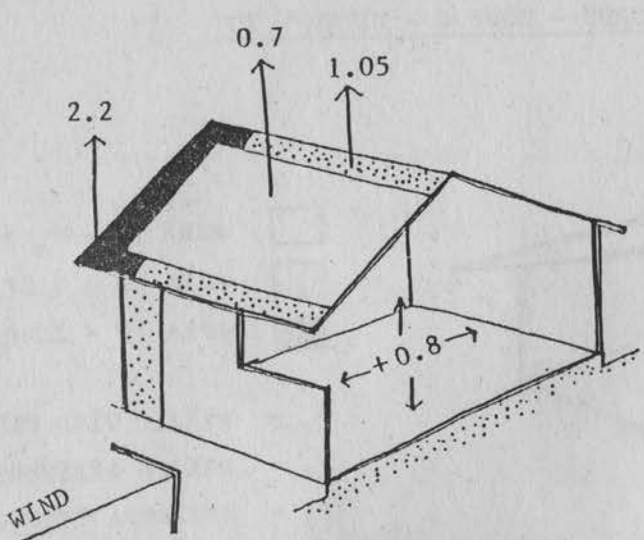
CLADDING LOADS $P_z = Q_z (K \times P_s + P_I)$

			DESIGN LOADS - Kgf/m²			
TERRAIN CATEGORY	HEIGHT	PRESSURE Q_z	AREA A $1.7 \times Q_z$	AREA B $2.15 \times Q_z$	AREA C $2.6 \times Q_z$	WIND SPEED m/sec
1	10 m.	186	316	400	484	54.5
	5 m.	162	275	348	421	51.0
2	10 m.	156	265	335	406	50.0
	5 m.	135	230	290	351	46.5
3	10 m.	113	192	243	294	42.5
	5 m.	98	167	211	255	39.5
4	10 m.	76	129	163	198	35.0
	5 m.	66	112	142	172	32.5
			STRUCTURAL LOAD	CLADDING LOADS*		

ROOF LOADS - DOMINANT OPENING IN WINDWARD WALL

* Local pressure factors must not be used in the determination of the total forces on a structure or a surface such as a wall or roof.

Table V.G DESIGN LOADS - ZONE B - PITCH $>20°$



	AREA A - $P_s + P_I$
	AREA B - $1.5P_s + P_I$
	AREA C - $2.0P_s + P_I$

Q_z = STATIC WIND PRESSURE

P_z = DESIGN PRESSURE

P_I = INTERNAL PRESSURE

P_s = EXTERNAL SUCTION

DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_z)

STRUCTURAL LOAD $P_z = Q_z\ (P_I + P_s)$

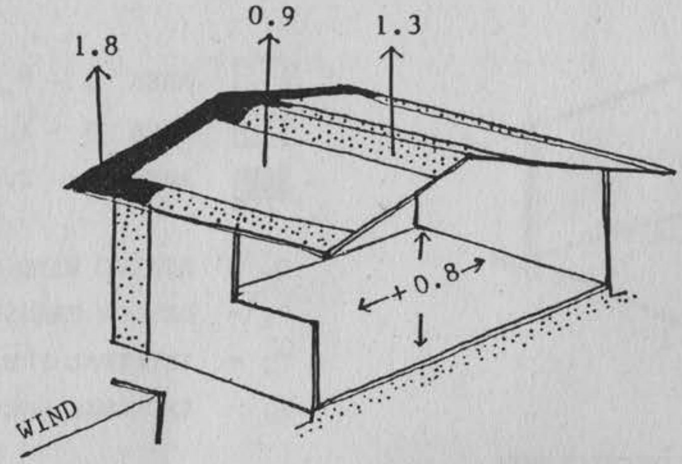
CLADDING LOADS $P_z = Q_z\ (K \times P_s + P_I)$

TERRAIN CATEGORY	HEIGHT	PRESSURE Q_z	DESIGN LOADS - Kgf/m² AREA A $1.5 \times Q_z$	AREA B $1.85 \times Q_z$	AREA C $2.2 \times Q_z$	WIND SPEED m/sec
1	10 m.	186	279	344	409	54.5
	5 m.	162	243	300	356	51.0
2	10 m.	156	234	289	343	50.0
	5 m.	135	203	250	297	46.5
3	10 m.	113	170	209	249	42.5
	5 m.	98	145	181	216	39.5
4	10 m.	76	114	141	167	35.0
	5 m.	66	99	122	145	32.5
			STRUCTURAL LOAD	CLADDING LOADS*		

ROOF LOADS - DOMINANT OPENING IN WINDWARD WALL

* Local pressure factors must not be used in the determination of the total forces on a structure or a surface such as a wall or roof.

Table V.H DESIGN LOADS - ZONE C - PITCH < 20°



☐	AREA A - $P_s + P_I$
▒	AREA B - $1.5P_s + P_I$
■	AREA C - $2.0P_s + P_I$

Q_Z = STATIC WIND PRESSURE
P_Z = DESIGN PRESSURE
P_I = INTERNAL PRESSURE
P_S = EXTERNAL SUCTION

DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_Z)

STRUCTURAL LOAD $P_z = Q_z (P_I + P_s)$
CLADDING LOADS $P_z = Q_z (K \times P_s + P_I)$

TERRAIN CATEGORY	HEIGHT	PRESSURE Q_z	DESIGN LOADS - Kgf/m² AREA A $1.7 \times Q_z$	AREA B $2.15 \times Q_z$	AREA C $2.6 \times Q_z$	WIND SPEED m/sec
1	10 m.	119	202	258	309	43.6
	5 m.	104	177	224	270	40.8
2	10 m.	100	170	215	260	40.0
	5 m.	87	148	187	226	37.2
3	10 m.	72	122	155	187	34.0
	5 m.	62	105	133	161	31.6
4	10 m.	49	83	105	127	28.0
	5 m.	42	71	90	109	26.0
			STRUCTURAL LOAD	CLADDING LOADS*		

ROOF LOADS - DOMINANT OPENING IN WINDWARD WALL

* Local pressure factors must not be used in the determination of the total forces on a structure or a surface such as a wall or roof.

Table V.I DESIGN LOADS - ZONE C - PITCH > 20°

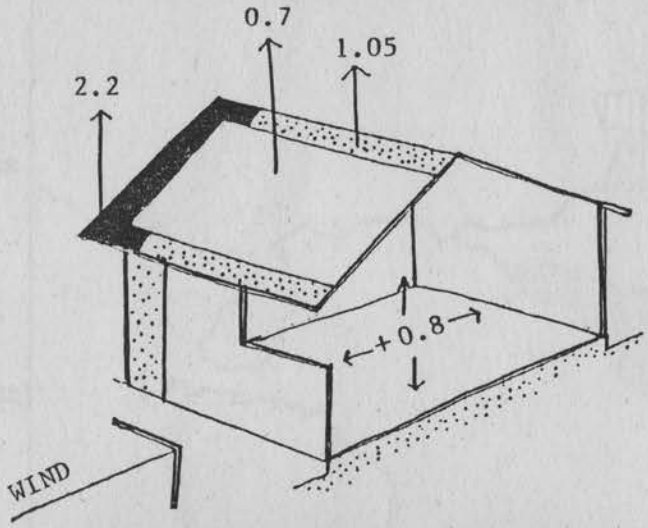


DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_Z)

AREA A - $P_s + P_I$
AREA B - $1.5P_s + P_I$
AREA C - $2.0P_s + P_I$

Q_z = STATIC WIND PRESSURE
P_z = DESIGN PRESSURE
P_I = INTERNAL PRESSURE
P_s = EXTERNAL SUCTION

STRUCTURAL LOAD $P_z = Q_z (P_I + P_s)$
CLADDING LOADS $P_z = Q_z (K \times P_s + P_I)$

TERRAIN CATEGORY	HEIGHT	PRESSURE Q_z	DESIGN LOADS - Kgf/m² AREA A $1.5 \times Q_z$	AREA B $1.85 \times Q_z$	AREA C $2.2 \times Q_z$	WIND SPEED m/sec
1	10 m.	119	179	220	262	43.6
	5 m.	104	156	192	229	40.8
2	10 m.	100	150	185	220	40.0
	5 m.	87	131	161	191	37.2
3	10 m.	72	108	133	158	34.0
	5 m.	62	93	115	136	31.6
4	10 m.	49	74	91	108	28.0
	5 m.	42	63	78	92	26.0
			STRUCTURAL LOAD	CLADDING LOADS*		

ROOF LOADS - DOMINANT OPENING IN WINDWARD WALL

* Local pressure factors must not be used in the determination of the total forces on a structure or a surface such as a wall or roof.

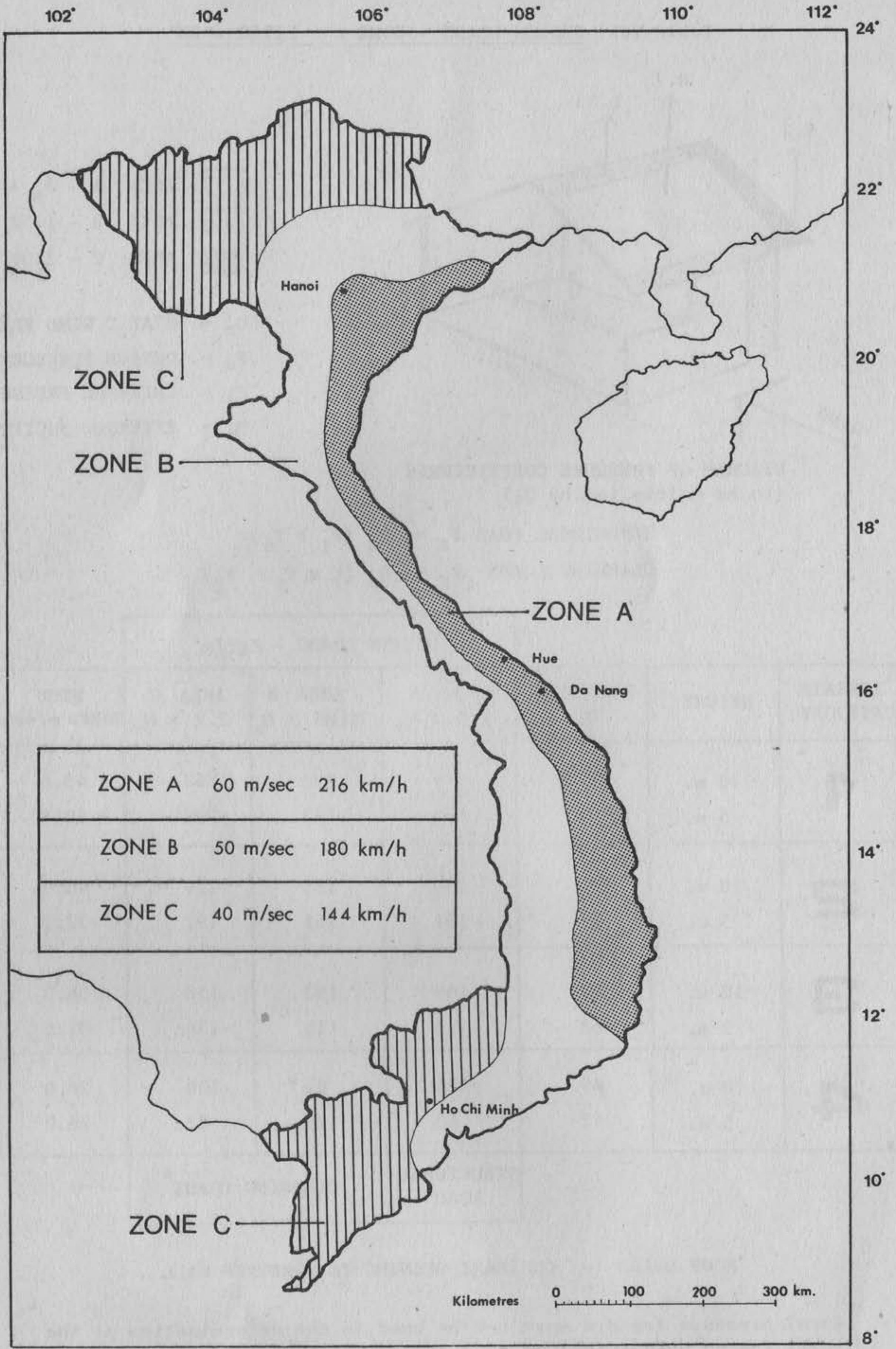


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Figure V.1 PROPOSED WIND ZONES FOR VIET NAM

PROPOSED WIND FORCES FOR VIET NAM
TERRAIN CATEGORIES - ROUGHNESS OF SITE

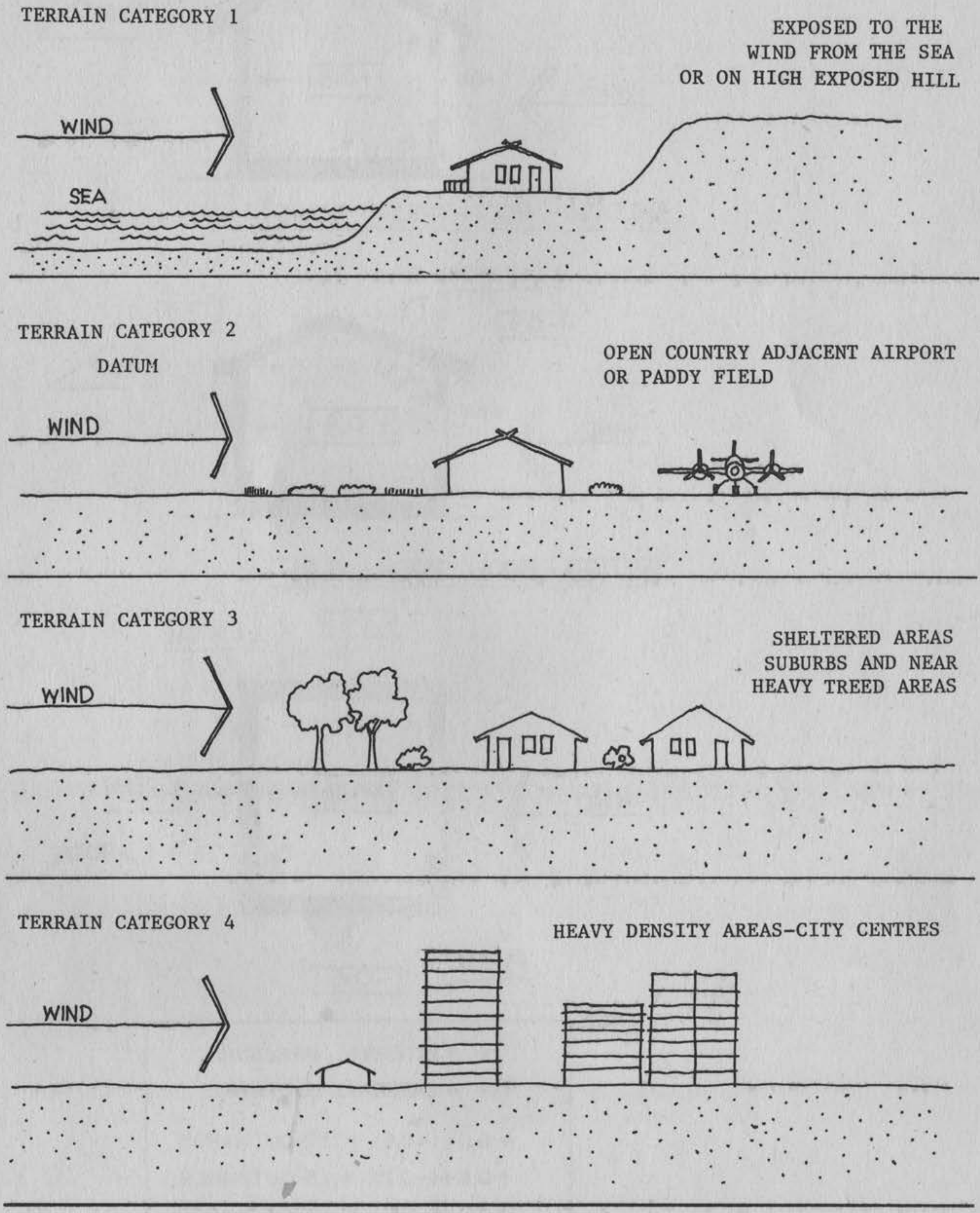


Figure V.2 DIAGRAM OF TERRAIN CATEGORIES

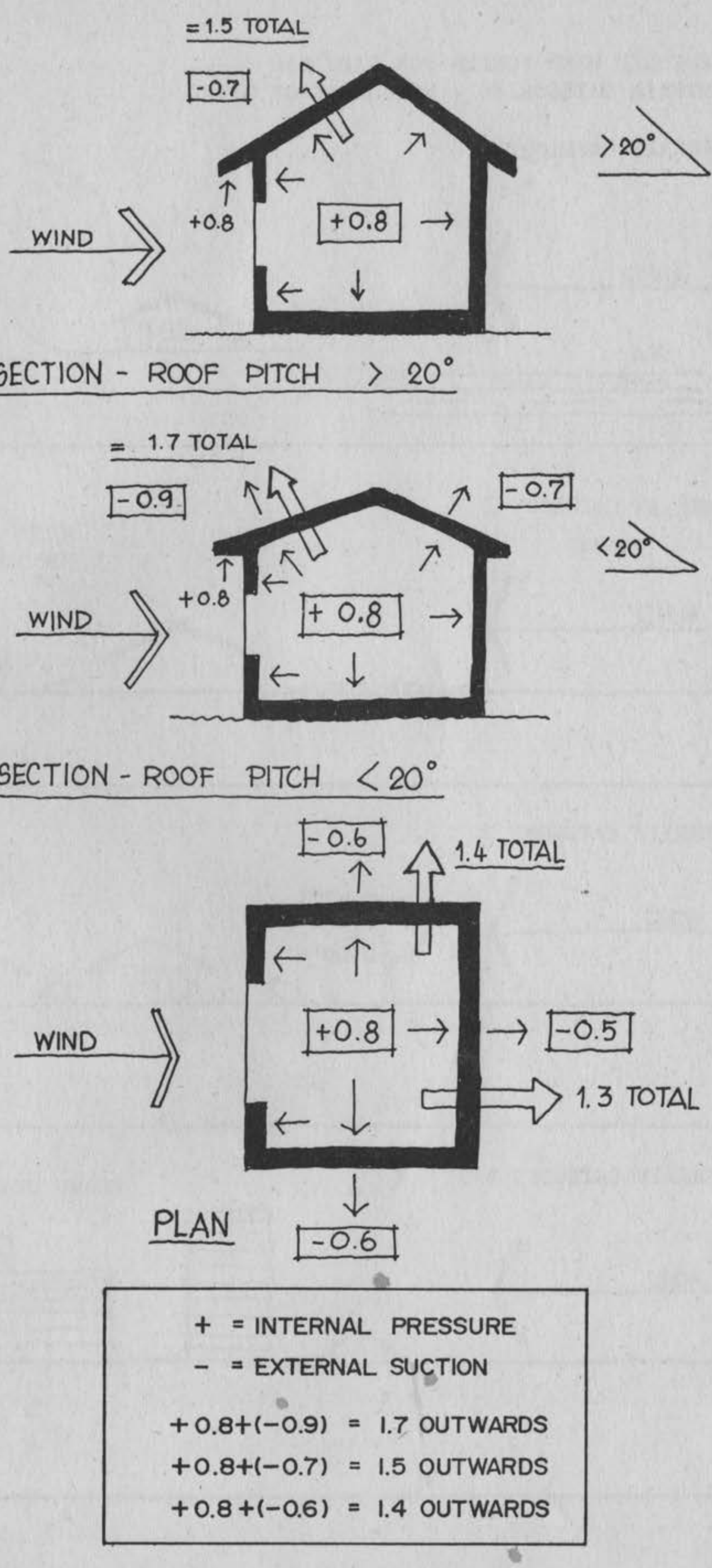


Figure V.3a STRUCTURAL LOAD COEFFICIENTS, INTERNAL AND EXTERNAL PRESSURE
- Dominant opening on windward side - internal pressure + 0.8

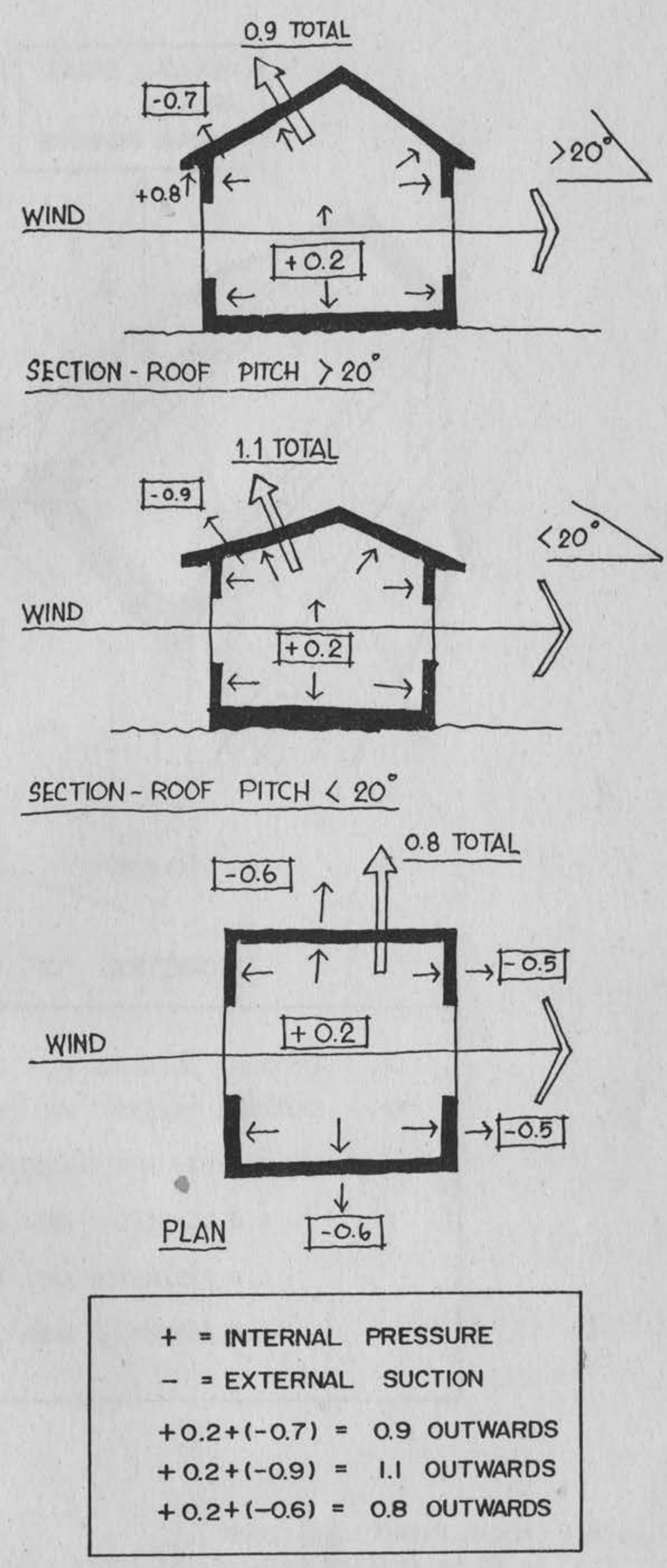
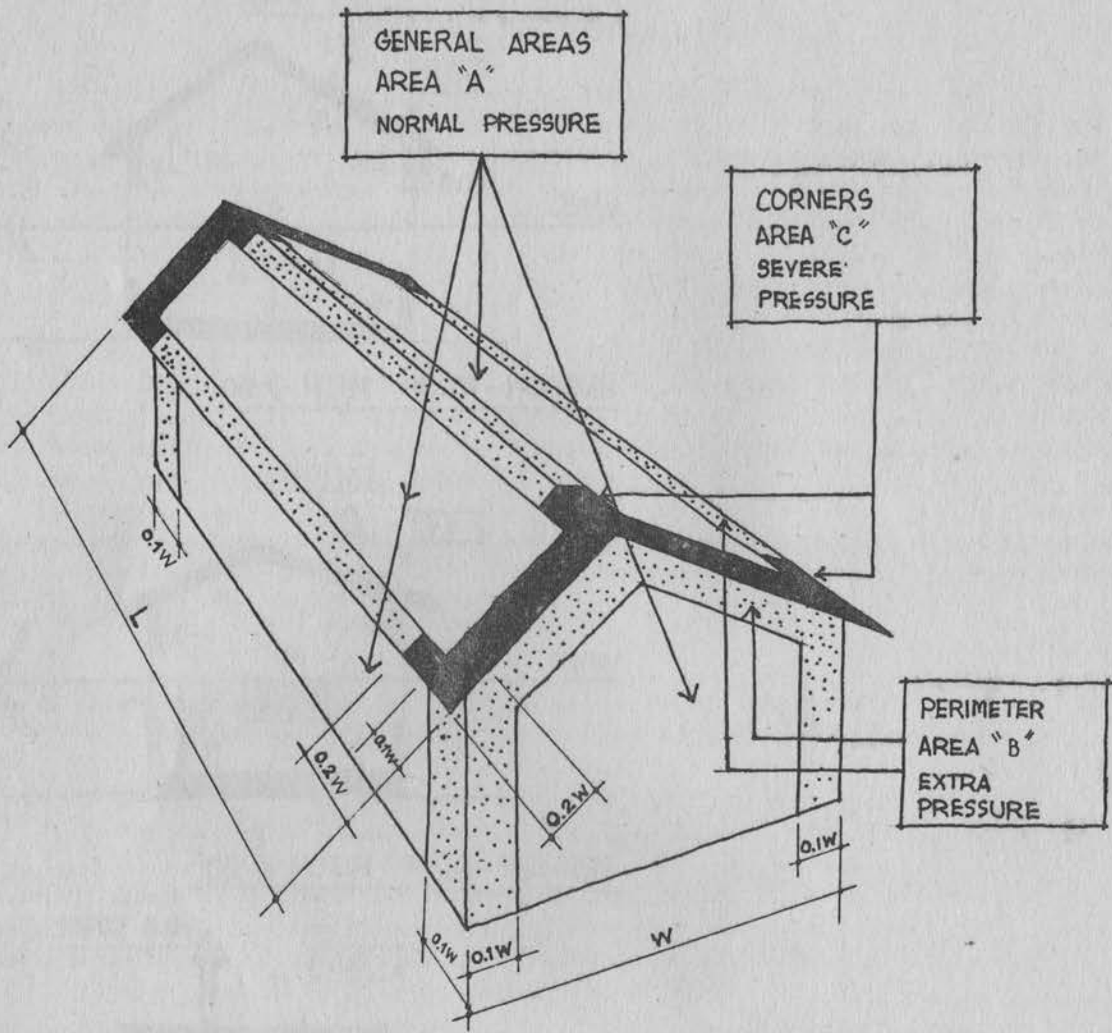


Figure V.3b STRUCTURAL LOAD COEFFICIENTS, INTERNAL AND EXTERNAL PRESSURE
- Openings on opposite walls - internal pressure + 0.2



ISOMETRIC OF BUILDING

IP. INTERNAL PRESSURE MAXIMUM - 0.8 x Force

EP. EXTERNAL PRESSURE MAXIMUM - 0.9 x Force

°K° FACTORS ARE CLADDING ONLY

1.0 GENERAL AREA A x EP. + IP.

1.5 PERIMETER AREA B x EP. + IP.

2.0 CORNER AREA C x EP. + IP.

Figure V.4 LOCAL PRESSURE FACTORS
<u>- To be applied to cladding loads only</u>

VI. SUMMARY OF CONCLUSIONS

The workshop and training course covered a wide variety of issues. While the project aims to develop a prototype design, it has been noted that here are many aspects to constructing educational buildings which can resist damages by typhoons. Some of the problems can be dealt with through technical actions but many other require action by administrators in the Ministries of education and construction at central provincial and district level.

In appendices 8 and 9, respectively, are summaries of all the points made during the workshop and the training course. These records show the active participation by both technical and administrative personnel from central government and the provinces. The conclusions which were reached in these five days of discussions are summarized below. For a full understanding of their context, the annexes should be consulted. The conclusions are assembled under three headings: technical; research and development; and administrative.

Technical

1. Wind zones must be established for the entire country. Based on available data, an interim zoning has been suggested.

2. Wind loads on buildings need to be established. Based on available data, an interim code for wind loading has been suggested.

3. Coefficients for wind load distribution need to be used to calculate the requirements for each building dependent on its size and location. Coefficients for cladding loads should also be applied. A full set of coefficients has been suggested.

4. Engineers need to understand the theory for designing buildings subjected to external and suction forces created by strong winds. This includes the need to follow a continuous chain of forces from the roof down to the foundation. This theory has been taught to the participants.

5. Local materials such as brick, timber and bamboo can perform satisfactorily in high winds *if* they are adequately fixed and the building structure as a whole has integrity. A dialogue was begun on how this could be accomplished.

6. The most critical need is to have fixings which are strong in tension and can tie down the various building components (see section on R & D).

7. Good site planning and appropriate landscaping can substantially improve the chances of a school building to survive a typhoon. Basic principles have been established for selecting sites and for planting hedges and trees.

8. The failures of weak doors and windows can initiate the destruction of buildings. Improved hardware should be used and better installation procedures adopted.

9. Air leaks on one side of the building only should be prevented.

10. Reinforced concrete ring beams should be used at the tops of external walls.

11. Long exterior walls should have strong supports in between transversal walls to resist overturning.

12. Building materials should be selected which will be low in maintenance needs. Sub-standard materials should not be accepted for educational buildings.

13. Construction should be supervised by experienced and knowledgeable technical personnel who understand the nature of forces which a typhoon places on a building.

14. Cost planning should be introduced to compare the cost of various design approaches.

Research and Development

1. A systematic study should be made of the problems being faced in order to identify all local research and development needs.

2. Single layers of tiles will inevitably lift up in typhoon speed winds, thus tile manufacturers need to develop tiles which can be securely attached to battens.

3. Sheet roofing is more easily secured than tiles and also uses less timber. Manufacturers need to develop new roofing types based on materials available in Viet Nam.

4. Galvanized steel strap fixings and tile clips need to be broadly applied. These can be manufactured in Viet Nam with some external assistance. Possibly these could be manufactured as a part of the programme to link education and work.

Administrative

1. A continuous chain of administrative responsibility for the creation of typhoon resistant schools needs to be established. This chain will stretch from central level to provincial to district to community and will include both educational administrators and technical personnel responsible for construction.

2. Public awareness needs to be intensified. In particular the public needs to understand that many local materials can effectively withstand typhoons if they are correctly used and the buildings are regularly maintained. School teachers and school directors have important roles to play in such a campaign. Strongly built schools may be designated as post disaster centres.

3. School buildings need to be places where effective teaching and learning can take place. School directors and teachers need to see

that classrooms are of an adequate size, satisfactorily equipped and provided with adequate natural light and ventilation. Furniture and equipment should not be damaged by typhoons. These criteria can still be respected in school buildings constructed to resist typhoons.

4. Existing educational buildings need to receive good maintenance. Periodic maintenance programmes should be scheduled for every educational building with those in wind zone 1 receiving first priority.

5. Existing educational buildings should be strengthened to a standard where they will suffer only minor damages by typhoons. Steps to be taken include introducing steel straps to tie together all roof members, a tie beam at the tops of walls and a steel tie from the trusses to the foundation. Educational buildings in wind zone 1 should receive first priority. This will involve rebuilding the roofs. A satisfactory method for attachment of tiles to battens has not yet been developed (see research and development above).

6. A rigorous programme to landscape school compounds is needed. This can be related to the educational activities of each school.

7. The results of the above activities needs to be recorded and circulated to all officers concerned and to the village authorities who are responsible for school building construction and maintenance.