Disaster preparedness and rehabilitation in Binh Tri Thien Province , Vietnam
Sử bão vệ chổng thãm-hoa thiên-nhiên ở tĩnh Bình Trị Thiên , Việt Nam

VIET/85/019

CHUYỂN GIAO KỸ THUẬT XÂY DỰNG NHÀ CHỐNG GIÓ BÃO
DEMONSTRATION OF STORM RESISTANT BUILDING TECHNIQUES

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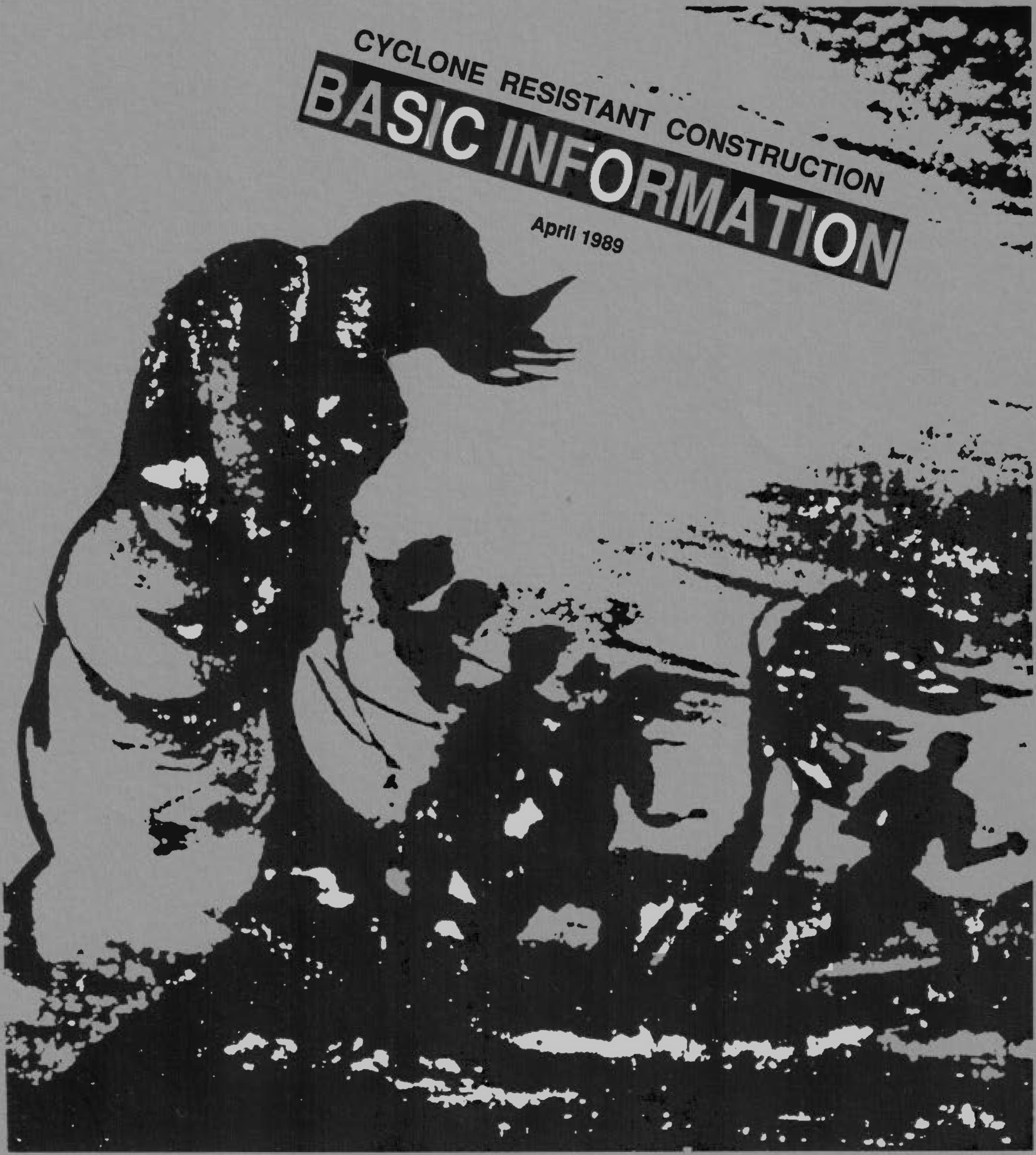

CYCLONE RESISTANT CONSTRUCTION
BASIC INFORMATION

April 1989

Development Workshop

Viện Thiết Kế Nhà Ở - Công Trình Công Công, Hànôi
Institute For Housing and Public Building Design

Xĩ Nghiệp Thiết Kế Khảo Sát Xây Dựng, Huế
Institute For Building Investigation and Design

GRET

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Sub-Project N°3 Demonstration of storm resistant building techniques

Vietnamese counterpart :	Institute for Housing and Public Building Design, Hanoï VIETNAM Institute for Building Investigation and Design, Hué VIETNAM
Sub-contractor :	GRET (Groupe de Recherche et d'Echanges Technologiques) 213, rue Lafayette 75010 Paris FRANCE DEVELOPMENT WORKSHOP , BP 10, Montayral 47500 Fumel FRANCE

PRESENTATION

This dossier provides basic information about cyclones (or typhoons) and cyclone resistant construction. The selected extracts have been drawn from a wide range of documentation (see Bibliography) which deals with cyclones and their effects.

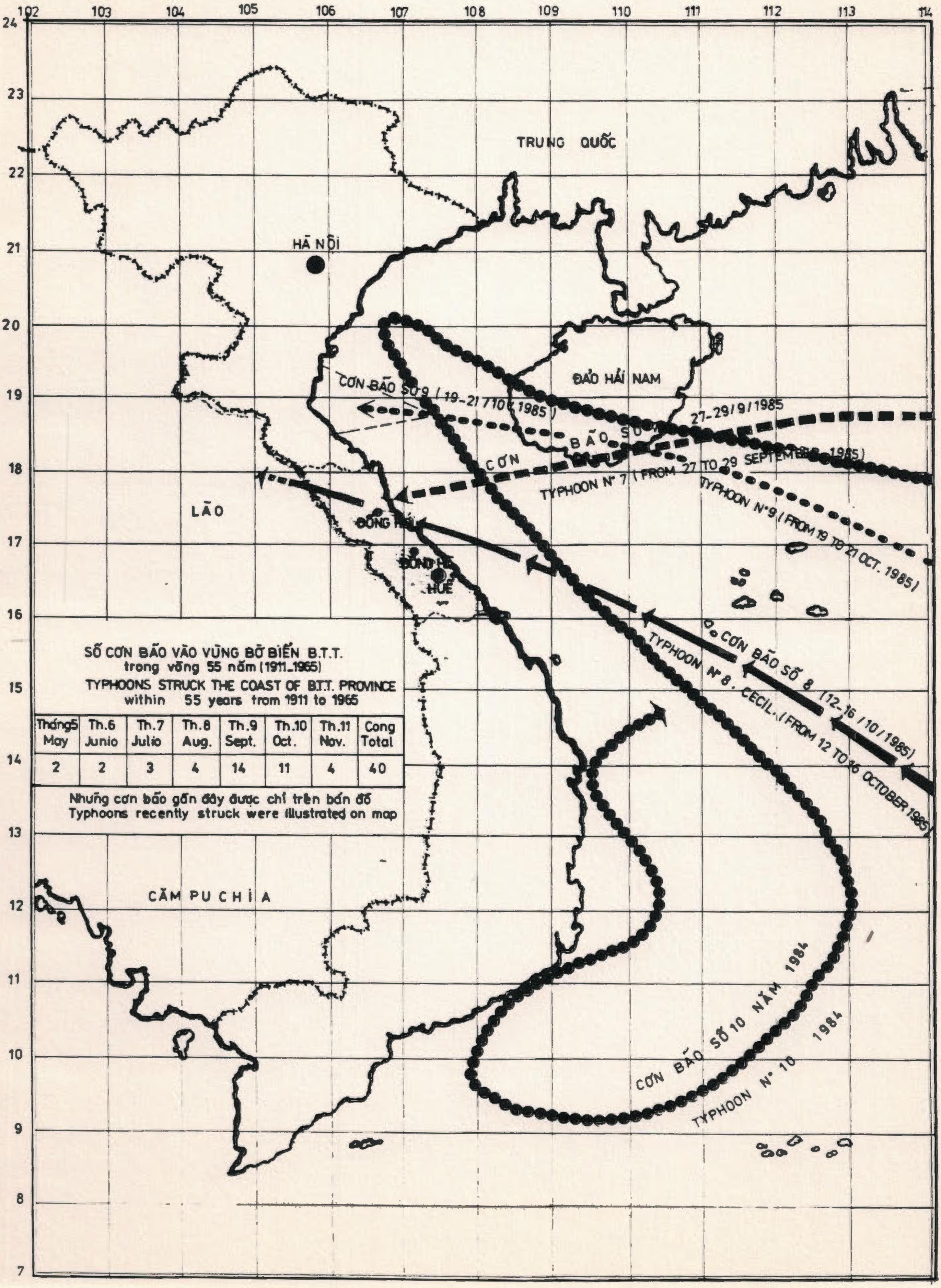
The present dossier is divided into the following sections :

1. **Basic data on cyclones in Vietnam.**
2. **An overview of cyclone and design measures to reduce damage risk.**
   From "Building and tropical windstorms", Dr K.J. Eaton, Overseas building notes n188, Building Research Establishment, England, 1981.
3. **Cyclone resistant building - the experience of Newtown School, Dominica / GRET**
   From "Construction d'une école en Dominique", C.Faure and E.Commissaire, GRET, Paris, 1981.
4. **Recommendations for site choice and protection.**
   From "Cyclone resistant rural primary school construction - a design guide", I.T. Sinnamon and G.van't Loo, UNESCO, Bangkok, 1977.
5. **Recommendations and codes for building design and detailing.**
   From "Minimum standards for cyclone resistant housing utilizing traditional materials found in the third world", INTERTECT, Dallas, 1987.
6. **Specific indicators for cyclone resistant design in Vietnam.**
   From "Typhoon resistant school buildings for Vietnam", K.J.Macks, UNESCO, Bangkok, 1987.
7. **Selected bibliography.**

The information in the dossier will form one of the bases for an examination of cyclone resistant construction principles during the workshops, out of which a more specific analysis and recommendations for Binh Tri Thien province will be developed.

1. Basic data on cyclones in Vietnam.

Paths of cyclones in Binh Tri Thien province (from IBID)



SỐ CƠN BÃO VÀO VÙNG BỜ BIỂN B.T.T.
trong vòng 55 năm (1911-1965)
TYPHOONS STRUCK THE COAST OF B.T.T. PROVINCE
within 55 years from 1911 to 1965

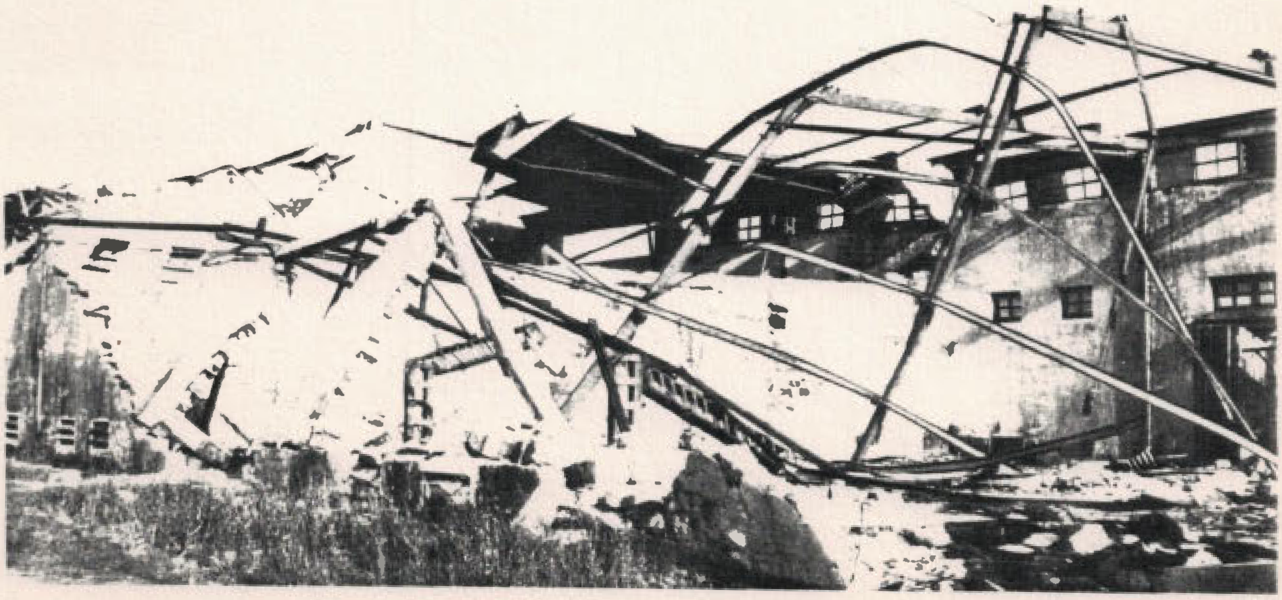
Tháng5 May	Th.6 Junio	Th.7 Julio	Th.8 Aug.	Th.9 Sept.	Th.10 Oct.	Th.11 Nov.	Cong Total
2	2	3	4	14	11	4	40

Nhưng cơn bão gần đây được chỉ trên bản đồ
Typhoons recently struck were illustrated on map

After the cyclone... (1985)

After the cyclone... (1985)

After the cyclone... (1985)



2. An overview of cyclone and design measures to reduce damage risk.

CONTENTS

BUILDINGS AND TROPICAL WINDSTORMS

by Keith J Eaton BSc(Eng), PhD,CEng, FRMetS, MIStructE

INTRODUCTION

Buildings and other structures should be designed to resist the worst effects of the strongest winds likely to occur within their design lifetimes. This is the basis of the guidance for design given in many wind loading codes, standards and regulations around the world. Most of the codes apply in countries with temperate climates, but this approach is just as valid in tropical regions that experience hurricanes, typhoons or cyclones.

Unfortunately, little information is available to assist architects, designers and engineers to take account of windstorms when buildings are being designed in developing countries. The Overseas Division of the Building Research Establishment has previously published reports to help fill the gap (Colonial Building Notes No 7 and No 9, 1952 and Overseas Building Note No 101, 1965), but these are all out-of-print, and in any case, some of the information in them is out-of-date since wind engineering is a subject that has advanced and developed rapidly in the past fifteen years. It is to remedy this situation, by providing up-to-date information and references, that this Note has been written.

After a description of tropical windstorms and storm surges that can occur in coastal regions, the Note deals with some of the reasons why buildings suffer extensive damage. Then the first step in the design process, the assessment of maximum wind speeds, is discussed. Where specific data are not available, the reader is given some useful sources of information on which to base a design. There then follows a section explaining the nature of airflow around buildings, which leads on to an assessment of pressures and forces for design purposes. Data published elsewhere is not extensively reproduced (particularly as there are so many different shapes of structure possible, and each one would generate its own peculiar wind flow pattern and set of pressures), but many references are given.

A particularly important consideration in the design of buildings to resist tropical winds is the assessment and control of internal pressures, and a section of the Note is devoted to this topic. Finally, a few particular points such as the siting and shape of buildings, details of joints in various forms of construction, and other practical considerations are outlined.

In writing this Note, the author has attempted to cover many aspects of a very broad subject, for which there is extensive literature in developed countries but not so much in the Third World countries. The audience for this Note is varied in discipline — architects; builders; building technicians; building inspectors; designers; engineers; planners; students and many more. Inevitably, different readers will require further amplification of some sections. If this information cannot readily be obtained from the sources quoted in the text, then advice should be sought from the Head of Overseas Division at the address given on the inside front cover.

It should also be noted that some knowledge of the basic procedures of structural design is assumed; this Note, in conjunction with local meteorological data, goes as far as allowing wind pressures and forces to be calculated, but no further steps are covered.

TROPICAL WINDSTORMS

What causes a tropical windstorm? The simple answer is the right combination of atmospheric and oceanic conditions in tropical areas. The two basic requirements are a warm sea and still air, and these conditions can exist for lengthy periods in six main areas of the world during late summer (Figure 1). The air is warmed by the sea and rises taking with it a considerable amount of water vapour. Its place is taken by air rushing in from the sides, and, because of the earth's rotation, this moving air is given a twist so that the whole system begins to revolve.

The warm humid air that is rising merges with high-altitude cooler air currents and the water vapour is released as rain. At the same time energy is released as heat, and this increases the rate of ascent of the air. The whole system is repeated, going faster and getting bigger. Under optimum conditions, these storms grow in size to span more than 800 km and can affect some four million cubic km of atmoshpere.

Because the wind system is revolving, centrifugal forces tend to throw the air outwards, and so the pressure in the centre becomes very low, thus forming the eye of the storm. Some of the dry air from high altitudes is forced down into the eye, creating relatively calm skies; the eye is typically 40 km across. At the same time, pressure is very high outside the storm and this attempts to fill the low pressure eye, with the result that the twisting air movement becomes even faster.

Like an enormous dynamic heat engine, the entire system therefore continues to sustain itself. Once established, it moves forward just as a spinning top moves along the ground. This brings it in contact with more warm sea and the process continues. The

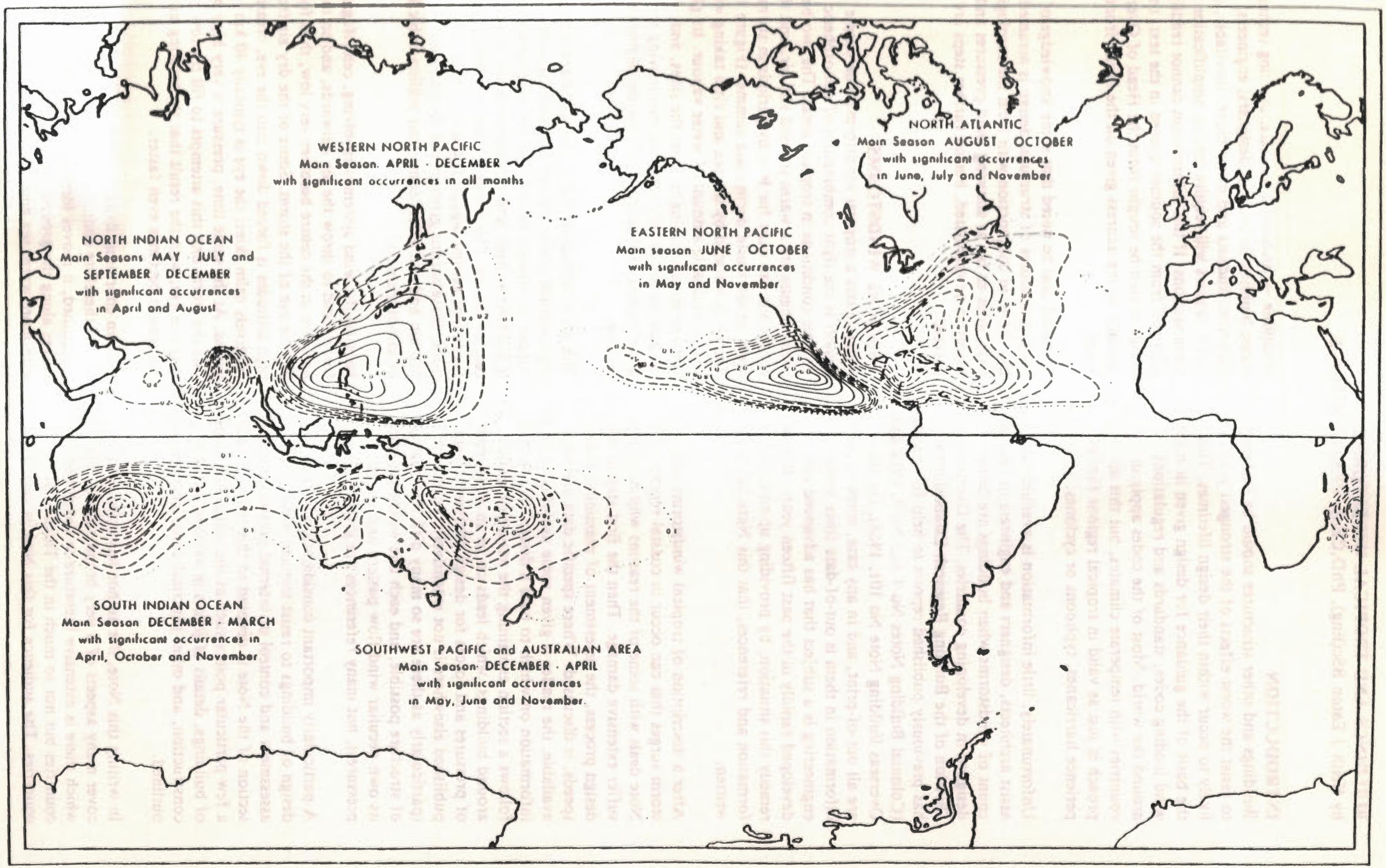


Figure 1 Areas of tropical cyclones and hurricanes, showing the average number of occurrences per five-degree square per year (adapted from Reference 6)

whole storm can go on living for many days provided it is moving over tropical oceans. As soon as it reaches land, or if it gets further away from tropical waters (ie over cooler temperate oceans), the supply of warm and moist air is removed and the storm rapidly decreases in intensity. Also, over land much of the energy is removed by friction with the ground, and the whole system is slowed down even more.

Within this overall cycle of a windstorm forming, developing and reaching maturity and then finally dissipating, it is called by several different names:

1 Tropical disturbance — the formative stage, when the weather is unsettled and disturbed;

2 Tropical cyclone — the start of a closed circulation over tropical oceans (anticlockwise in the northern hemisphere, clockwise in the southern hemisphere), the energy being derived from warm seas where the temperature exceeds 27°C;

3 Tropical depression — a larger and more intense tropical cyclone, with mean speeds up to 17 metres per second (m/s);

4 Tropical storm — a larger and more intense tropical depression, with mean wind speeds greater than 17 m/s but not exceeding 33 m/s;

5 Hurricane — a very intense tropical storm with mean wind speeds exceeding 33 m/s. Gust speeds will be much greater;

6 Dissipation stage — the stage when there is a decrease in wind speed and an increase in the barometric pressure.

To add a further complication, the name of the mature stage (5) varies in different parts of the world. Over the Western North Pacific Ocean, it is known as a typhoon. Over the Northern Indian Ocean (and in some areas around the South-West Pacific and Australia) it is known as a cyclone — in this case strictly where the mean wind speed exceeds 25 m/s. Elsewhere, the term hurricane is used; for convenience throughout this Note all the storms are referred to as hurricanes, even where the term typhoon or cyclone would be more appropriate.

The low air pressure in the hurricane eye allows the surface of the sea to rise near the centre of the storm, often to a height of one metre. In addition, the wind drives more water on to this bulge, and as the storm approaches land, the sloping sea-bed and shore line add further to the height of the water. Total surges have been recorded as high as 8 m above the normal tide, causing devastation along miles of coast. This fact is now recognised in the drafting of building codes and standards in order to reduce future building damage. For example, along the Texas Gulf Coast, four zones are delineated:

Zone A : On or close to the beach, where wind and flood water will cause damage, where buildings will be battered by floating objects, and where scour will occur around the foundations.

Zone B : Just inland from the beach, subject to everything experienced in Zone A except scour.

Zone C : Much further inland — up to 15-25 km, depending on the height above sea level — and subject to wind damage and less severe flooding.

Zone D : Possibly up to hundreds of km inland, depending on how quickly the hurricane dissipates, and only subject to wind forces.

The classification of hurricanes, allowing for this combined effect of wind and storm surge, is standardised according to the Saffir-Simpson scale, devised by consulting engineer Herbert Saffir and Dr Robert H Simpson, former director of the US National Hurricane Center.

Table 1 The Saffir-Simpson Scale

Category	Description	Mean wind speeds (m/s)	Storm surge (m)	North Atlantic examples	
1	Minimal	33 – 42	1.2 – 1.6	Agnes	1972
2	Moderate	43 – 49	1.7 – 2.5	Cleo	1964
3	Extensive	50 – 58	2.6 – 3.8	Betsy	1965
4	Extreme	59 – 69	3.9 – 5.5	David	1979
5	Catastrophic	Greater than 69	Greater than 5.5	Camille	1969

The use of this scale, when combined with the basic meteorological data, gives the designer a very good standard against which to compare his designs. Knowledge gained from past failures will go towards improved hurricane-resistance and less building damage in the future.

DAMAGE TO BUILDINGS

Every year, many hurricanes develop in the six main areas shown in Figure 1. Some of these only occur over the oceans and therefore cause no damage to buildings; some blow over uninhabited land and only cause damage to vegetation; but many strike islands or populated coastal zones of continents, causing major structural damage to buildings, making many people homeless and causing loss of life. Throughout the world on average 23 000 people are killed and 2.6 million are injured or left homeless each year due to windstorms and the associated flooding from storm surges. It is impossible to put a monetary value on the total loss due to destroyed or damaged buildings — it is enormous.

Some buildings are damaged by virtue of their siting and position; for example wind speeds can be enhanced near the top of a hill, so any structure in such a position might experience much greater forces than a counterpart on flat land. Conversely, many buildings resist hurricanes very well because they are in a locally sheltered position — sheltered either by natural windbreaks such as trees or by other surrounding buildings.

It is often the case that a building is destroyed or has a large part (such as a complete roof) removed because of its particular geometrical shape. Tall buildings are an obvious example; projections to buildings such as parapets or other architectural features are always vulnerable; large roof overhangs present an easy target for the wind; and flat or low-pitched roofs will experience a much greater uplift than more steeply pitched roofs.

By far the majority of structures, however, fail because of poor construction details. In general this arises because the forces that can be exerted during a hurricane are not fully appreciated — either at the design stage, or at the construction stage when site supervision may be inadequate, so that the building is not constructed according to plan. And of course the majority of buldings in the world (low-rise houses) are not designed at all — they are built by home-owners or small contractors, using traditional methods and without any specialist building knowledge. Unfortunately this results in vital connections (such as those required between roofs and walls) being too small or even omitted with subsequent disastrous consequences in a hurricane. Several examples of hurricane damage to different types of building are shown in Figure 2.

An important factor in designing buildings to prevent wind damage is a knowledge of the likely exposure to storms. There are two components to this assessment; first, the overall meteorological data and probabilities of a given wind speed and second, local terrain and surroundings which will affect factors such as the likelihood of storm surge.

METEOROLOGICAL DATA

The starting point for any calculation of wind loads on a building is the basic meteorological information. In the previous Section, a brief account was given of some of the main features of hurricanes, but there will be many local influences which modify this general flow. For example, there is a mechanical stirring, caused by friction between the air and the ground, creating turbulence of varying scales. Some major eddies may be as much as a kilometre in extent; at the other end of the scale, small, though possibly severe eddies may be due to the passage of the wind past a building or other obstruction. The superimposed pattern of all these disturbances results in wind speeds varying greatly from place to place and from moment to moment within the hurricane. Thus, the result of any measurement of wind speed will depend on the duration over which the sample is taken and the precise location of the anemometer.

Typical chart outputs from an anemometer during a hurricane are shown in Figure 3. From traces like these, meteorologists can extract information such as mean-hourly wind speeds and direction, and maximum gust speeds in each hour. The maximum gusts are averaged over a short period which depends on the response time of the anemometer.

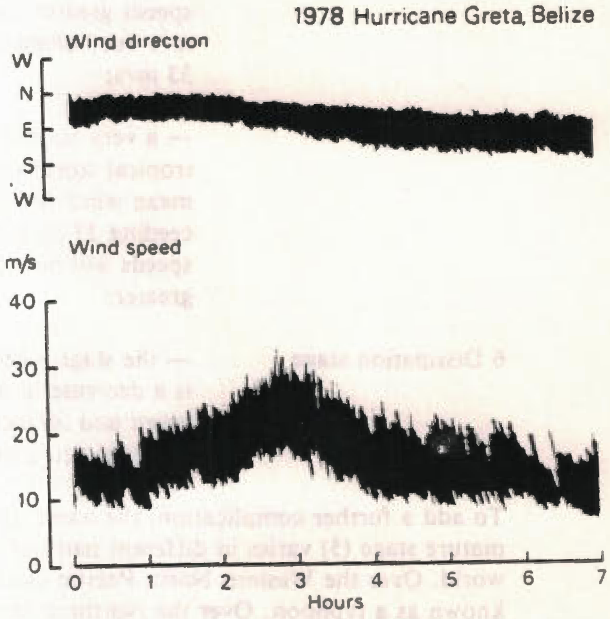


Figure 3 Typical traces from an anemometer during a hurricane

Figure 2 Examples of damage to buildings by hurricanes

Because different instruments are used this time varies, but it is typically in the range one to five seconds.

From all the data collected from each anemometer, maximum values can be tabulated for each year. These annual maxima can then be fitted to extreme value distributions in order to estimate wind speeds for various return periods — typically 50 or 100 years. Unfortunately, in most tropical areas, there is a great scarcity of data because of the small number of anemometers, and because many of these have only produced reliable, homogeneous records for a few (often less than ten) years.

Nevertheless, analyses have been carried out and the results published — usually in the form of an estimate for the 'once-in-50-years' gust speed. Some countries that could possibly experience hurricanes have incorporated this information into wind loading codes of practice; they are Australia, Canada, Hong Kong, India, Japan, New Zealand and USA. Three of these (Hong Kong, India, Japan) do not give the data in terms of wind speeds; instead they convert the figures directly to design pressures for the loading calculations.

Many other countries have data on windspeeds, and the reader should obtain information from the local meteorological service, if possible. The UK Meteorological Office has collated a considerable amount of wind gust data, and some suggested values are given in Table 2. For the larger countries, where a range of speeds is given, specific advice should be sought for any particular location.

Details of the published meteorological data in the wind loading codes of practice, and information on sources of data in other countries, can be obtained from the Overseas Division of Building Research Establishment. Alternatively, any other source of wind data can be used, provided there is a data set that can be extrapolated using valid extreme-value distributions. Further information on this can be found in the referenced papers.

Table 2 Once-in-50-years design gust speeds for various countries which experience hurricanes

	m/s
NORTH INDIAN OCEAN	
India	34-61
Sri Lanka	36
SOUTH INDIAN OCEAN	
Mauritius	68
Mozambique	31-38
Reunion	57
Rodriguez	90
WESTERN NORTH PACIFIC	
Hong Kong	71
Japan	27-68
Macau	56
Malaysia	25-35
Philippines	20-69
South Korea	30-55
Taiwan	79
SOUTHWEST PACIFIC	
New Caledonia	35-54
Pacific (East) Islands	27-52
Samoa	39
NORTH ATLANTIC	
Antigua	53
Barbados	53
Bermuda	60
Grenada	45
Jamaica	53
Martinique	44
Mexico	27-60
Panama	26
Puerto Rico	49
St Barthelemy	53
Trinidad and Tobago	42
Venezuela	29-42

As time passes, the recorded maxima of hurricanes tend towards more extreme values and statistical methods have to be used to estimate these extremes. Having calculated a wind speed likely to be expected, on average, say once in 50 years, it must be remembered that there is always an element of risk that this speed may be exceeded, and a probability has to be assigned, so that a client knows what risk is involved. Table 3 gives the probabilities of the 50-year return-period wind occurring, for example, in periods of 20 years and 50 years, and includes probabilities for multiple occurrences.

From this it can be seen that it is by no means certain (only a 63.6 per cent chance, in fact) that the 50-year return-period wind will occur in any 50-year period; nor, on the other hand, that it will occur only once. It is important for designers and clients to bear this in mind.

Finally it is important to consider whether or not

Table 3 Extreme wind probabilities

Number of years during the specified period in which the 50 year return period wind speed is equalled or exceeded	Probability in a period of 20 years	Probability in a period of 50 years
None	0.668	0.364
One or more	*0.332*	*0.636*
One	0.272	0.372
Two or more	*0.060*	*0.264*
Two	0.053	0.186
Three or more	*0.007*	*0.078*
Three	0.006	0.061
Four or more	*0.001*	*0.017*
Four	0.001	0.015

any factors should be applied to modify the windspeed to take account of terrain roughness, local exposure or shelter, and variations of windspeed with height above ground level. For the majority of low-rise buildings in most developing countries it is not considered necessary to apply small modification factors when much larger uncertainties exist in the basic extreme-value hurricane data. However, for larger structures, or any building where an extensive engineering design is being carried out, factors should be used as detailed in the appropriate Codes of Practice.

THE NATURE OF AIRFLOW AROUND BUILDINGS

When the wind blows more or less square-on to a rectangular building, it is slowed down against the front face with a consequent build-up of pressure against that face. This pressure decreases in magnitude towards the edges, particularly near the ground where an eddy forms. (It is common experience in moderately strong winds that at ground level the wind blows away from the windward face of a building, opposing the general direction of the wind. This might not be noticed in hurricane winds!) The flow in the windward eddy spirals along the face of the building and escapes round the sides with increased speed, to join the general flow of air that has already passed around the sides. In these areas of enhanced flow, there is a pressure reduction, ie a suction, exerted on the building. The greater the speeding up of the wind, the greater will be the suction. Suctions can be much larger that pressures, and are more likely to lead to damage. Behind the building, a large turbulent area is created exerting a small suction on the rear face. Suction may also be produced over the windward slope of the roof, depending on whether or not the airflow separates from the roof surface. This depends primarily on the pitch of the roof, the flow separating more readily from a low pitch than from a steep one. Separation also varies with the height of the building, creating greater suctions on the roof of a tall building than a low one. The distribution of pressures and suctions over all these surfaces is subject to considerable variation.

The wind does not however always blow normal to a face of the building and it is necessary to consider the pattern of flow when the wind strikes a building obliquely. The flow divides at the leading corner, and can cause entirely different conditions on the two front faces as shown in Figure 4.

There is less upward flow over the front faces and consequently less flow over the roof than when the flow is normal to a major face of the building. There will consequently be less total suction over the roof. However, the upward flow that does occur will be moving along the windward faces and when it lifts over the edge of the roof it curves downwards in a spiral to form strong vortices along the roof edges (Figure 5). These in turn give rise to severe local suction on the parts of the roof that are under the influence of the vortices. Since at most locations the wind can blow from any direction, particularly as a hurricane passes, all edges and corners could experience these intense local flows.

The wind flow patterns discussed above all apply to isolated simple rectangular plan buildings with no protruding architectural features such as parapets, canopies, balconies or chimneys. When such features are present, or when the building plan in-

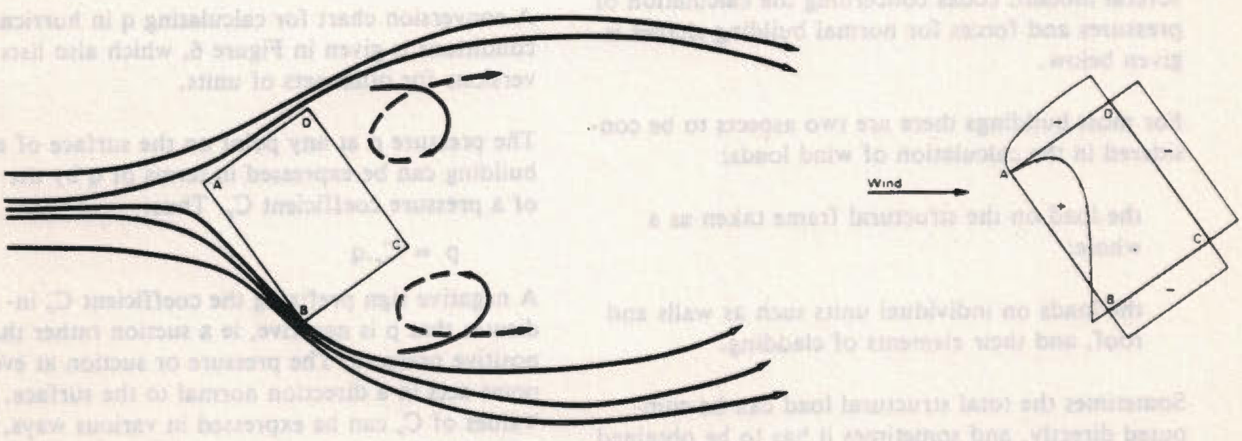


Figure 4 Oblique wind flow around a building, and the resulting pressure distribution on the walls

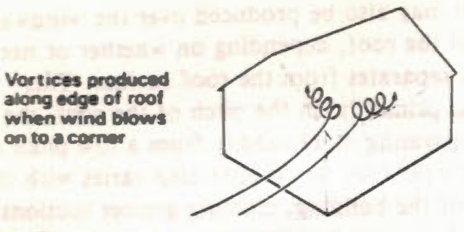


Figure 5 Oblique windflow

cludes projections or recesses, there will be modifications and complications imposed on the simple flow patterns. Similar modifications will also apply to more complex building shapes such as L-shaped buildings, to buildings with openings underneath them, and to groups of buildings where the flow past one building may affect (either adversely or beneficially) the flow past another. Details of all these specific situations can be found in the references.

THE ASSESSMENT OF WIND LOADS

Some countries that experience hurricanes have codes of practice, so that wind loads can be readily assessed. These calculated loads can be related directly to the permissible stresses in structural design codes. In a few countries, limit state design methods are now used, and in these cases the calculated wind loads are assumed to be the characteristic loads.

In countries where there are no codes or regulations, design wind loads for buildings likely to experience hurricanes should be based on the extreme-value meteorological data, and valid procedures for wind loading calculations from other countries, eg Australia, Sri Lanka, UK and Canada. A brief account of the main points from several modern codes concerning the calculation of pressures and forces for normal building shapes is given below.

For most buildings there are two aspects to be considered in the calculation of wind loads;

the load on the structural frame taken as a whole;

the loads on individual units such as walls and roof, and their elements of cladding.

Sometimes the total structural load can be computed directly, and sometimes it has to be obtained by the vectorial summation of the loads on the various wall and roof surfaces. In this latter case, care should be taken to summate only those loads which occur simultaneously, ie for a given wind direction, rather than the absolute maxima for the various wall and roof elements.

In all cases, wind loads are based on the dynamic pressure of the wind. If the wind is brought to rest against the windward face of an obstacle, all its kinetic energy is transferred to dynamic pressure q (sometimes referred to as the 'stagnation pressure'). This can be calculated from the formula:

$$q = \tfrac{1}{2}\varrho V^2$$

where V is the design wind speed for hurricanes in the particular location, and ϱ is the air density. Air density depends on the ambient temperature and pressure. In temperate countries a value of 1.226 kg/m³ is normally used, based on a temperature of 15°C and the standard atmospheric pressure of 1013.25 millibars (mb), but in tropical countries the temperature will be greater, and near the eye of a hurricane the pressure will be much less. An indication of how ϱ varies with temperature and pressure can be seen in Table 4.

Table 4 Variation of air density, ϱ (kg/m³)

Temperature (°C)	Pressure 960 mb	980 mb	1000 mb	1020 mb
0	1.225	1.250	1.276	1.302
5	1.203	1.228	1.253	1.278
10	1.182	1.206	1.231	1.255
15	1.161	1.185	1.209	1.234
20	1.141	1.165	1.189	1.213
25	1.122	1.145	1.169	1.192
30	1.103	1.126	1.149	1.172
35	1.086	1.108	1.131	1.153

It is suggested that in hurricane conditions an air temperature of 25°C and a pressure of 960 mb are used, giving $\varrho = 1.122$ kg/m³. The formula then becomes $q = 0.561 V^2$ instead of $0.613 V^2$ used in codes for temperate climates.

A conversion chart for calculating q in hurricane conditions is given in Figure 6, which also lists conversions for other sets of units.

The pressure p at any point on the surface of a building can be expressed in terms of q by the use of a pressure coefficient C_p. Thus:

$$p = C_p . q$$

A negative sign prefixing the coefficient C_p indicates that p is negative, ie a suction rather than a positive pressure. The pressure or suction at every point acts in a direction normal to the surface. Values of C_p can be expressed in various ways, the most complete information, representing the changes of value across a surface, being given by a contour diagram. However, this is not usually the most convenient form for design purposes; a simplified presentation giving mean pressure coefficients over whole surfaces or parts thereof is shown in Tables 5 and 6.

Conversion chart for wind speed and dynamic pressure in tropical cyclones

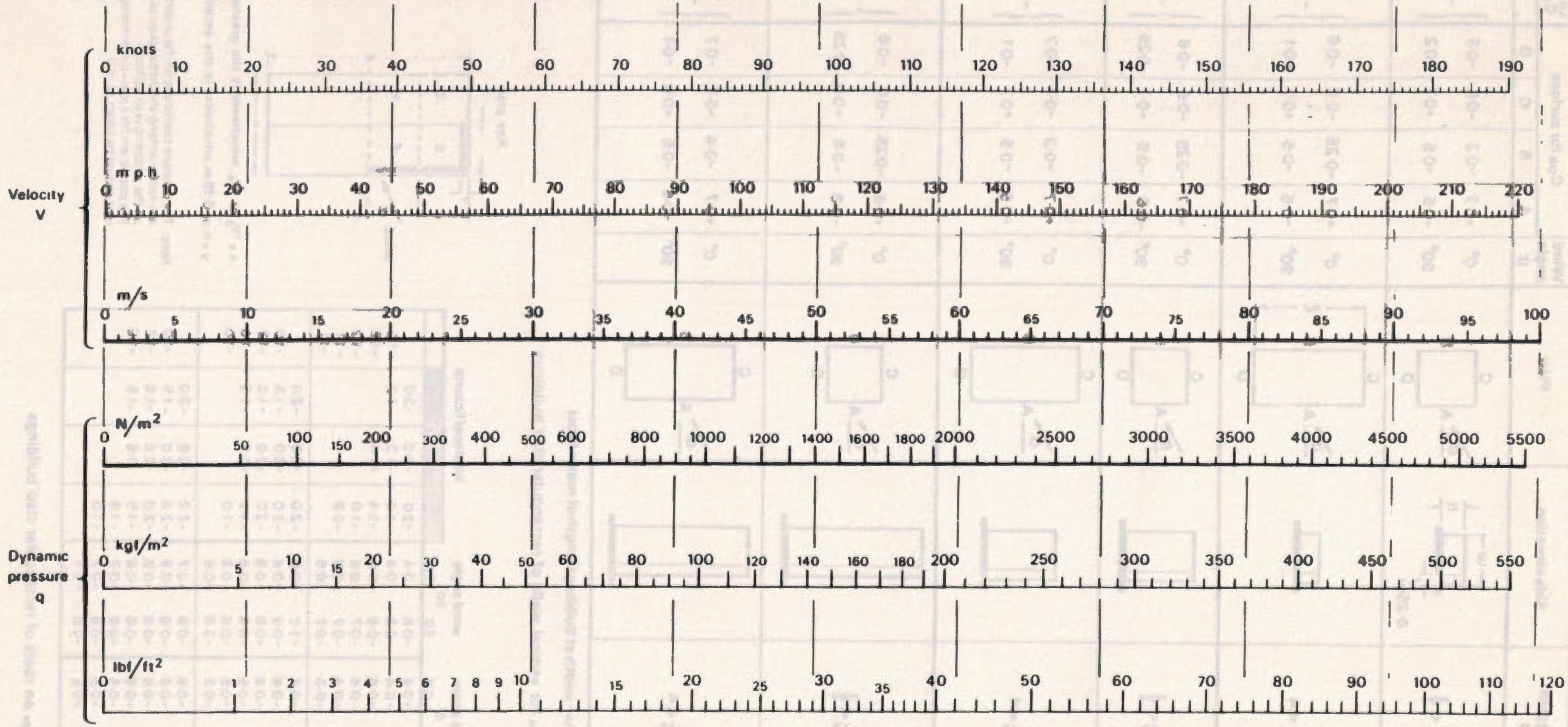
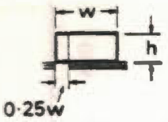
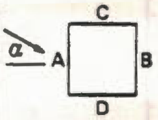
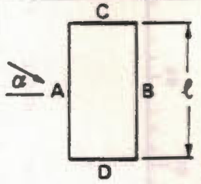
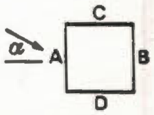
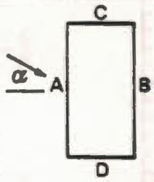
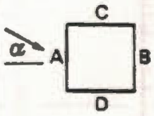
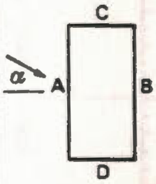
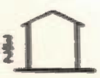


Figure 6 Chart for calculating dynamic pressures from windspeeds in hurricanes
1 m/s = 1.946 knots = 2.237 mph
1 kgf = 9.81 Newtons (N) = 2.208 lbf

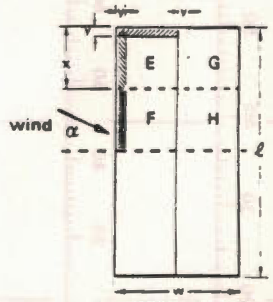
Building height ratio	Building plan ratio	Side elevation	Plan	Wind angle α	C_{pe} for surface A	B	C	D	Local C_{pe}
$\frac{h}{w}<\frac{1}{2}$	$1<\frac{\ell}{w}<\frac{3}{2}$			0°	+0·7	-0·2	-0·5	-0·5	-0·8
				90°	-0·5	-0·5	+0·7	-0·2	
	$\frac{3}{2}<\frac{\ell}{w}<4$			0°	+0·7	-0·25	-0·6	-0·6	-1·0
				90°	-0·5	-0·5	+0·7	-0·1	
$\frac{1}{2}<\frac{h}{w}<\frac{3}{2}$	$1<\frac{\ell}{w}<\frac{3}{2}$			0°	+0·7	-0·25	-0·6	-0·6	-1·1
				90°	-0·6	-0·6	+0·7	-0·25	
	$\frac{3}{2}<\frac{\ell}{w}<4$			0°	+0·7	-0·3	-0·7	-0·7	-1·1
				90°	-0·5	-0·5	+0·7	-0·1	
$\frac{3}{2}<\frac{h}{w}<6$	$1<\frac{\ell}{w}<\frac{3}{2}$			0°	+0·8	-0·25	-0·8	-0·8	-1·2
				90°	-0·8	-0·8	+0·8	-0·25	
	$\frac{3}{2}<\frac{\ell}{w}<4$			0°	+0·7	-0·4	-0·7	-0·7	-1·2
				90°	-0·5	-0·5	+0·8	-0·1	

ℓ - length of major face of building. w - width of building (length of minor face)

Table 5 Pressure coefficients C_{pe} for vertical walls of rectangular clad buildings

Building height ratio	Roof angle degrees	wind angle 0° EF	GH	wind angle 90° EG	FH	local coefficients ▧	▨	■	
$\frac{h}{w}<\frac{1}{2}$ 	0	-0·8	-0·4	-0·8	-0·4	-2·0	-2·0	-2·0	
	5	-0·9	-0·4	-0·8	-0·4	-1·4	-1·2	-1·2	-1·0
	10	-1·2	-0·4	-0·8	-0·6	-1·4	-1·4		-1·2
	20	-0·4	-0·4	-0·7	-0·6	-1·0			-1·2
	30	0	-0·4	-0·7	-0·6	-0·8			-1·1
	45	+0·3	-0·5	-0·7	-0·6				-1·1
$\frac{1}{2}<\frac{h}{w}<\frac{3}{2}$ 	0	-0·8	-0·6	-1·0	-0·6	-2·0	-2·0	-2·0	
	5	-0·9	-0·6	-0·9	-0·6	-2·0	-2·0	-1·5	-1·0
	10	-1·1	-0·6	-0·8	-0·6	-2·0	-2·0	-1·5	-1·2
	20	-0·7	-0·5	-0·8	-0·6	-1·5	-1·5	-1·5	-1·0
	30	-0·2	-0·5	-0·8	-0·8	-1·0			-1·0
	45	+0·2	-0·5	-0·8	-0·8				
$\frac{3}{2}<\frac{h}{w}<6$ 	0	-0·7	-0·6	-0·9	-0·7	-2·0	-2·0	-2·0	
	5	-0·7	-0·6	-0·8	-0·8	-2·0	-2·0	-1·5	-1·0
	10	-0·7	-0·6	-0·8	-0·8	-2·0	-2·0	-1·5	-1·2
	20	-0·8	-0·6	-0·8	-0·8	-1·5	-1·5	-1·5	-1·2
	30	-1·0	-0·5	-0·8	-0·7	-1·5			
	40	-0·2	-0·5	-0·8	-0·7	-1·0			
	50	+0·2	-0·5	-0·8	-0·7				

Key plan



$x = w/3$ or $\ell/4$ whichever is the greater

$y = h$ or $0{\cdot}15\,w$ whichever is the smaller

Note: The pressure coefficient on the underside of any roof overhang should be taken as that on the adjoining wall surface
The coefficient for a low-pitch monopitch roof should be taken as -1·0

Table 6 Pressure coefficients C_{pe} on roofs of rectangular clad buildings

For each building shape, these Tables give pressure coefficients for individual surfaces (or parts of a surface) for wind directions that produce critical loading. This enables calculations to be made of the maximum individual load on each surface and, by vectorial summation of individual loads, the total load on the building. Although the wind has been shown blowing against one face and the pressure coefficients given for that wind direction, the wind may, in practice, blow against any face of a building particularly when the different parts of a hurricane are passing a given location. Therefore each face should, in turn, be considered as the windward one and the pressure calculated using $p = C_p.q$. This will indicate the maximum external loading, positive or negative, on each face.

The term 'external loading' has been used because in calculating the wind load on any element of a building it is essential to take account of the pressure difference between opposite sides of the element. For clad buildings it is therefore necessary to know the internal pressure as well as the external, and it is convenient to use distinguishing pressure coefficients:

C_{pe} = external pressure coefficient

C_{pi} = internal pressure coefficient

The values in Tables 5 and 6 are all external coefficients (C_{pe}). Further discussion on internal pressures is given in the next section.

Tables 5 and 6 also give an indication of the high local suctions that may occur under certain wind conditions, with values as large as -2.0 q over considerable areas of roofs. They should be taken into account in determining the local loads on elements of cladding and their supporting members in these regions, but should not be taken into account in calculating the total structural loads.

For some structural shapes, total wind forces have been measured directly and force coefficients derived such that:

$$F = A_e.q.C_f$$

where F is the force in the direction of the wind

A_e is the effective frontal area of the structure

C_f is the force coefficient in the direction of the wind.

Most codes of practice present the data for a range of structural shapes. By far the most common are rectangular buildings, and values of C_f for those buildings can be obtained from Figure 7.

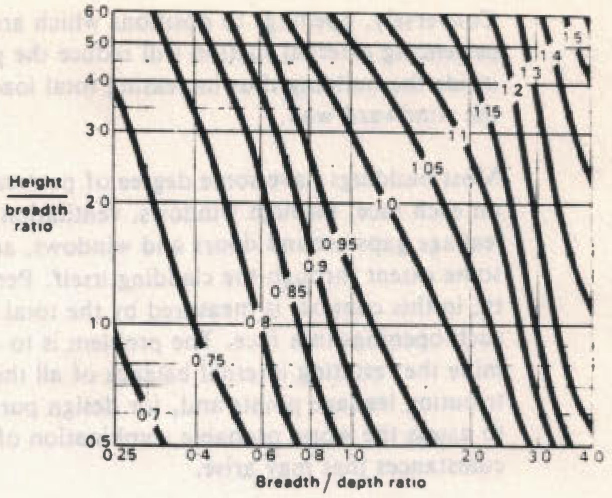


Figure 7 Force coefficients C_f for rectangular buildings

In this Figure, breadth is the dimension of the building across the wind direction, depth is the dimension of the building in the wind direction, and height is that of the windward facade of the building.

INTERNAL PRESSURES

The total wind force on a wall or roof depends on the difference of pressure between the outer and inner faces. Open doors, windows or ventilators on the windward side of a building will increase the air pressure inside the building and this will increase the loading on those parts of the roof and walls which are subjected to external suction (Figure 8).

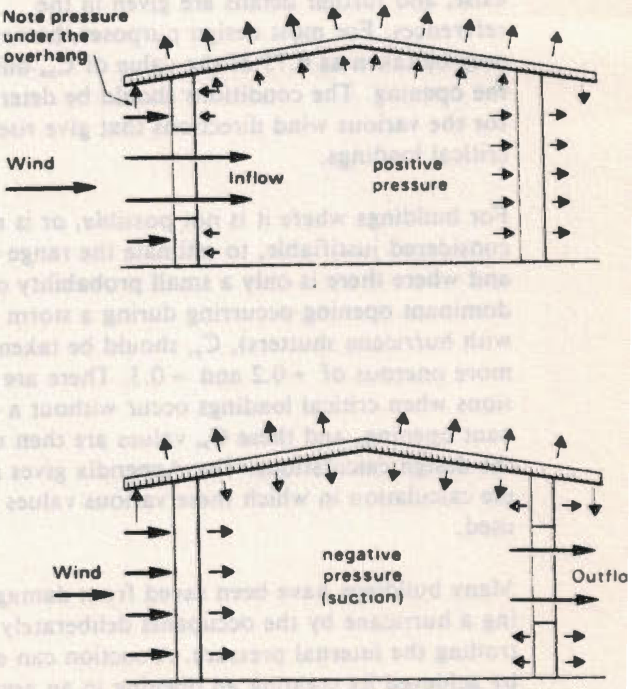


Figure 8 Internal pressure in a building with dominant openings

Conversely, openings to positions which are experiencing external suction will reduce the pressure inside the building thus increasing total loads on the windward wall.

Most buildings have some degree of permeability on each face, through windows, ventilation louvers, leakage gaps around doors and windows, and to some extent through the cladding itself. Permeability, in this context, is measured by the total area of such openings in a face. The problem is to determine the resulting internal balance of all the contributing leakage points and, for design purposes, to assess the worst probable combination of circumstances that may arise.

Dominant openings have to be considered in the design process in most buildings that might experience hurricanes, since flying debris is quite likely to break a window or cause other damage to the windward face during a storm. A positive pressure will be admitted inside the building and this will act in conjunction with the external suctions (particularly on the roof) and greatly increase the loads. This situation frequently occurs, as can be seen during any wind storm; most damage occurs to roofs, and examples are shown in Figure 2. The only occasion when it is safe not to design for this situation is when hurricane shutters are available for all windows and it is known that they will be put in place when a hurricane warning is given.

Values of the internal pressure coefficient C_{pi} can be calculated accurately when dominant openings exist, and further details are given in the references. For most design purposes, however, C_{pi} may be taken as 0.75 of the value of C_{pe} outside the opening. The conditions should be determined for the various wind directions that give rise to critical loadings.

For buildings where it is not possible, or is not considered justifiable, to estimate the range of C_{pi}, and where there is only a small probability of a dominant opening occurring during a storm (eg with hurricane shutters), C_{pi} should be taken as the more onerous of $+0.2$ and -0.3. There are occasions when critical loadings occur without a dominant opening, and these C_{pi} values are then used in the design calculations. The Appendix gives a sample calculation in which these various values are used.

Many buildings have been saved from damage during a hurricane by the occupants deliberately controlling the internal pressure. A suction can easily by achieved by creating an opening in an area away from the windward wall. This tends to be advantageous in reducing uplift forces on roofs. If this action is taken, careful checks should be made for changes in the mean wind direction during the passage of the storm. Alternatively, the deliberate provision of a venting device can be extremely advantageous, provided it serves as a dominant opening to a region of suction for all wind directions. An example of such as application is a ridge ventilator on a low-pitch roof.

BUILDING DESIGN AND CONSTRUCTION

In most countries at present there is little engineering design input into those aspects of buildings which relate to wind resistance. If the amount of damage that occurs due to hurricanes is going to be reduced, it is important that the level of this engineering input is increased. This will require a greater and more widespread understanding of the structural principles involved in resisting the pressures and forces. It is particularly important to realise that pressures act at right-angles to a surface, and in the case of low-pitched roofs the uplift forces concerned are extremely large.

Specific design details and load factors to be used in conjunction with the calculations, are not included in this Note. These details will vary with the construction materials being used and information is given in relevant codes of practice or standards; further aspects are covered in some of the references to this Note.

The writer has inspected numerous damaged buildings after many hurricanes, and the most common factor that is immediately apparent — and the cause of much of the damage — is a lack of attention to details and connections, both at the design stage and during the construction stage. Better site supervision — for example, to ensure that all connections between roofs and walls are actually incorporated — would drastically reduce the number of damaged buildings after any hurricane. An example of inexpensive houses, specifically designed for low-income families in St Vincent, is shown in Figure 9.

Other useful points are given in a BRE paper entitled 'How to make your building withstand strong winds'. This contains guidelines to help reduce the forces exerted on a building whilst strong winds are blowing, or to help increase the structural resistance to the forces. The guidelines cover;

the siting and location of the building
the shape of the building
influence of architectural details
position of openings
joints and connections in masonry construction
joints and connections in timber construction
reinforcement of masonry
foundation/structural connections
roof/wall connections
ridge ventilators
details of roof construction

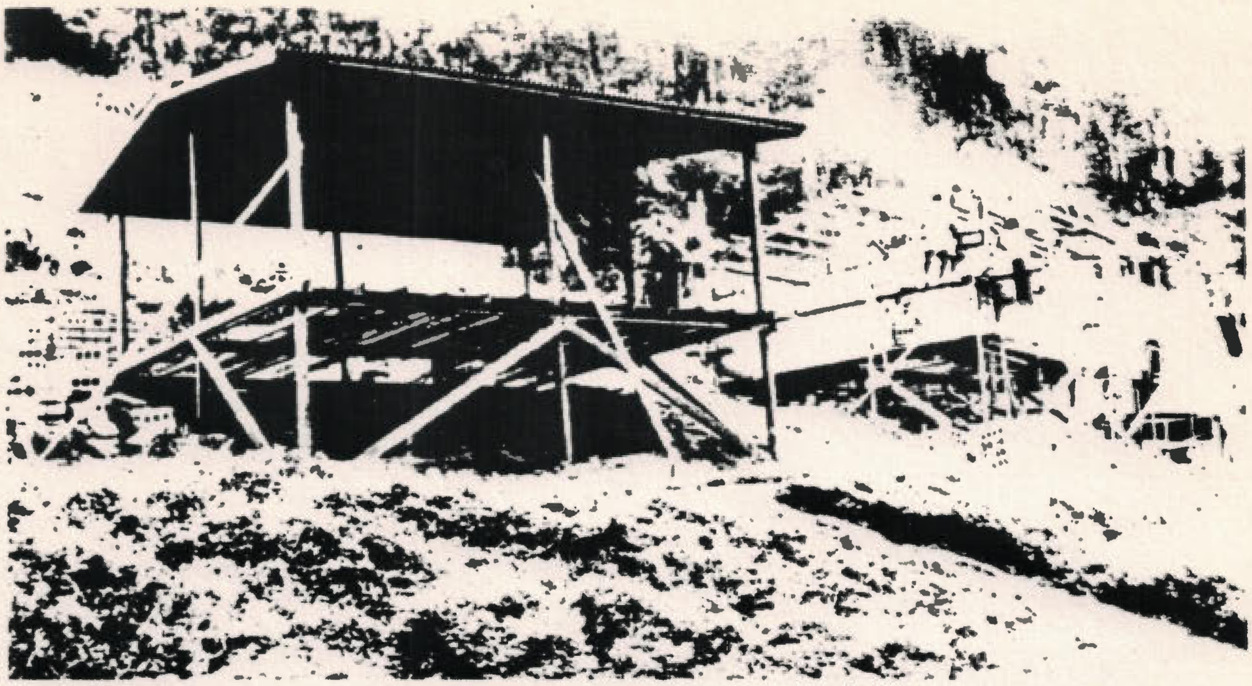


Figure 9 Part of an estate of houses being built in St Vincent using the author's designs

This paper has also proved very useful in situations after a hurricane where rebuilding work is in progress. It includes simple diagrams of the 25 guidelines, and can be used on site to improve the hurricane resistance for the future. (Bulk copies are available from BRE Overseas Division.)

CONCLUDING REMARKS

Several hundred million people live in areas around the world that are vulnerable to hurricanes and their associated storm surges. About three quarters of them have never experienced a direct hit by a major hurricane, because in any one particular location the probability of the eye of a storm passing directly over is small. However, no one knows where the next storm will make its landfall, when it will come, or how intense it will be. Everyone in the vulnerable areas should be made aware of the potential problems and of disaster procedures. And everyone involved in the building and construction industry in the developing countries that experience these storms must incorporate suitable safeguards in their buildings.

Wind engineering is a rapidly advancing subject, as research and past experience of damage and design problems are combined, and methods of resisting the forces are improved. The latest thinking for codes and standards is moving towards an entirely probabilistic approach to ensure that realistic design forces are used. This Note does not include complete details of this approach as the writer believes that the deterministic methods of the 'seventies' are more relevant in most tropical countries. Some time in the future, however, many countries are expected to modify their wind loading codes, and at that time this Note may require a revision.

At present, it is sufficient to summarise the procedures outlined in this Note as follows:

i Assess the design wind speeds, from available meteorological information, extrapolated to a design life, and possibly modified by local terrain and topographical factors.

ii Convert this speed to a dynamic pressure q.

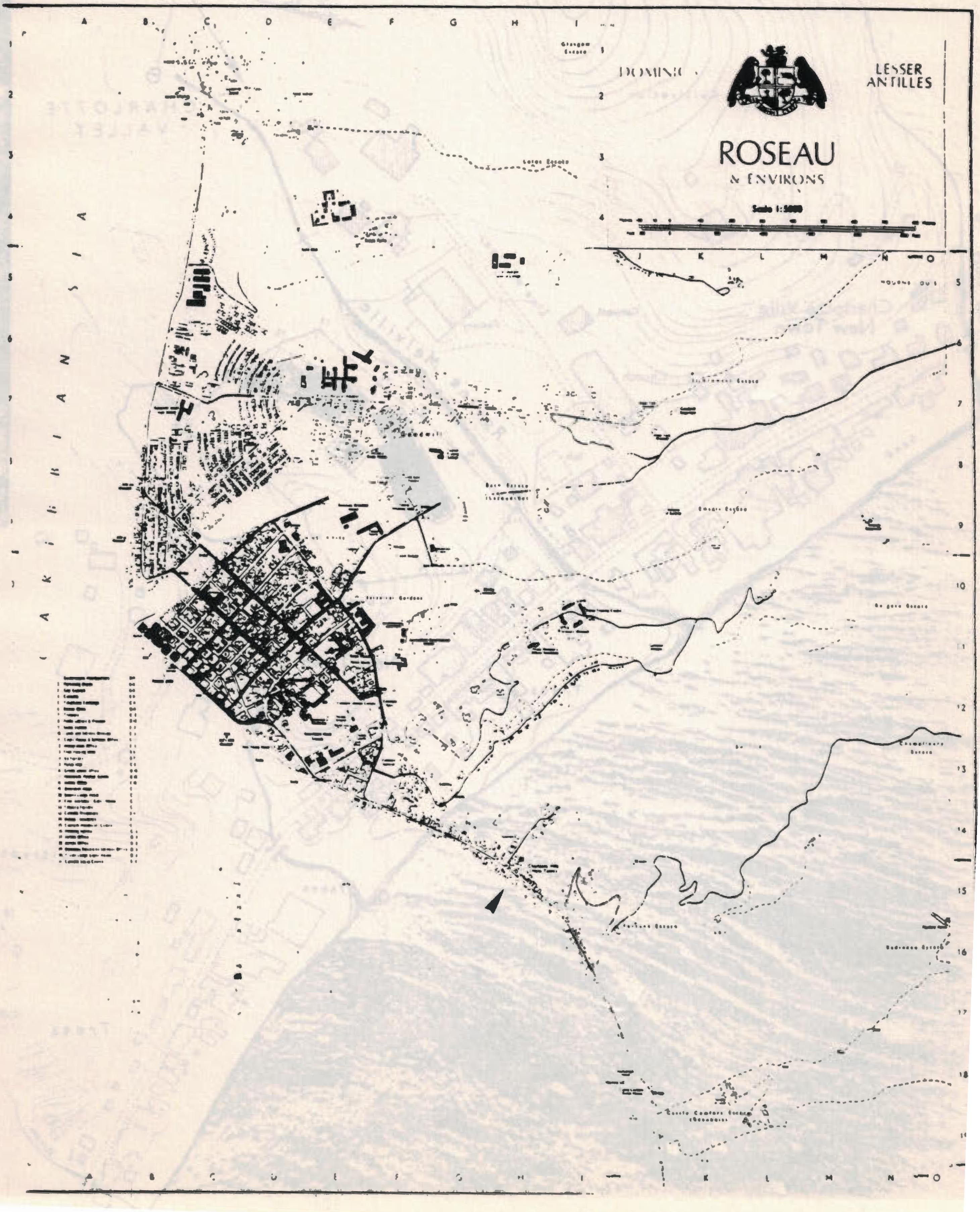
iii For structural loads and moments, obtain a force coefficient C_f and calculate overall forces.

iv For cladding loads and local pressures, obtain external pressure coefficients C_{pe} and calculate internal pressure coefficients C_{pi} to calculate the loads across each surface of the building.

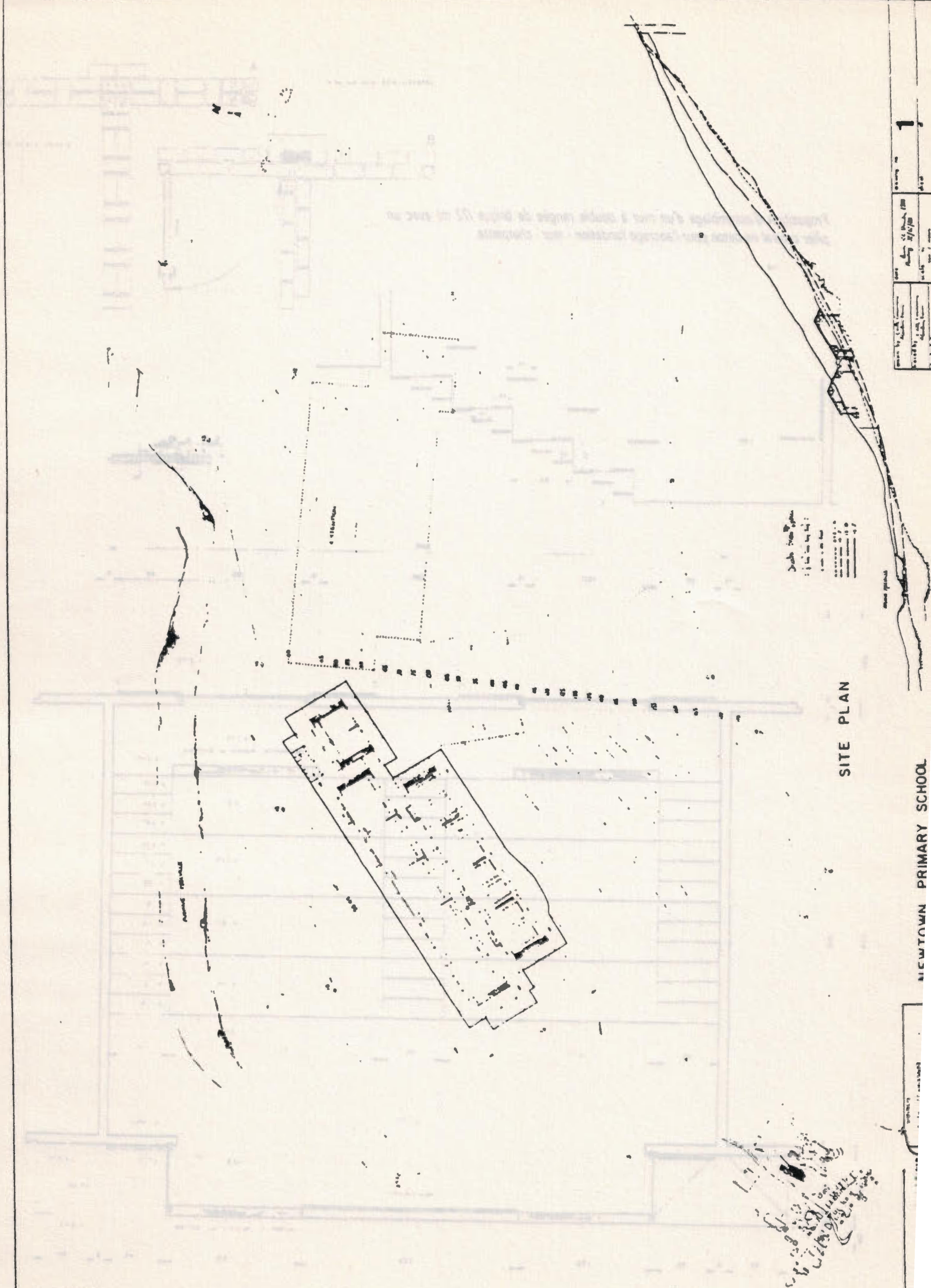
3. Cyclone resistant building - the experience of Newtown School, Dominica.

A. RAPPEL DU PROGRAMME pour la construction de « NEW TOWN SCHOOL »

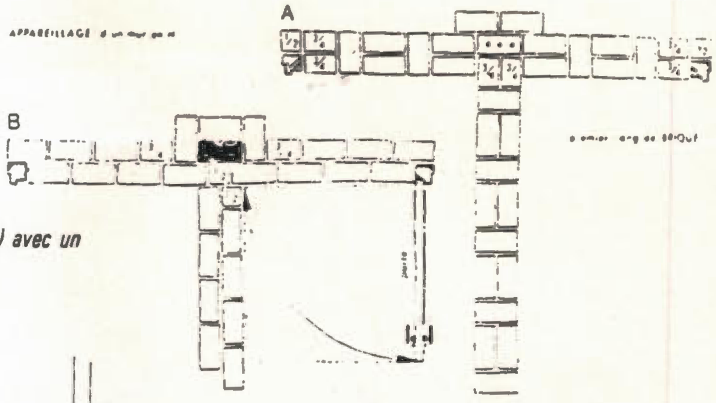
Pour cette agglomération située à la sortie sud de ROSEAU, le programme prévoit la construction de 20 classes de 35 élèves environ du primaire, plus les locaux techniques et administratifs nécessaires à leur fonctionnement et à leur gestion. Le terrain choisi pour l'implantation des bâtiments est situé dans une vallée relativement protégée des vents violents, mais suffisamment aérée pour une ventilation naturelle efficace des futurs locaux. Le terrain pentu, planté de quelques beaux arbres, longe la ravine MELVILLE qui se transforme en torrent à la saison des pluies abondantes.



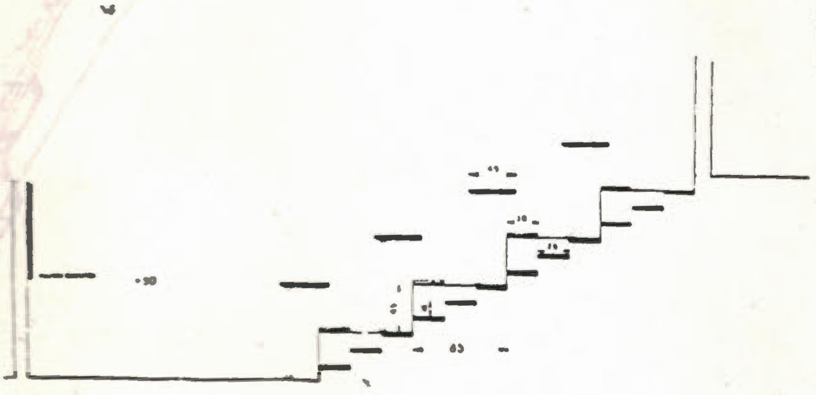

N
N-E
main wind
S
CHARLOTTE VALLEY
Trees
Cultivation
Line of Trees
Charlotte Ville
New Town
Convent
Factory
Church
Ravine Melville
Sand
Sch
Stream
Toilet
Cultivation
New Town
Trees
VICTORIA STREET
Trees
Cultivation
TB 29
237
Cultivation
Trees
Stream

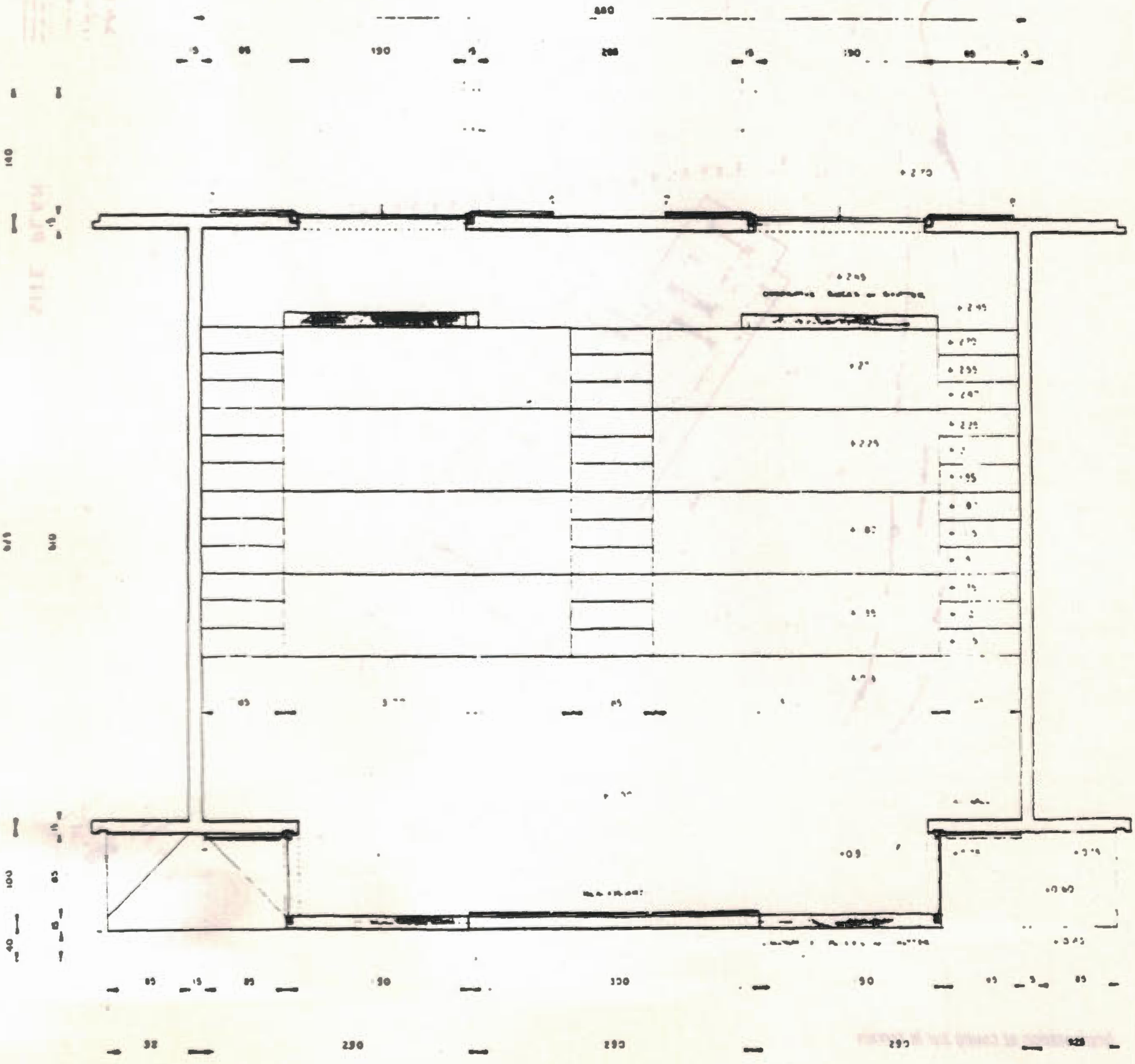


Implantation et coupe sur le terrain



Proposition d'assemblage d'un mur à double rangée de brique (22 m) avec un pilier central en béton pour l'ancrage fondation - mur - charpente.





TYPICAL CLASSROOM LAYOUT

Plan d'une classe type en gradin

B. DESCRIPTION DU PROJET

La prise de contact avec le terrain s'est faite de façon indirecte. Le véhicule après avoir emprunté une route perpendiculaire à l'axe principal, qui traverse NEW TOWN et suit la côte vers le sud de l'île, longe d'abord un terrain devant une église où beaucoup d'enfants s'amusent, ensuite se trouvent des maisons délabrées sur la droite pendant cent mètres et c'est tout. La voiture fait demi-tour sur un terrain vague devant un entrepôt et la colline de l'école est là, limitée de ce côté par la ravine MELVILLE.

L'arrivée des élèves ne pourra se faire par ce chemin trop indirect qui nécessiterait la construction d'un pont pour le passage de la ravine. Sur le terrain devant l'entrepôt doit être construit un centre de santé. Le terrain est très pentu, les limites de la parcelle noyées dans une végétation basse. Il faudrait utiliser au maximum les ombres portées du relief et des arbres existants pour la fraîcheur qu'ils apportent. La première chose à faire pour y voir clair serait le nettoyage du terrain et le repérage des arbres à conserver.

Avant le choix d'une solution technologique, l'étude de l'école a été réalisée suivant les facteurs climatiques et physiques du lieu. Ces données spécifiques ont aidé à l'adaptation de la construction au terrain par rapport à son environnement particulier. Bien sûr, d'autres facteurs tels que la fonction du bâtiment, l'observation d'un rythme de vie, l'analyse des besoins, les matériaux locaux, ont orienté d'une façon définitive les contours de l'école.

La mise à l'abri des débordements saisonniers de la ravine oriente le choix de l'implantation de l'école à mi-pente du terrain. Cette situation « en hauteur » favorisera aussi une meilleure ventilation des locaux tout en considérant la violence des vents qui viennent de l'Est. La zone plate dans le bas du terrain sera utilisée pour les récréations des élèves.

La pente du terrain, la situation préférentielle de l'école sur le site, la minimisation de la fouille, amènent à cette solution alternative entre une surface de classes plane et une autre en gradins, séparées par un espace de circulation ouvert et ombragé. Le type de classe en gradins propose une économie au niveau du mobilier scolaire puisque le sol se module en assises qui sont alors intégrées au gros-œuvre du bâtiment.

Pour la ventilation, élément essentiel à prendre en compte, c'est une circulation d'air axiale desservant chaque volume qui a été utilisée. L'espace tampon de circulation entre les deux groupes de classes, compose une zone d'ombre dans laquelle les courants d'air chaud se rafraîchissent puis irriguent chaque module dont le système d'ouverture favorise la circulation de l'air à l'intérieur du volume. Ces couloirs d'ombre sont recouverts sur leur totalité d'une treille dont les lattes de bois sont disposées de manière à opposer le minimum de résistance au vent. Sur ces treilles peuvent s'accrocher des plantes d'ombrage, vivaces, grimpantes et à fleurs, telles que le liseron à grandes corolles mauves, le bougainvillier, etc...

Vue du terrain

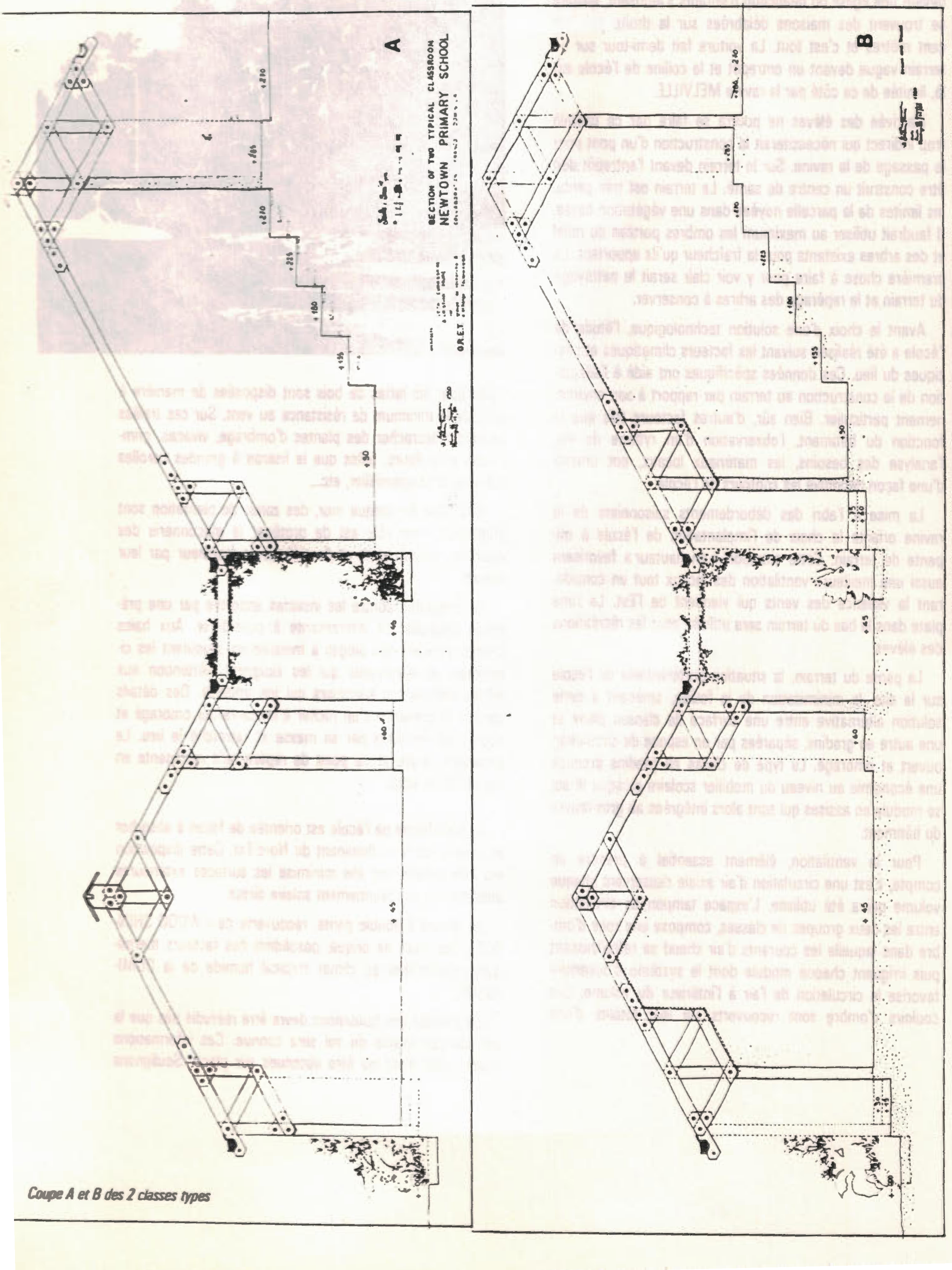
A la base de chaque mur, des zones de plantation sont proposées. Leur rôle est de protéger la maçonnerie des eaux de ruissellement et de diffuser la fraîcheur par leur masse.

La protection contre les insectes apportée par une présence végétale est intéressante à considérer. Aux haies basses qui sont des pièges à moustiques s'ajoutent les citronniers et eucalyptus qui les éloignent. (Attention aux arbres comme les bananiers qui les attirent). Des détails comme la présence d'un rocher à un carrefour ombragé et ventilé qui équilibre par sa masse et rafraîchit le lieu. Le caractère de jeu et de point de repère qu'il représente en fait un décor actif.

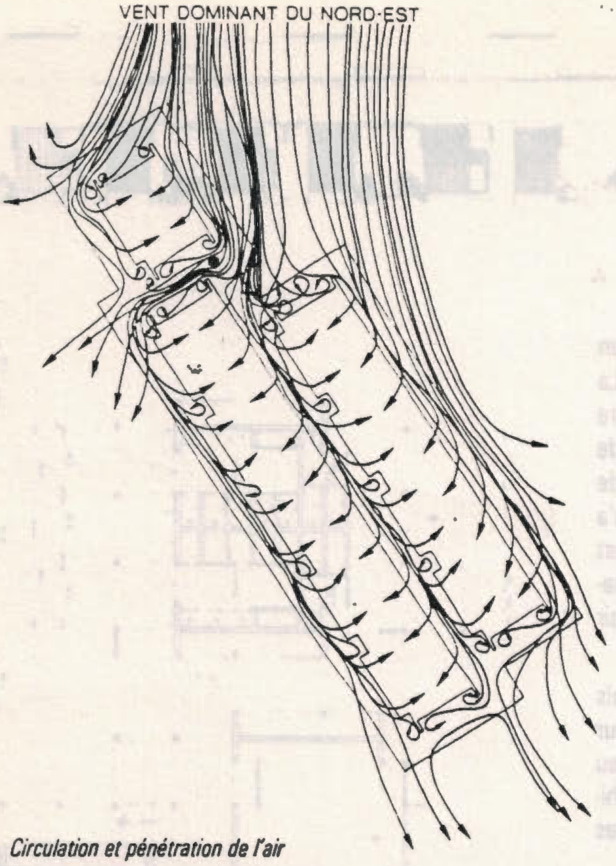
La plateforme de l'école est orientée de façon à absorber et résister au vent dominant du Nord-Est. Cette disposition est intéressante car elle minimise les surfaces extérieures absorbantes de rayonnement solaire direct.

La toiture à double pente, recouverte de « WOOD SHINGLE », les murs de brique, possèdent des facteurs thermiques appropriées au climat tropical humide de la DOMINIQUE.

Le principe des fondations devra être réétudié dès que la composition exacte du sol sera connue. Ces informations importantes n'ont pu être obtenues sur place. Soulignons



Coupe A et B des 2 classes types



Circulation et pénétration de l'air

que la difficulté de recevoir à temps des renseignements précis, peut amener des modifications du projet au niveau du socle.

L'ensemble des bâtiments comprend deux groupes de 8 à 9 classes, des locaux administratifs, deux blocs sanitaires, un hall couvert dont l'usage peut s'étendre à des animations de quartier, comme l'utilisation du lieu en salle des fêtes, de meetings, en espaces couverts pouvant recevoir des groupes d'expression artistique divers, en salles d'expositions ou de projections, etc...

Le choix d'un module qui s'adapte aux différents besoins d'espace de l'école permettra d'appliquer à l'ensemble des bâtiments un système constructif simple.

Des modifications de cloisonnement intérieur suffisent à passer du module des classes à celui des bureaux administratifs ou des blocs sanitaires.

Pour rompre la monotonie d'alignement des bâtiments et pour favoriser la pénétration de la ventilation naturelle à l'intérieur de chaque volume, un dégagement frontal et un jeu de niveau évitant la pénétration du ruissellement des eaux, organisent un accès indirect et protégé aux classes.

De par sa situation à mi-pente du terrain, d'éventuels mouvements du sol peuvent devenir menaçants pour l'école. En amont de l'ensemble des bâtiments sont prévus trois murs de soutènement successifs en GABION. (panier de grillage rempli de galets). Ce système est couramment utilisé en Dominique pour la protection du littoral ou des fondements des routes côtières.

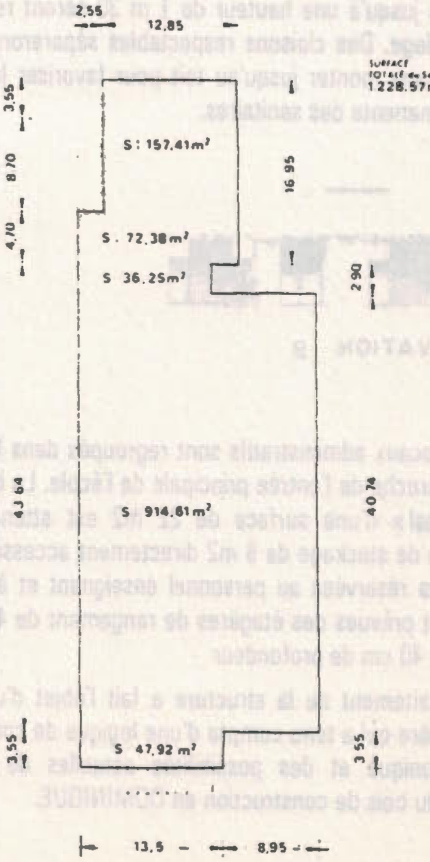
Les groupes de marches qui permettent d'accéder d'un niveau à un autre dans la circulation extérieure sont soit de modèle commun soit de type rampant ou pas d'âne de 85 cm de profondeur.

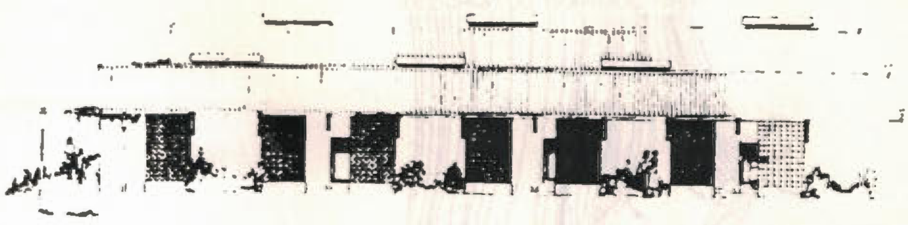
Le module de base des différents volumes de l'école est de 8 m 50 par 6 m 20 soit une surface de 50 mètres carrés environ.

Chaque classe peut recevoir confortablement une quarantaine d'enfants. La largeur des unités de passage est de 85 cm, la hauteur des marches de 15 cm, celle des assises en gradins de 45 cm. A un mur face aux élèves, s'accroche un tableau noir de 3 mètres de long. L'éclairage naturel pénètre par des persiennes à lamelles orientables réparties de chaque côté du tableau, ou par des clostras situés au fond de la classe.

L'utilisation de systèmes d'ouvertures réglables permet d'orienter les filets d'air tout en assurant une bonne protection du rayonnement solaire qui doit être totale de 10 heures à 16 heures.

Surface du socle



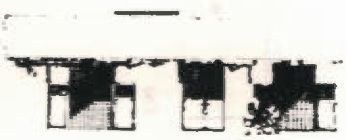


ELEVATION A

Les murs protecteurs en forme de I sont montés en double rangées de briques soit 22 cm d'épaisseur. La construction en matériau léger comme la brique de terre cuite, de faible masse, sans accumulation, est ce qu'il y a de mieux approprié pour profiter au maximum des baisses de température la nuit. La hauteur du volume des classes n'a aucune incidence sur le confort thermique si la toiture est correctement ventilée. Une ouverture protégée est aménagée au faîtage de chaque volume pour l'évacuation de l'air chaud.

Le matériau idéal à utiliser pour le revêtement des sols de l'école est un carrelage de terre cuite procurant fraîcheur et isolation à l'humidité. D'un entretien facile pour un lieu fréquenté, sa pose peut faire l'objet d'une recherche graphique dans l'assemblage d'éléments carrés et rectangulaires proportionnels à l'unité de passage de 85 cm.

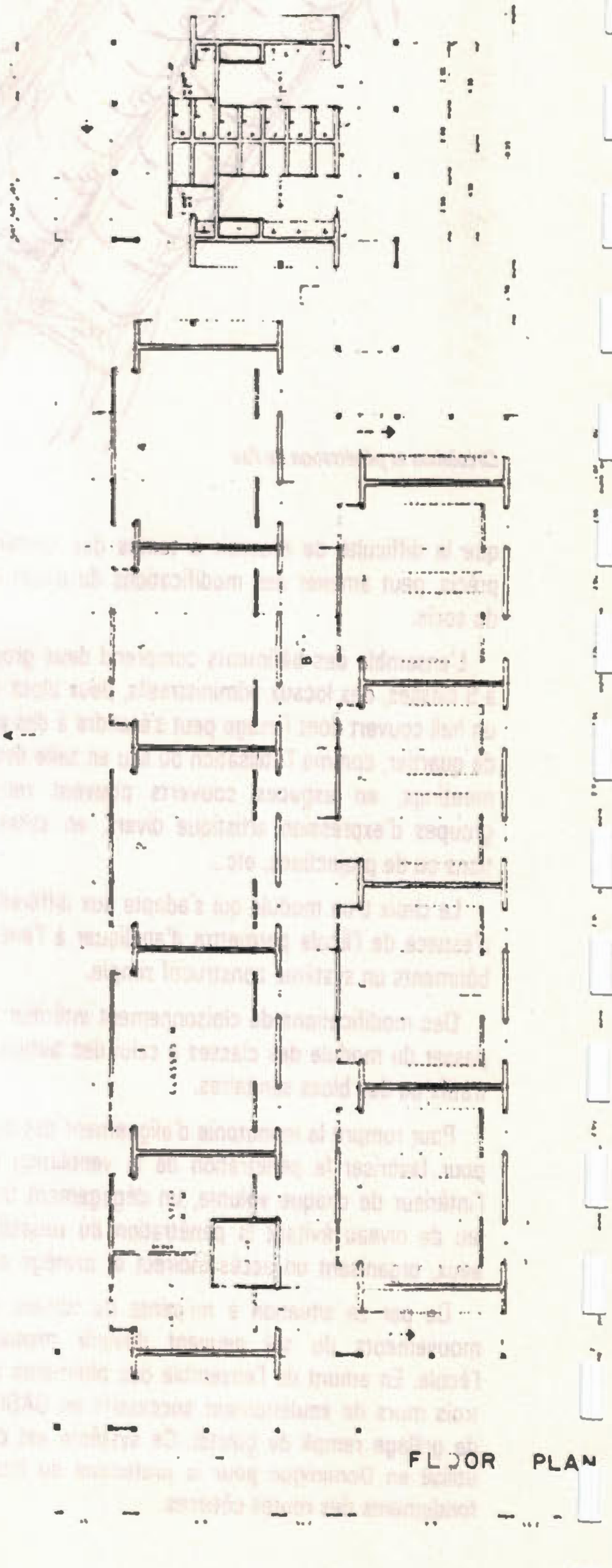
Deux blocs sanitaires indépendants sont répartis entre les groupes de classes. Chaque unité est divisée en quatre parties : une, réservée aux filles, l'autre aux garçons, une au personnel féminin, l'autre au personnel masculin. Sont prévues des paillasses intégrant des lave-mains ainsi que des surfaces de rangement réservées à l'entretien. Le sol et les murs jusqu'à une hauteur de 1 m 30 seront recouverts de carrelage. Des cloisons respectables sépareront chaque toilette sans monter jusqu'au toit pour favoriser la ventilation permanente des sanitaires.



ELEVATION B

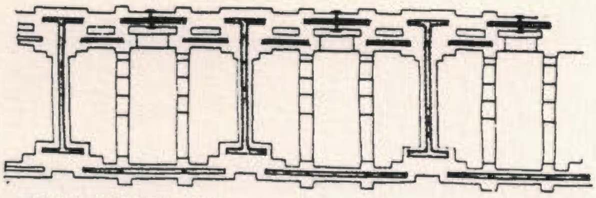
Les locaux administratifs sont regroupés dans le volume le plus proche de l'entrée principale de l'école. Le bureau du « Principal » d'une surface de 22 m2 est attenant à un magasin de stockage de 8 m2 directement accessible. Dans les salles réservées au personnel enseignant et à la direction sont prévues des étagères de rangement de 4 m 30 de long sur 40 cm de profondeur.

Le traitement de la structure a fait l'objet d'une étude particulière qui a tenu compte d'une logique de construction anticyclonique et des possibilités actuelles de mise en œuvre du bois de construction en DOMINIQUE.

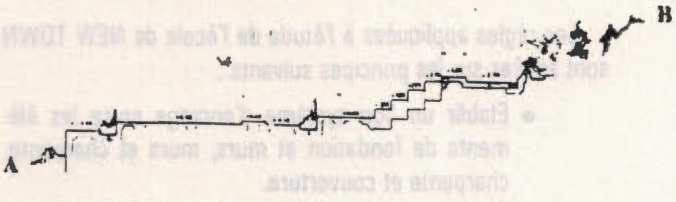


FLOOR PLAN

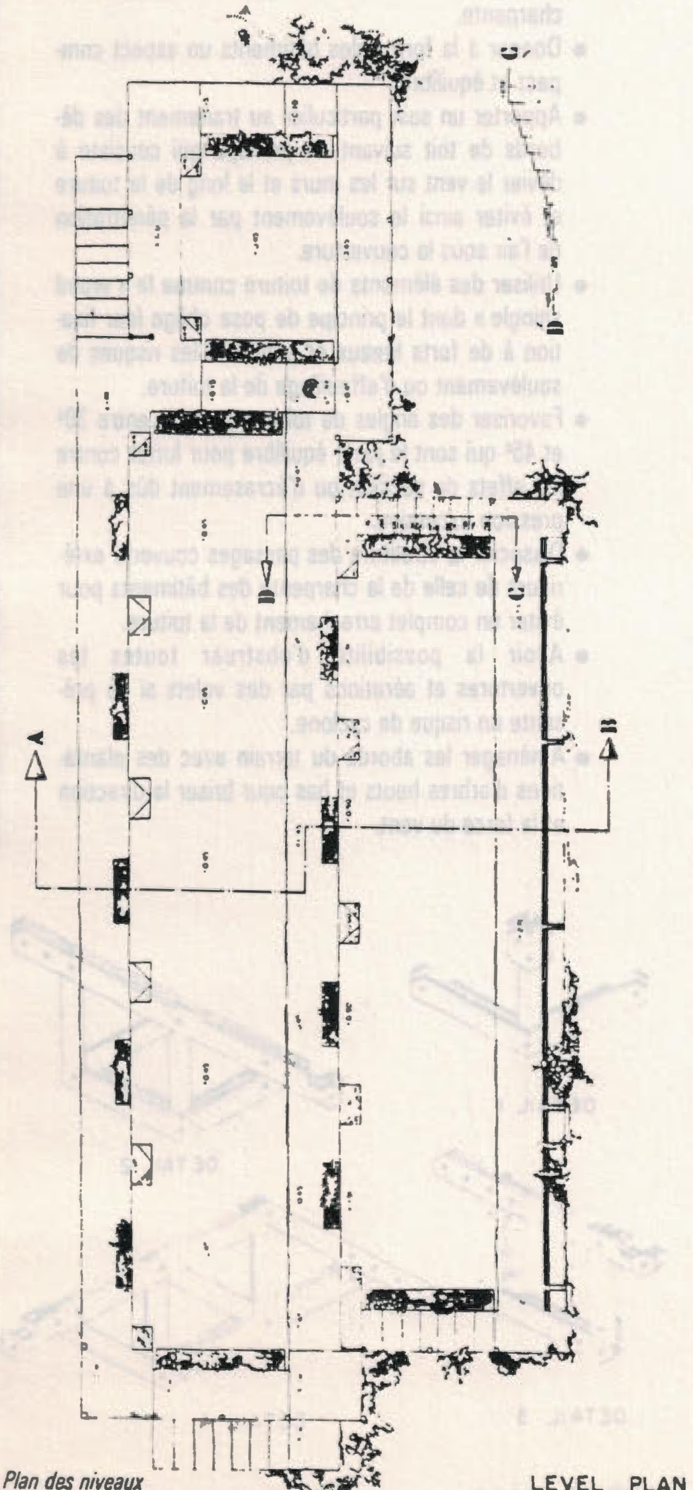
Plan et élévations



FOUNDATION PLAN

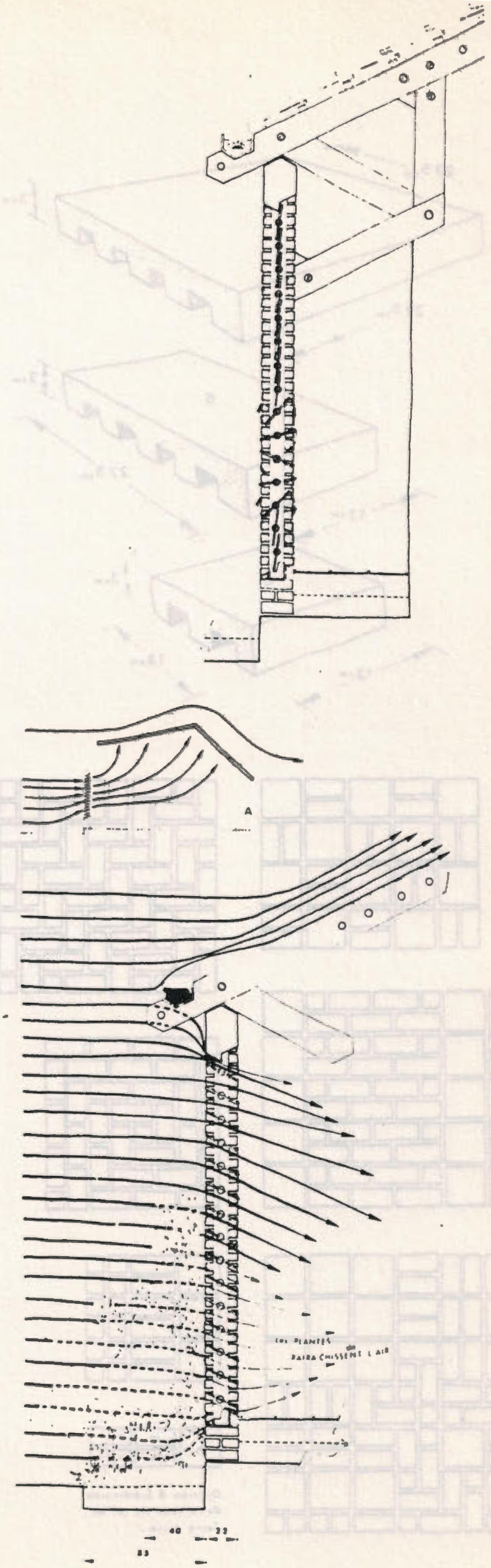


SECTION

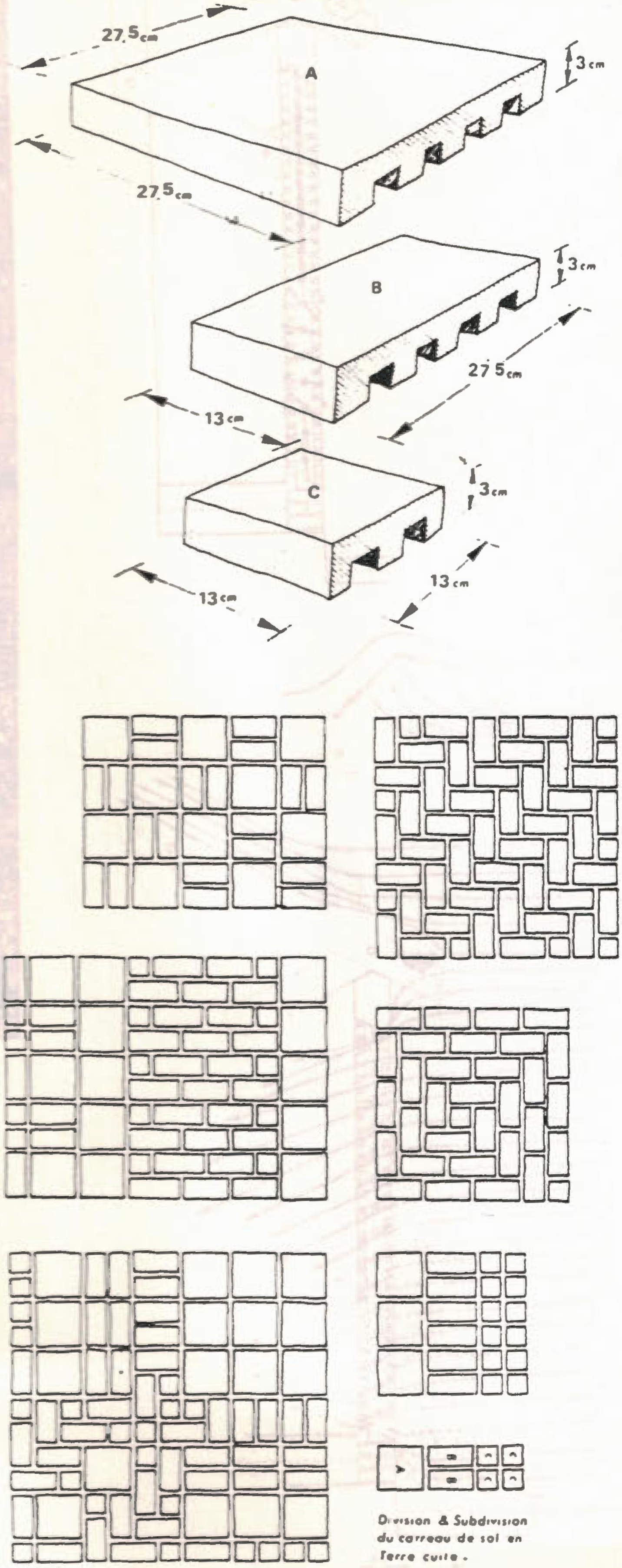


Plan des niveaux

LEVEL PLAN



Coupe sur système d'ouverture à lamelles orientables

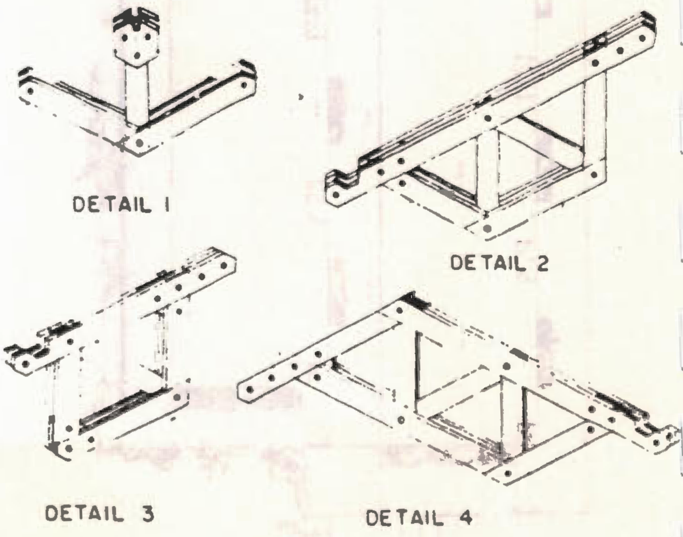


Division & Subdivision du carreau de sol en Terre cuite.

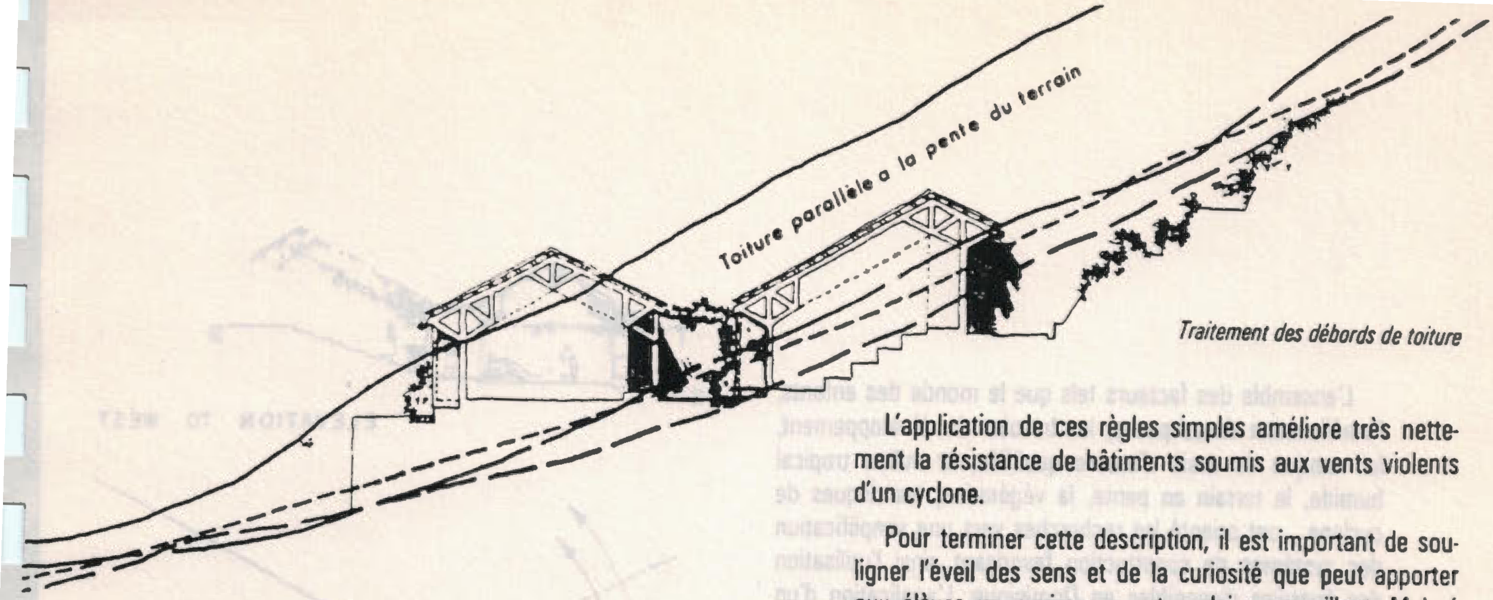
Modules pour le carrelage et exemples d'assemblage

Les règles appliquées à l'étude de l'école de NEW TOWN sont basées sur les principes suivants :

- Etablir un bon système d'ancrage entre les éléments de fondation et murs, murs et charpente, charpente et couverture.
- Renforcer par triangulation les points faibles de la charpente.
- Donner à la forme des bâtiments un aspect compact et équilibré.
- Apporter un soin particulier au traitement des débords de toit suivant un principe qui consiste à dévier le vent sur les murs et le long de la toiture et éviter ainsi le soulèvement par la pénétration de l'air sous la couverture.
- Utiliser des éléments de toiture comme le « wood shingle » dont le principe de pose oblige leur fixation à de forts liteaux et minimise les risques de soulèvement ou d'effeuillage de la toiture.
- Favoriser des angles de toiture compris entre 30° et 45° qui sont le juste équilibre pour lutter contre les effets de succion ou d'écrasement dûs à une pression excessive.
- Dissocier la structure des passages couverts extérieurs de celle de la charpente des bâtiments pour éviter un complet arrachement de la toiture.
- Avoir la possibilité d'obstruer toutes les ouvertures et aérations par des volets si se présente un risque de cyclone.
- Aménager les abords du terrain avec des plantations d'arbres hauts et bas pour briser la direction et la force du vent.



détails de la charpente



Traitement des débords de toiture

L'application de ces règles simples améliore très nettement la résistance de bâtiments soumis aux vents violents d'un cyclone.

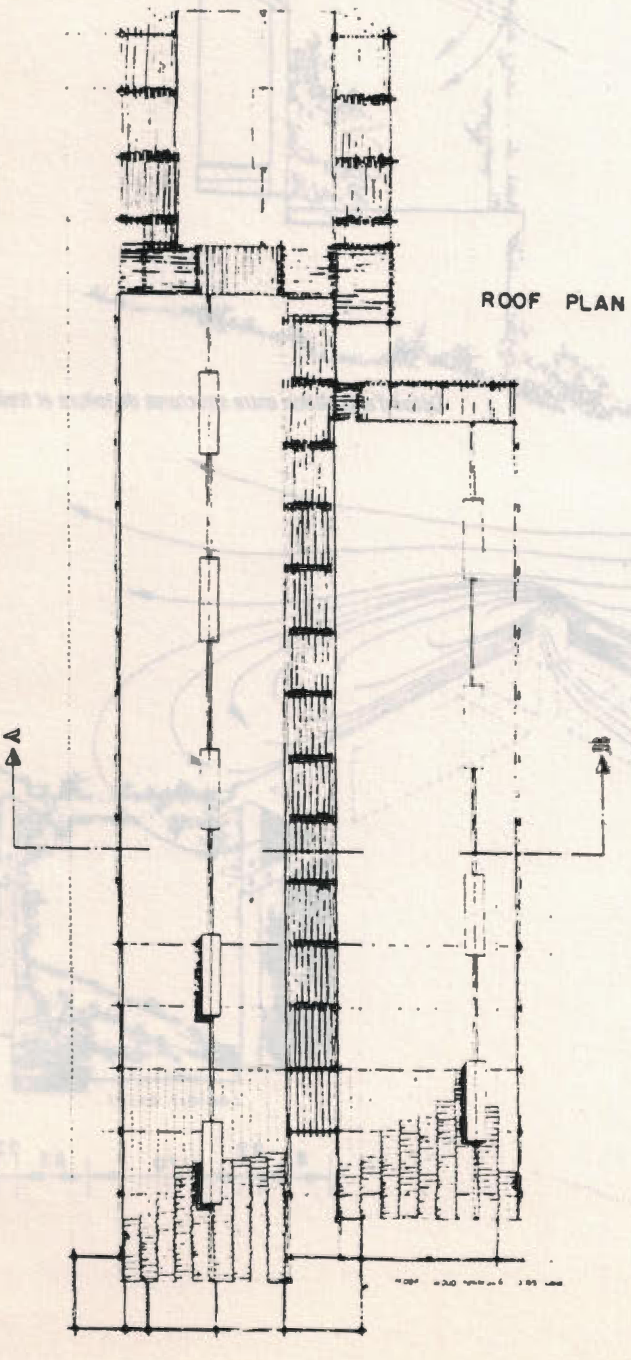
Pour terminer cette description, il est important de souligner l'éveil des sens et de la curiosité que peut apporter aux élèves un environnement scolaire accueillant. Malgré les diversités dues au milieu géographique, aux conditions de vie, aux structures sociales et aux valeurs culturelles, tous les enfants du monde présentent un certain nombre de caractères communs. Les remarques qui suivent sont empruntées à une étude effectuée par le Centre International de l'Enfance.

« – De 4 à 5 ans

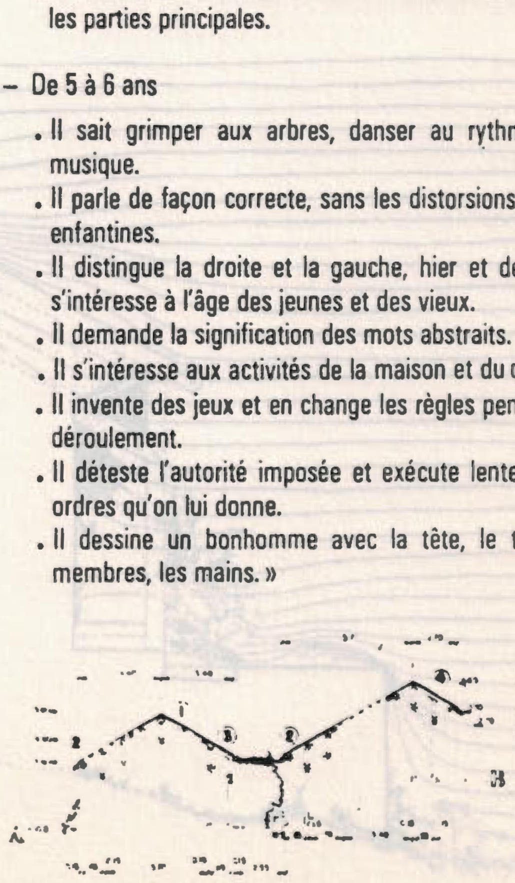
- Il bondit, saute, se balance.
- Il copie un carré, un triangle, et peut dessiner un bonhomme avec la tête et les membres.
- Il sait compter ses doigts.
- Il écoute une histoire et peut répéter les épisodes principaux.
- Il proteste si on l'empêche de faire ce qu'il veut.
- Il peut apprécier la taille et la forme, distinguer le gros et le petit.
- Il dessine un bonhomme avec la tête, les membres et les parties principales.

– De 5 à 6 ans

- Il sait grimper aux arbres, danser au rythme de la musique.
- Il parle de façon correcte, sans les distorsions verbales enfantines.
- Il distingue la droite et la gauche, hier et demain, et s'intéresse à l'âge des jeunes et des vieux.
- Il demande la signification des mots abstraits.
- Il s'intéresse aux activités de la maison et du quartier.
- Il invente des jeux et en change les règles pendant leur déroulement.
- Il déteste l'autorité imposée et exécute lentement les ordres qu'on lui donne.
- Il dessine un bonhomme avec la tête, le tronc, les membres, les mains. »



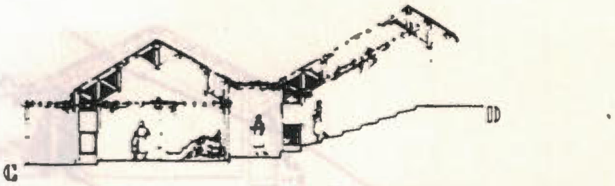
Plan de toiture

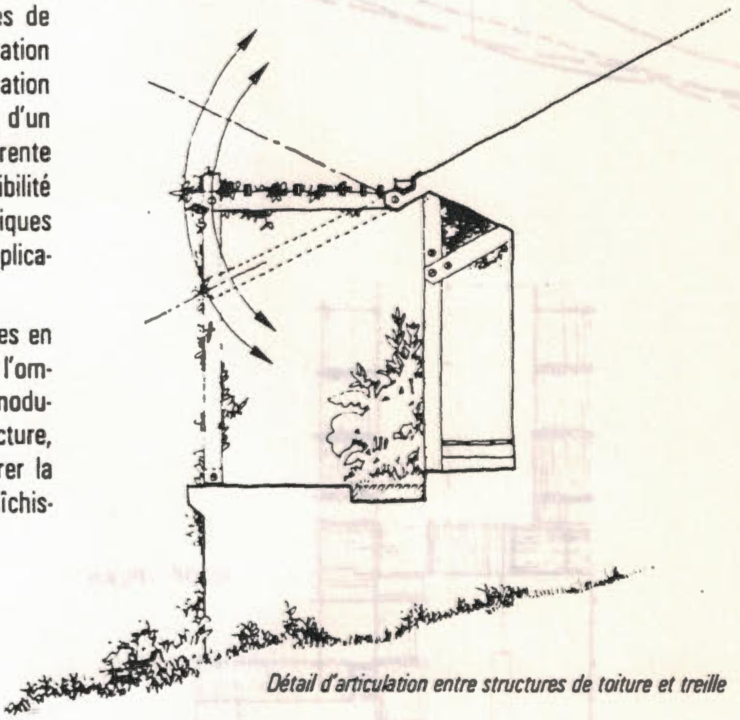


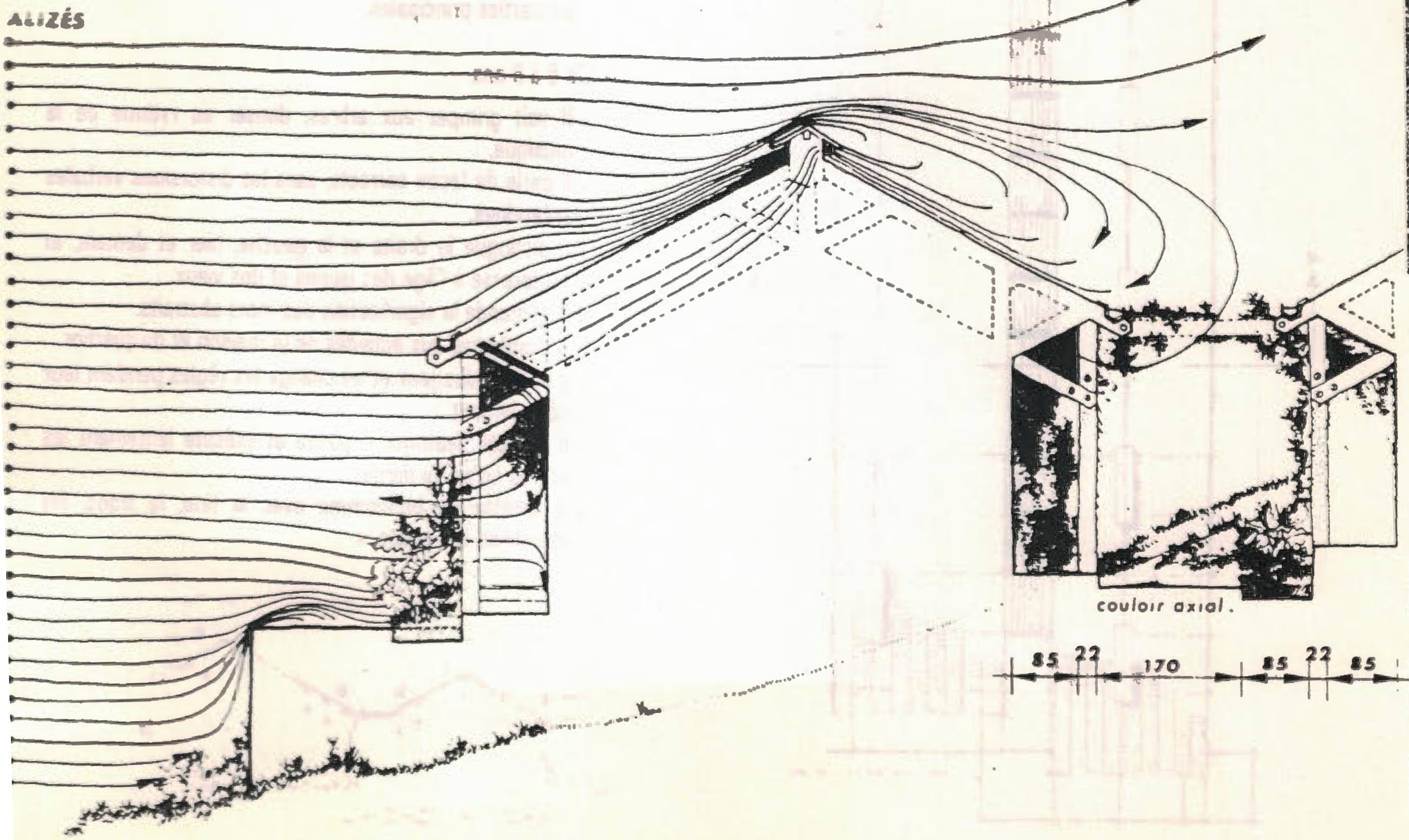
SECTION A-B

L'ensemble des facteurs tels que le monde des enfants, l'amélioration des espaces, les besoins de développement, le manque de main d'œuvre qualifiée, le milieu tropical humide, le terrain en pente, la végétation, les risques de cyclone... ont orienté les recherches vers une simplification des systèmes de construction favorisant ainsi l'utilisation des énergies disponibles en Dominique. L'application d'un système constructif pour la réalisation d'une école différente encouragera la diffusion de l'information sur la disponibilité des matériaux de construction locaux, sur les techniques utilisées et les améliorations apportées par leurs applications.

Le souci d'améliorer le confort thermique des classes en apportant aux circulations extérieures la tranquillité de l'ombre qui adoucira l'ambiance des espaces intérieurs en modulant ventilation et luminosité est lié à l'étude de structure, de volume, des matériaux et au désir de faire pénétrer la végétation dans l'architecture pour ses qualités rafraîchissantes.


ELEVATION TO WEST


Détail d'articulation entre structures de toiture et treille



4. Recommendations for site choice and protection.

CHAPTER THREE

FACTORS INFLUENCING THE SELECTION AND USE OF THE SITE

General

Only in a minority of cases will selection of the site be a matter of of choice, but some of the following influences might be significant.

The school will normally be situated within walking distance of its population (in the Philippines about a two-kilometre maximum radius for primary schools). Ideally the site will contain variegated types of terrain, including flat ground for playing fields, small rises and hillocks to provide shelter from strong winds, vegetation of various kinds including wooded areas and, if possible, windbreaks sheltering the site from bad weather.

If the school serves a flood-prone area, and is intended as a community refuge during floods, it should clearly be situated as high as possible. If there is no high ground, consideration might be given to earth works (which should be relatively cheap) designed to raise the general ground level, or a critical part of it to whatever height is feasible. These elevated areas could be supplemented over time by supervised filling with building debris and (selected) refuse.

Such earthworks can serve several functions:

1. They would offer outdoor spaces for teaching or drama by creating 'amphitheatre' spaces in the vicinity of the school buildings;
2. They would reduce the tendency for schools to be situated in bleak, undifferentiated flat areas without identity or human scale;
3. They could relate to outdoor gardening and nature study programmes;
4. In flood conditions they would provide some outdoor high ground convenient to school buildings;
5. If properly located in relation to strong prevailing winds they would deflect some winds without interrupting beneficial breezes. (As cyclones may blow from any direction, the earthworks will only provide partial shelter, at least from cyclonic winds).
6. Ventilation in normal conditions is better if buildings are raised on mounds than if they are at ground level.[1]

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[1] Unesco. Regional Office for Education in Asia, Bangkok. *Induced air movement for wide-span schools in humid Asia.* Bangkok, 1976. (Educational Building Digest No. 9).

Vegetation

Although the study of the Darwin cyclone (December 1974) reported many uprooted trees and advocated pruning of large trees before the cyclone season,[2] the observations of a mission to the Philippines indicated little damage to trees compared to the devastation of buildings and other man-made objects.[3] Plate 1 shows trees in Bangladesh, substantially undamaged after the major 1970 cyclone.

Plate 1. Trees in Bangladesh, substantially undamaged after the major 1970 cyclone.

In general, trees which are blown down are of the large, older types having shallow or restricted root structures. Trees of softer wood which have little bending resistence lose some of their limbs. Coconut palms, stands of bamboo and small banana orchards survive with very little damage. At a rough guess, possibly 25-30% of large trees are uprooted but these, in turn, represent quite a small proportion of all tree growth in the areas observed. It is suggested that the planting of groves of trees of an appropriate kind may reduce wind speeds and provide some sheltering effect without seriously risking further damage by their own destruction, or even impeding gentle winds. The educational value of trees for biological and general studies is, of course, undisputed, as is their value in creating more pleasant external spaces, and shading buildings and grounds against thermal excesses.

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2. Australia. Department of Housing and Construction. *Report on cyclone "Tracy" and effect on buildings*, by George R. Walker, Vol 3, Canberra, 1975.

3. Mackey, Finney and Okubo. *Philippines: the typhoon of October and November 1970*, op. cit., p. 3.

Wind breaks

In the case of normal prevailing strong winds, the logical procedure for protection is to present the minimum area of building towards the wind, to shape it in such a way as to reduce strains in the building fabric, and to protect it with windbreaks of whatever kind. In the case of cyclone-prone areas, this is not so easy, since the cyclone, while following a general path which may be relatively straight and predictable, may blow strongly in virtually all directions within a small area.

By the same token, although a site may have good and bad aspects from the viewpoints of prevailing winds, breezes, sun and other factors, a cyclone will render the careful layout in relation to these considerations largely irrelevant. One cannot provide shelter against wind from all directions without discarding the important benefits of cooling breezes in normal times.

Nevertheless, it may be possible for strong winds to be mitigated by either permeable or shaped obstructions that cause less interference with gentle winds. Some experiments suggest that this may be done, but there seem as yet to be few conclusions from detailed study of the problem.

Buildings and trees as wind-breaks

A rudimentary wind-break occurs when one building is erected on the windward side of another. The detailed effect this has on wind movements is complicated, and seldom entirely beneficial. Depending on the height of the wind-break, there is a considerable blocking of wind from buildings on the leeward side. See Figure 7, (a) and (b). Angling the blocks in plan, or staggering them as shown in the adjoining diagrams, causes only minor differences in the amount and direction of wind penetrating beyond the wind breaks. Olgyay[4] claims that the arrangements shown in Figure 7(c) and (d) result in good breezes to all units. If the successive rows of buildings are spaced

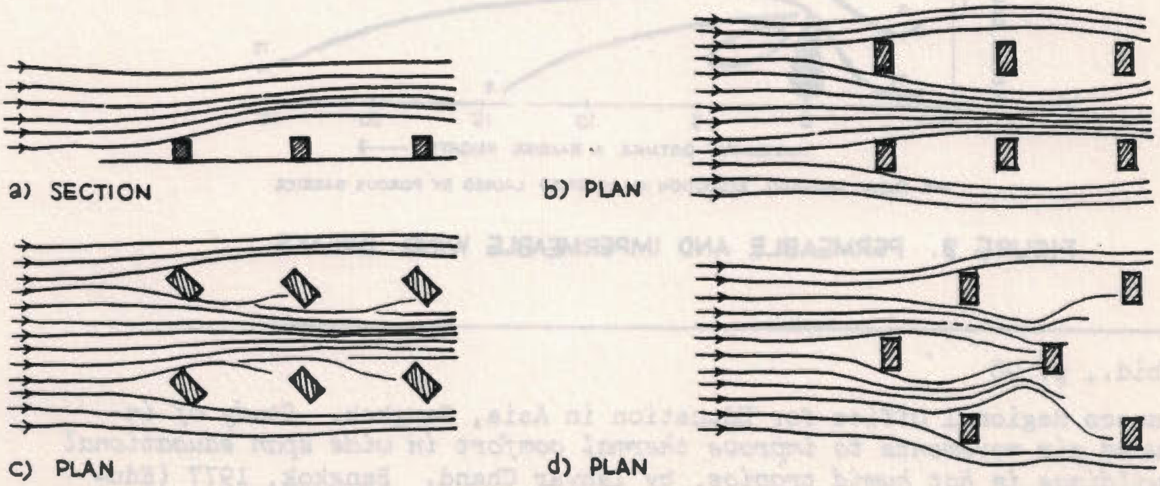
a) SECTION
b) PLAN
c) PLAN
d) PLAN

FIGURE 7. BUILDINGS AS WIND BREAKS

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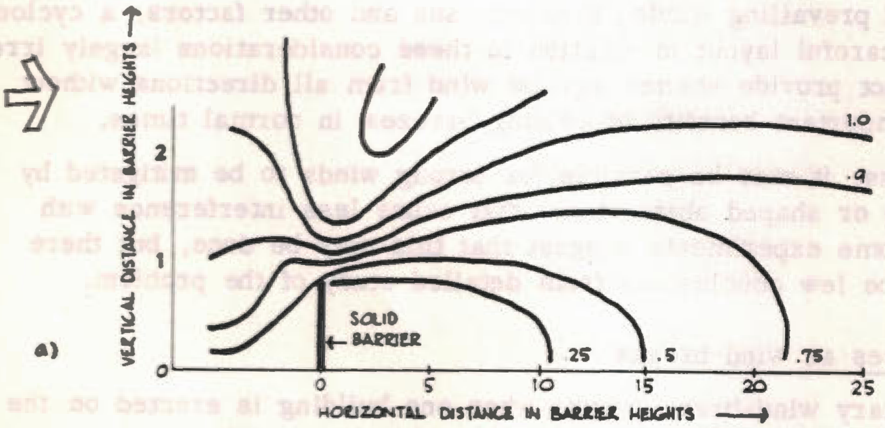
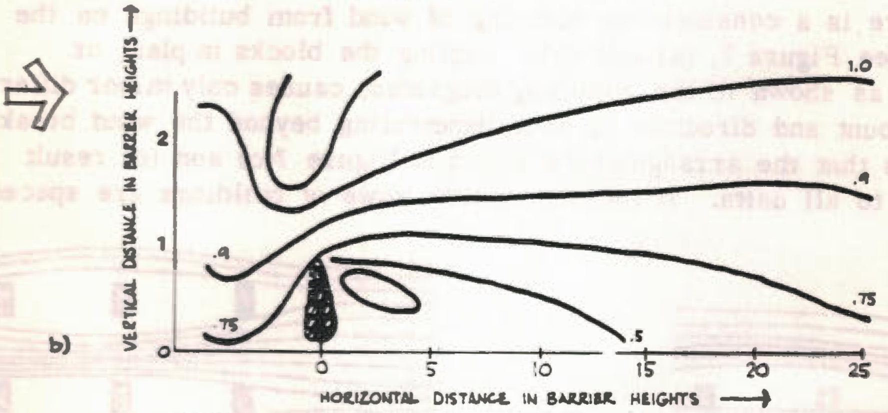
[4] Victor Olgyay. *Design with climate.* Princeton, Princeton University Press, 1963.

at about seven times their height apart, the wind movement will not be seriously diminished; at a closer spacing some wind protection is afforded.

Wind-tunnel tests have been made of wind-breaks of various kinds[5], [6]. The type of wind-break has some effect on the result; solid windbreaks - for example, walls - cause eddies over the top which reduce their value (Figure 8a). Permeable barriers such as belts of trees are more effective in some ways because, while not reducing wind velocities as markedly as solid barriers, there is a greater depth of protection (Figure 8b).



AIR FLOW SHOWING REDUCTION IN AIR SPEED CAUSED BY SOLID BARRIER



AIR FLOW SHOWING REDUCTION IN AIR SPEED CAUSED BY POROUS BARRIER

FIGURE 8. PERMEABLE AND IMPERMEABLE WIND BREAKS

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5. Ibid., p. 98

6. Unesco Regional Office for Education in Asia, Bangkok. *Study of induced air movements to improve thermal comfort in wide span educational buildings in hot humid tropics,* by Ishwar Chand. Bangkok, 1977 (Educational Building Report No. 6)

The air bleeding through a permeable wind-break tends to reduce the formation of leeward eddies (Plate 2).

Plate 2. Trees seem to have reduced wind speeds sufficiently to prevent damage to these flimsy buildings

The permeability of different kinds of trees and other barriers can be varied (Figure 9). The optimum porosity of the barrier is in the range 30-to-50 per cent.[7] A lower figure will cause a greater reduction in wind speeds, but the more open barrier will be effective for a greater distance.

The performance of different types of permeable barriers - boarded fences, dense belts of trees, thinner belts of lighter texture trees - will produce considerable differences for the first five to ten times or so of their height, in horizontal distance from the barrier, after which the differences diminish. At about 30 height units there is no appreciable effect, and not much at 20.

It should be remembered that, as well as affording protection, wind-breaks divert wind to other places. This can have a beneficial or adverse effect. Similarly, in using trees to reduce wind speeds in a particular area, the effect in other locations will probably be to increase speeds (for example, immediately above and below the foliage).

Seasons

Many school buildings are in use for only some parts of the day and year. Ideally, the long school vacation would coincide with the months of

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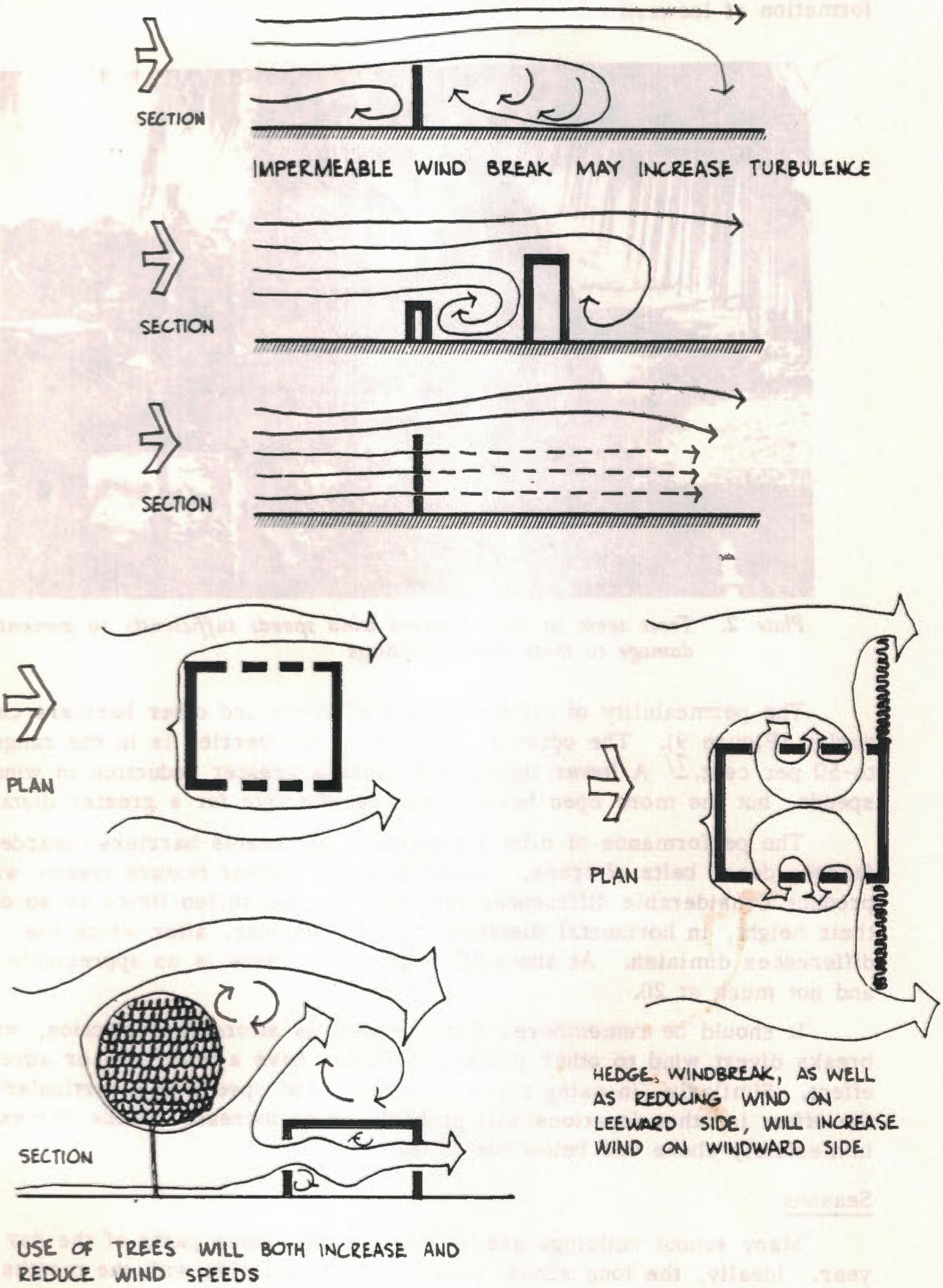
[7] Newberry. *Wind loading handbook,* op. cit. p. 34



IMPERMEABLE WIND BREAK MAY INCREASE TURBULENCE

HEDGE, WINDBREAK, AS WELL AS REDUCING WIND ON LEEWARD SIDE, WILL INCREASE WIND ON WINDWARD SIDE

USE OF TREES WILL BOTH INCREASE AND REDUCE WIND SPEEDS

FIGURE 9. WIND FLOW

cyclones or other bad weather. Some parts of the school do not need as much protection as other parts, and some parts may be able to shelter other parts from unfavourable winds.

Flooding and storm-surge

When a history of flooding exists, there are probably locally evolved building practices in which some adjustments have been made to meet flood problems. For example, earth-block construction may have evolved with additives such as cement or asphalt which are more resistant to still or turbulent floodwater. Local observations about scouring and the dynamics of flood water will be valuable.

There is a proposal for small flood shelters, community-built on raised earth platforms, for Bangladesh. These shelters will give minimum protection against an 8 metre storm surge, which is a fairly extreme surge height. The shelters are capable of construction by voluntary community labour (Figure 10).[8]

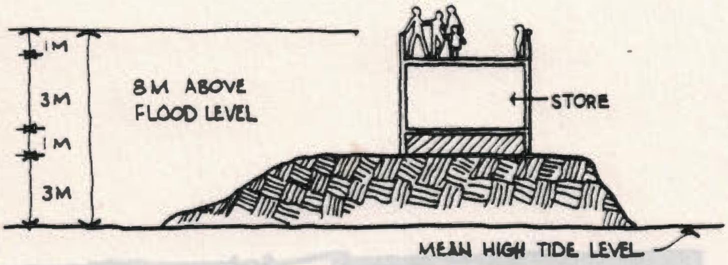


FIGURE 10. STORM SHELTER WITH ROOF REFUGE

A more commodious shelter of this type is being provided in Bangladesh through the school-building programmes.

Important site considerations which have a bearing on storm-surge are these

1. The history of storm surge from cyclonic disturbance, i.e., the probability of severe storms and therefore the likely height of water over normal sea level;
2. Tide level at the time of arrival of the storm;
3. Land configuration and wind direction;
4. Elevation of site (natural and constructed);
5. Distance from body of water, characteristic ground cover resisting surge;

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[8] Stephen A. Liment. *Housing in extreme winds report.* Washington, D.C., National Bureau of Standards, Center for Building Technology, Office of Federal Building Technology, 1973, p. 20.

The last two are capable of being varied by an anti-flood policy. A recommendation by the Institute of Engineers, Pakistan, discouraged the construction of permanent buildings within a belt of one-and-one-half miles of the sea coast and of estuarial rivers, and proposed a one-quarter mile belt of afforestation within that area, and coastal embankments along the sea coast and estuarial rivers to exclude saline water (Plate 3), the outside area to be cultivated with planned afforestation. A further recommendation was that all public buildings, including schools, should be of double-storeyed masonry construction. [9] This last recommendation was the subject of further work resulting in specific proposals for schools as cyclone shelters. These proposals include the following:

1. Floors above storm-surge level;
2. An accessible roof;
3. Sanitary facilities;
4. Drinking water storage facilities. [10]

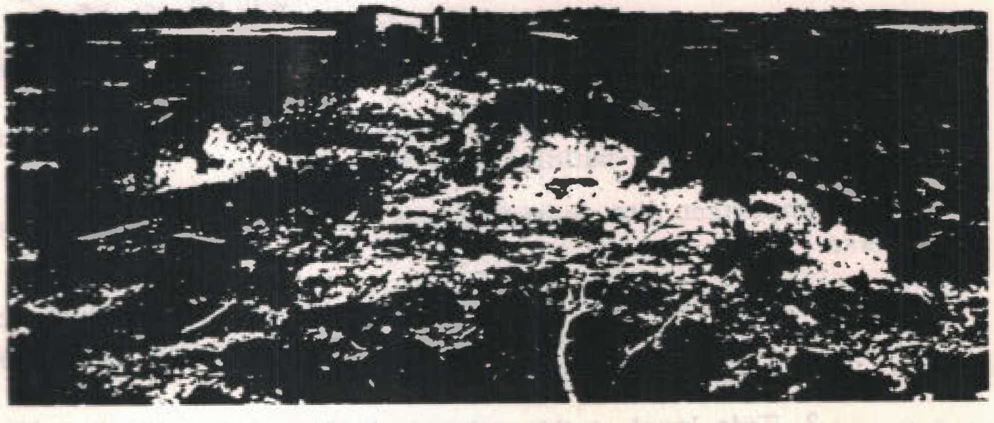

Plate 3. Part of the embankment along the coast and estuaries of Bangladesh. The cyclone of 1970 resulted in a storm surge which raised water over the embankment, washing away the part shown in the foreground.

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[9] Pakistan. Institute of Engineers. *Report of Institute of Engineers, Sub-Committee on Cyclone Disasters in East Pakistan.* Dacca, 1962, p.26.

[10] Asian Regional Institute for School Building Research, Colombo. *The Primary School Building Programme, East Pakistan with special reference to cyclone affected areas.* Colombo, 1968, p. 30.

5. Recommendations and codes for building design and detailing.

SITING

A. In locating a house, take advantage of natural windbreaks such as stands of trees, small hills or hedges to reduce the impact of prevailing winds.

B. Be especially careful of sites on or near tall hills. These can increase wind speeds by as much as 50%.

C. Valleys funnel winds; they can create abnormally high wind speeds.

D. Buildings placed near one another can affect wind speeds. Intense suction can develop on the gable ends of pitched roofs. If the building is in the wake of another, expect turbulence and some high local loading on small elements such as cladding.

E. When building a windbreak or shield, such as a row of trees or a wall, include small gaps to stabilize the flow on the lee side.

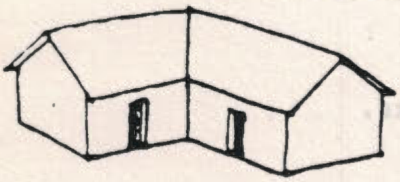
CONFIGURATION

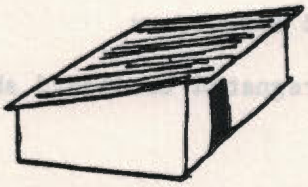
A. The best shape of wood frame house to resist high winds is square or rectangular. A rectangular configuration should have a length to width ratio of 2.5 to 1.

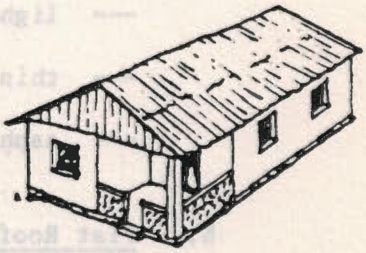
B. The parallel walls of all structures must be of equal length and of equal height.

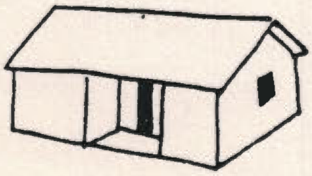
C. L-shaped houses should be avoided as they have demonstrated poor performance in high winds.

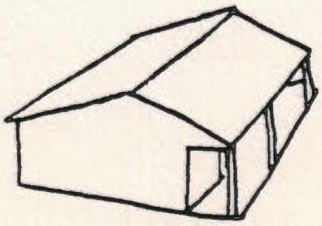
D. The following configurations can be expected to receive a high proportion of damage due to wind entrapment:

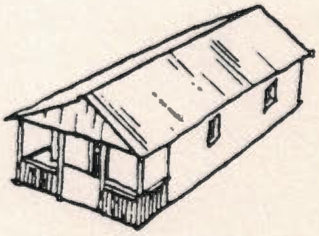












ROOF DESIGN

A. Pitched Roofs

--- If a pitched roof is desired, a hipped roof configuration is recommended. This reduces the overall forces lifting on the roof. A gable roof may be used with a wood frame house, but care should be taken to reinforce the roof at the connection between the roof ridge and the gable.

--- The roof pitch should be approximately 30°. (Wind loads are severe when roofs are pitched around 5° to 10°).

--- Avoid outside overhangs of more than half a meter, even if supported at the edge by columns. If this is unavoidable, consider using vents or louvers along the roof edge to relieve the upward pressure.

Houses using a pitched roof should use roofing materials that are strong, shatter-resistant, and of medium weight. Recommended are:

--- heavy-gauge metal roofing sheets;

--- medium weight fiber-reinforced cement roofing sheets (non-brittle);

--- wood sheets; and

--- wood tiles.

Not recommended are:

--- lightweight metal roofing sheets (30-gauge or less);

--- lightweight fiber-reinforced cement roofing sheets;

--- lightweight composite tiles and roofing sheets;

--- thin plywood sheets; or

--- asphalt-impregnated cardboard sheets.

B. Flat Roofs

Flat roofs are not recommended.

WIND RESISTANT DESIGN FEATURES

The forces applied to a building by high winds are:

--- upwards,
--- sideways or lateral; and
--- twisting or racking.

To build a structure which can resist these forces, there are three basic specifications that must be met:

A. Anchorage

The first specification is to hold the roof on. This entails tying the roof down to the ground or foundation by an adequate and continuous chain of strength. Traditional construction is directed toward holding the roof up. In wind-resistant construction, the purpose is to hold the roof down.

B. Bracing

The second specification is to brace the structure to withstand the lateral wind loadings and the racking effect. The methods used to brace traditional buildings are inadequate for the much greater forces existing in high wind conditions. Strength must be added not only at the corners of buildings, but also at key locations throughout each wall.

C. Continuity

The third specification is to provide the structure with integrity, i.e., to ensure all components are properly connected so that they can satisfactorily perform their function. Because the forces are often much greater than and in the opposite direction from those occurring normally, far more attention must be given to providing adequate connections between members and components of a building.

There are many design features that can significantly reduce the effect of the forces of high winds on a structure. Most of the building features that are dangerous are designed to provide comfort during normal times. For example, many of the areas where high winds occur encompass subtropical and tropical regions. Houses in these zones generally feature lightweight materials, with large overhanging eaves for shade, elevated openings around the base of the roof and in the gables to facilitate ventilation, and large window areas for through ventilation. Each of these features is contrary to ideal requirements for a wind-resistant house, so compromises in the design will have to be made. For the designer, there are several rules of thumb:

1. Do not build any opening which cannot be closed off during a wind storm.

2. Do not build openings which cannot be reached to be sealed off. (For example, an opening high on the wall under a gable may be difficult to reach and close prior to the onset of a storm.)

3. Leave openings in suitable locations where pressure can escape (e.g., at the ridge of the roof).

4. Design the roof to reduce suction and break up lifting patterns.

5. Design corners to reduce the pressures by allowing wind to slip around the corners. (This can often be done by rounding or beveling the corners of a building.)

6. Avoid creating areas where wind can be trapped and excessive pressure can build up. (For example, sealing off the eave of a house at an angle parallel to or inclined towards the ground can significantly reduce the uplifting pressures at that point.)

7. Avoid creating courtyards or patios which will increase circular or turbulent winds.

8. All doors and windows should be a minimum of one meter from the end of a wall.

9. All doors and windows should be a minimum of one meter from each other.

STRUCTURAL SPECIFICATIONS

All wood frame houses must meet the following structural specifications:

A. Walls should be built on concrete footings securely anchored to the ground. Avoid placing wood directly in or on the ground as this will cause rapid deterioration and a subsequent loss of internal and vertical resistance. Posts should be solidly anchored to the footings. Imbed the posts at least 40 centimeters into the footing.

B. Houses should have wood posts in each corner and spaced at appropriate intervals throughout each wall. (Generally, posts should be spaced so that with the floor joists and upper ring beam, they form a square.)

C. Vertical posts should be reinforced diagonally with wood braces.

D. Wood siding should be securely nailed to each post.

E. Houses should have a ring beam at the top of the wall formed by the upper part of the frame. Diagonal braces should be added at each corner.

F. Gables must be reinforced where they join the main wall. Preferably, a single post running from the gable to the foundation can be used.

G. Interior walls should be fastened securely to exterior walls and a diagonal brace should be attached at the ring beam.

H. Positive connections should be made between door and window frames and the walls in which they are placed.

I. When connecting the roof frame to the wall, special care must be taken to attach the roof frame securely to the frame of the building. In addition to nailing the roof joist to the frame, a fastener strap or angle iron should be nailed to the joist. Then the ends of the fastener should be attached to the ring beam or post.

J. Corregated roofing materials (such as metal roofing sheets, asbestos cement roofing sheets, or composite materials) should be secured at every corregation along the bottom purlin (at the eaves), at every corregation along the top purlin (at the ridge), at every corregation on the end sheets (at the gable end), and at every third corregation over the rest of the roof. To secure the roof sheets, it is recommended that self-drilling screws be used if possible. Nails are permissible, so long as the nail is long enough to penetrate deep into the purlin. When either screws or nails are used, a washer of at least 20 millimeters in diameter (approximately 3/4 of an inch) should also be used. (Note: Special roofing nails with a wide, flat head are often supplied with roofing sheets. The quality and length of these nails vary and, before they are used in high wind areas, it should be determined whether these are suitable).

K. Corregated roofing should be fastened to purlins through the top of the corregations.

L. All wood joints and splices should be securely fastened and reinforced.

MATERIALS

Wood chosen for use should be of high quality and strength and should be properly and sufficiently seasoned and treated with an approved preservative. All load bearing timbers must be treated by a pressure treatment method. Wood siding may be treated by immersion or brush application methods. All exterior wood should be painted with a water resistant paint.

SAFETY MEASURES

A. Doors and windows should be designed so that storm shutters can be placed over them during wind storms.

B. Windows should be designed so that glass panes are relatively small and the window frame is supported by a wooden super-structure.

C. Window frames should be designed so that, if screens are used on the outside, they can be removed before a storm period and attached to the inside to provide protection against flying glass or other debris. All louvered windows must have outside storm shutters and be designed to lock into a closed position.

D. One specific area should be designed to be especially strong so it can be used as an in-house shelter during wind storms. This area may be a closet or any small room of the house which can be strengthened.

MINIMUM STANDARDS FOR CYCLONE RESISTANT BRICK HOUSING

SITING

A. In locating a house, take advantage of natural windbreaks such as stands of trees, small hills or hedges to reduce the impact of prevailing winds.

B. Be especially careful of sites on or near tall hills. These can increase wind speeds by as much as 50 percent.

C. Valleys funnel winds; they can create abnormally high wind speeds.

D. Buildings placed near one another can affect wind speeds. Intense suction can develop on the gable ends of pitched roofs. If the building is in the wake of another, expect turbulence and some high local loading on small elements such as cladding.

E. When building a windbreak or shield, such as a row of trees or a wall, include small gaps to stabilize the flow on the lee side.

CONFIGURATION

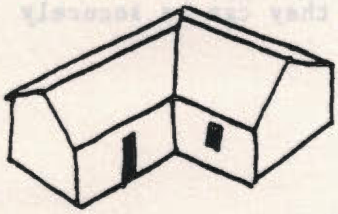
A. The best shape for a brick house to resist high winds is square or rectangular.

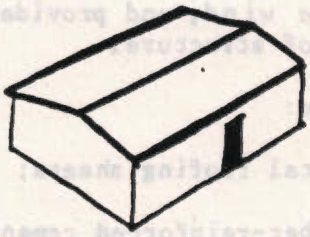
B. The length-to-width ratio should not exceed 2.5 to 1.

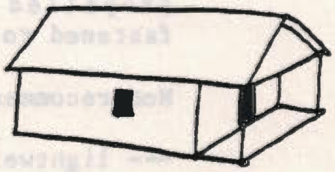
C. The parallel walls of all structures must be of equal length and of equal height.

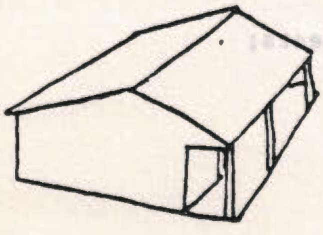
D. An L-shaped configuration should be avoided. (These buildings have a high percentage of failure due to racking in high winds.)

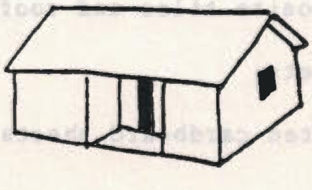
E. The following configurations are especially prone to major damages in high winds:

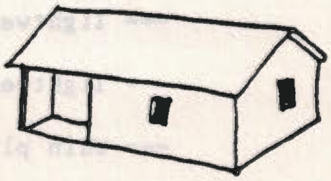


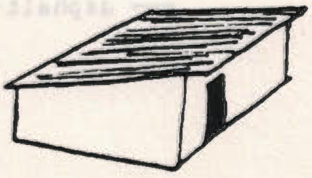












ROOF DESIGN

A. Pitched Roofs

--- If a pitched roof is desired, a hipped roof configuration is recommended. This reduces the overall forces lifting on the roof. A gable roof may be used so long as adequate diagonal bracing is used between the roof trusses to provide lateral resisting strength for the roof, and if the gables are adequately reinforced so that they will not topple into the house.

--- The roof pitch should be approximately 30°. (Wind loads are severe when roofs are pitched around 5° to 10°.)

--- Avoid outside overhangs of more than half a meter, even if supported at the edge by columns. If this is unavoidable, consider using vents or louvers along the roof edge to relieve the upward pressure.

Houses using a pitched roof should use roofing materials that are strong, shatter-resistant, and of medium weight. Recommended are:

--- heavy-gauge metal roofing sheets;

--- medium-weight fiber-reinforced cement roofing sheets (non-brittle);

--- wood sheets;

--- wood tiles; and

--- concrete panels (those which can be fastened to the roof frame).

Clay tile may also be used provided that a suitable substructure is built which will prevent individual tiles from falling inward and striking occupants should the roof be hit by missiles propelled by the wind, and provided that they can be securely fastened to the roof structure.

Not recommended are:

--- lightweight metal roofing sheets;

--- lightweight fiber-reinforced cement roofing sheets;

--- lightweight composite tiles and roofing sheets;

--- thin plywood sheets;

--- asphalt-impregnated cardboard sheets.

B. Flat Roofs

--- A flat roof may be used as long as the roofing material is monolithic and is firmly attached.

--- A parapet should be used around the edge of a flat roof to help reduce high suction along roof edges. (This will have little effect, however, on overall roof uplift.)

--- If a flat roof is desired, the following materials are recommended:

--- reinforced concrete;
--- ferrocement.

Flat roofs made of other materials such as metal or wood roofing sheets are not recommended.

WIND RESISTANT DESIGN FEATURES

The forces applied to a building by high winds are:

--- upwards;
--- sideways or lateral; and
--- twisting or racking.

To build a structure which can resist these forces, there are three basic specifications that must be met:

A. Anchorage

The first specification is to hold the roof on. This entails tying the roof down to the ground or foundation by an adequate and continuous chain of strength. Traditional construction is directed toward holding the roof up. In wind resistant construction, the purpose is to hold the roof down.

B. Bracing

The second specification is to brace the structure to withstand the lateral wind loadings and the racking effect. The methods used to brace traditional buildings are inadequate for the much greater forces existing in high wind conditions. Strength must be added not only at the corners of buildings, but also at key locations throughout each wall.

C. Continuity

The third specification is to provide the structure with integrity, i.e., to ensure all components are properly connected so that they can satisfactorily perform their function. Because the forces are often much greater than and in the opposite direction from those occurring normally, far more attention must be given to providing adequate connections between members and components of a building.

There are many design features that can significantly reduce the effect of the forces of high winds on a structure. Most of the building features that are dangerous are designed to provide comfort during normal times. For example, many of the areas where high winds occur encompass subtropical and tropical regions. Houses in these zones generally feature lightweight materials with large overhanging eaves for shade, elevated openings around the base of the roof and in the gables to facilitate ventilation, and large window areas for through ventilation. Each of these features is contrary to ideal requirements for a wind resistant house, so compromises in the design will have to be made. For the designer, there are several rules of thumb:

1. Do not build any opening which cannot be closed off during a wind storm.

2. Do not build openings which cannot be reached to be sealed off (e.g., an opening high on the wall under a gable may be difficult to reach and close prior to the onset of a storm).

3. Leave openings in suitable locations where pressure can escape (i.e., at the ridge of the roof).

4. Design the roof to reduce suction and break up lifting patterns.

5. Design corners to reduce the pressures by allowing wind to slip around the corners. (This can often be done by rounding or beveling the corners of a building.)

6. Avoid creating areas where wind can be trapped and excessive pressure can build up. (For example, sealing off the eave of a house at an angle parallel to or inclined towards the ground can significantly reduce the uplifting pressures at that point.)

7. Avoid creating courtyards or patios which will increase circular or turbulent winds.

8. All doors and windows should be a minimum of one meter from the end of a wall.

9. All doors and windows should be a minimum of one meter from each other.

STRUCTURAL SPECIFICATIONS

All houses built of brick must meet the following structural specifications:

A. Brick walls should be built on a continuous concrete footing in a trench. Avoid placing bricks directly on the ground, as this will cause the building to settle unevenly, causing wall cracks and openings for wind to penetrate.

B. The houses should have vertical columns made of reinforced concrete in each corner and spaced at appropriate intervals throughout each wall. (Generally, columns should be spaced so that, with the foundation and upper ring beam, they form a square.)

C. All windows and doors should have vertical columns on each side of the openings.

D. Bricks should be laid according to a running bond rather than a stack bond method.

E. Corner columns or posts should be securely tied to adjacent walls, using tie bars and/or horizontal reinforcement.

F. Intersecting walls should be made continuous by means of tie bars and/or horizontal reinforcement that extends into neighboring walls and partitions.

G. The houses should have a minimum of one horizontal ring beam placed close to the center of the wall.

H. Houses should have ring beams at the top of the wall.

I. Gables must be reinforced with vertical columns and surrounded by poured concrete on all sides.

J. Interior walls should be jointed to exterior walls at a vertical column.

K. Positive connections should be made between door and window sills, posts and lintels, and the walls in which they are placed.

L. When connecting a timber roof frame to a brick wall, special care must be taken to attach the roof frame securely to the structure of the building. The roof joists must be ready prior to the pouring of the upper ring beam. As the upper ring beam is poured, the roof joist is put in place. A fastener strap should be placed over and around the roof joist, then nailed to the joist. Then the ends of the fastener should be imbedded in the concrete to a depth of 25 centimeters. Fasteners may be made by cutting strips of galvanized sheet metal to dimensions of 30 millimeters by 50 centimeters. Galvanized sheets should be 28-gauge or thicker.

M. Corregated roofing material, such as metal roofing sheets, asbestos cement roofing sheets, or composite materials should be secured at every corregation along the bottom purlin (at the eaves), at every corregation along the top purlin (at the ridge), at every corregation on the end sheets (at the gable end), and at every third corregation over the rest of the roof. To secure the roof sheets, it is recommended that self-drilling screws be used if possible. Nails are permissible so long as the nail is long enough to penetrate deep into the purlin. When either screws or nails are used, a washer of at least 20 millimeters in diameter (approximately 3/4 of an inch) should also be used. (Note: Special roofing nails with a wide, flat head are often supplied with roofing sheets. The quality and length of these nails vary and, before they are used in high wind areas, it should be determined whether these are suitable.)

N. Corregated roofing should be fastened to purlins through the top of the corregations.

O. All wood joints and splices should be securely fastened and reinforced.

MATERIALS

Bricks chosen for use should be of high quality and strength and should be properly fired.

SAFETY MEASURES

A. Doors and windows should be designed so that storm shutters can be placed over them during wind storms.

B. Windows should be designed so that glass panes are relatively small and the window frame is supported by a wooden super-structure.

C. Window frames should be designed so that, if screens are used on the outside, they can be removed before a storm period and attached to the inside to provide protection against flying glass or other debris. All louvered windows must have outside storm shutters and be designed to lock into a closed position.

D. In large buildings, or those which have numerous rooms, one specific area should be designed to be especially strong so it can be used as an in-house shelter during wind storms. This area may be a closet, a work room, an area beneath the main floor of the house (if flooding is not a threat), or any small room of the house which can be strengthened without undue additional cost.

6. Specific indicators for cyclone resistant design in Vietnam.

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/ft²	kgf/m²	N/m² 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/m² (Pa) for V in m/sec

$P = 0.0625V^2$ kgf/m² for V in m/sec

$P = 0.00256V^2$ lbf/ft² 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.

Post Disaster Functions. 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%.

Cyclonic Overload Position. 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. PROCEDURE TO DETERMINE WIND LOADS

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 <u>AIRFOIL AFFECT : WHEN ROOFS FLY</u>

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

$q_o = \frac{(av)^2}{16}$ kgf/m²

$= \frac{0.85 \times 50^2}{16}$

$= 112.9$ kgf/m²

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

United States of America

$Q_{30} = 0.00256\ V^2_{30}$ lb/ft²

$= 32$ lbf/ft²

$= 156$ kgf/m²

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

Australia

$Q_z = 0.6\ V^2_z \times 10\text{-}3$ kpa

$= 1.5$ kpa

$= 153.4$ kgf/m²

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

Sri Lanka

$q = KV_z^{o2}$ lbf/ft²

$= 0.00232 \times 111.84^2$ lb/ft²

$= 29$ lb/ft²

$= 141.6$ kgf/m²

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

British Standards

$q = KV_s^2$

$= 0.0625 \times 50^2$ kgf/m²

$= 156.25$ kgf/m²

where:
V_s = wind speed
K = 0.00256 lb/ft²
K = 0.0625 kgf/m²

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/m^2 for V in m/sec.
Assessed adjustments made to wind speed to suit site roughness and height.

			Q_z - kgf/m^2			Q_z - kgf/m^2		
Terrain Category	Height	Velocity Multiplier	Wind Speed (m/sec)			Free Stream Dynamic Pressure		
(Site roughness)	(meters)		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

---

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°

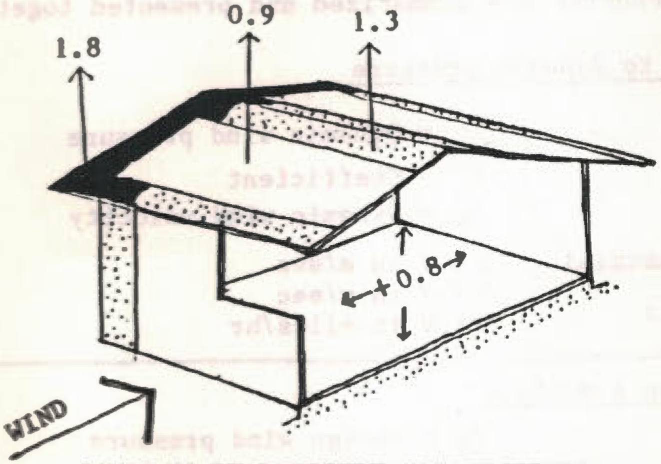


DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_z)

☐ 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 $P_z = Q_z (P_I + P_s)$

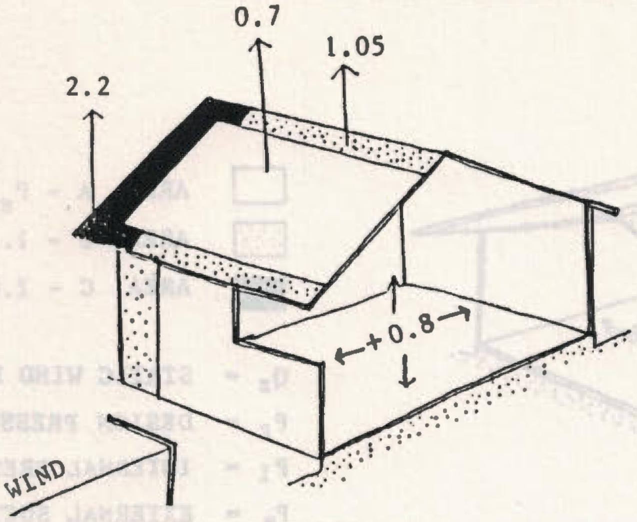
CLADDING LOADS $P_z = Q_z (K \times P_s + P_I)$

			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)

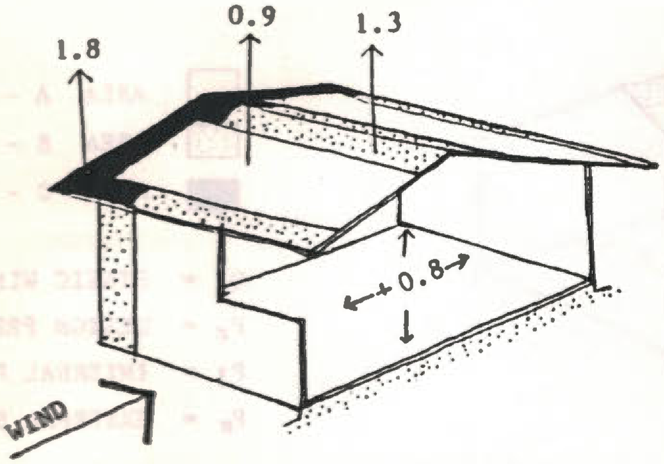
STRUCTURAL LOAD $P_z = Q_z (P_I + P_s)$
CLADDING LOADS $P_z = Q_z (K \times P_s + P_I)$

			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 $P_z = Q_z (P_I + P_s)$

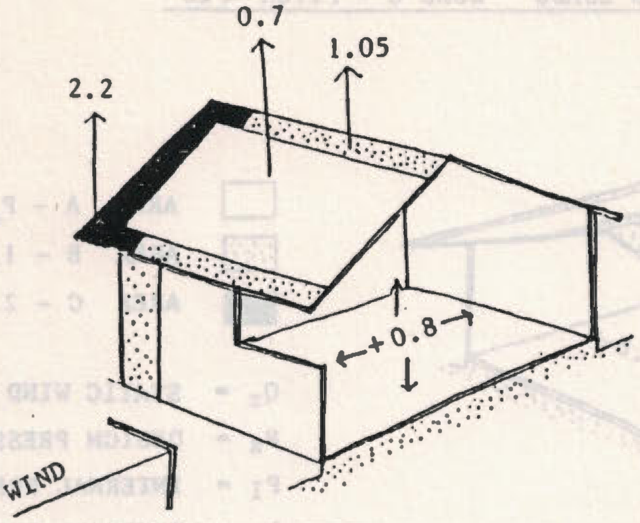
CLADDING LOADS $P_z = Q_z (K \times P_s + P_I)$

			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 $P_z = Q_z\ (P_I + P_s)$

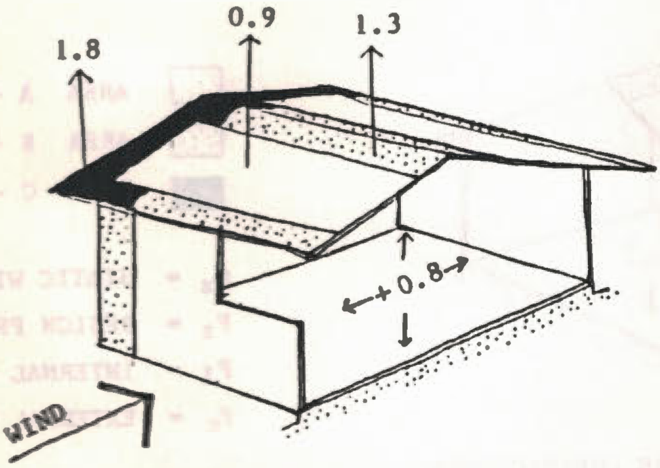
CLADDING LOADS $P_z = Q_z\ (K \times P_s + P_I)$

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

			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.	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°

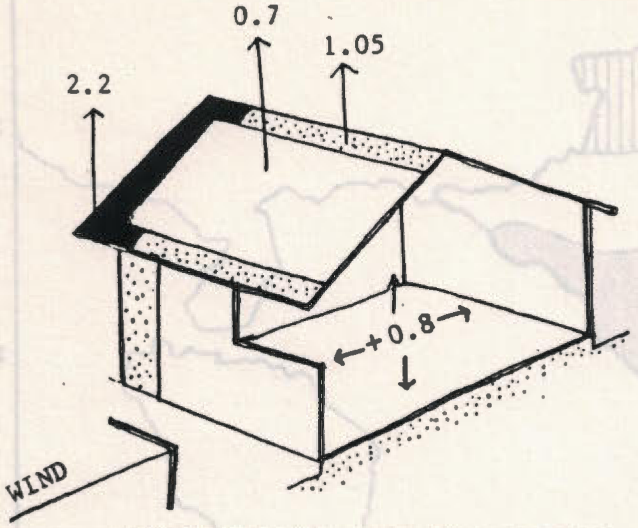


DIAGRAM OF PRESSURE COEFFICIENTS
(to be multiplied by Q_z)

☐ 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			WIND SPEED m/sec
			AREA A $1.5 \times Q_z$	AREA B $1.85 \times Q_z$	AREA C $2.2 \times Q_z$	
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.

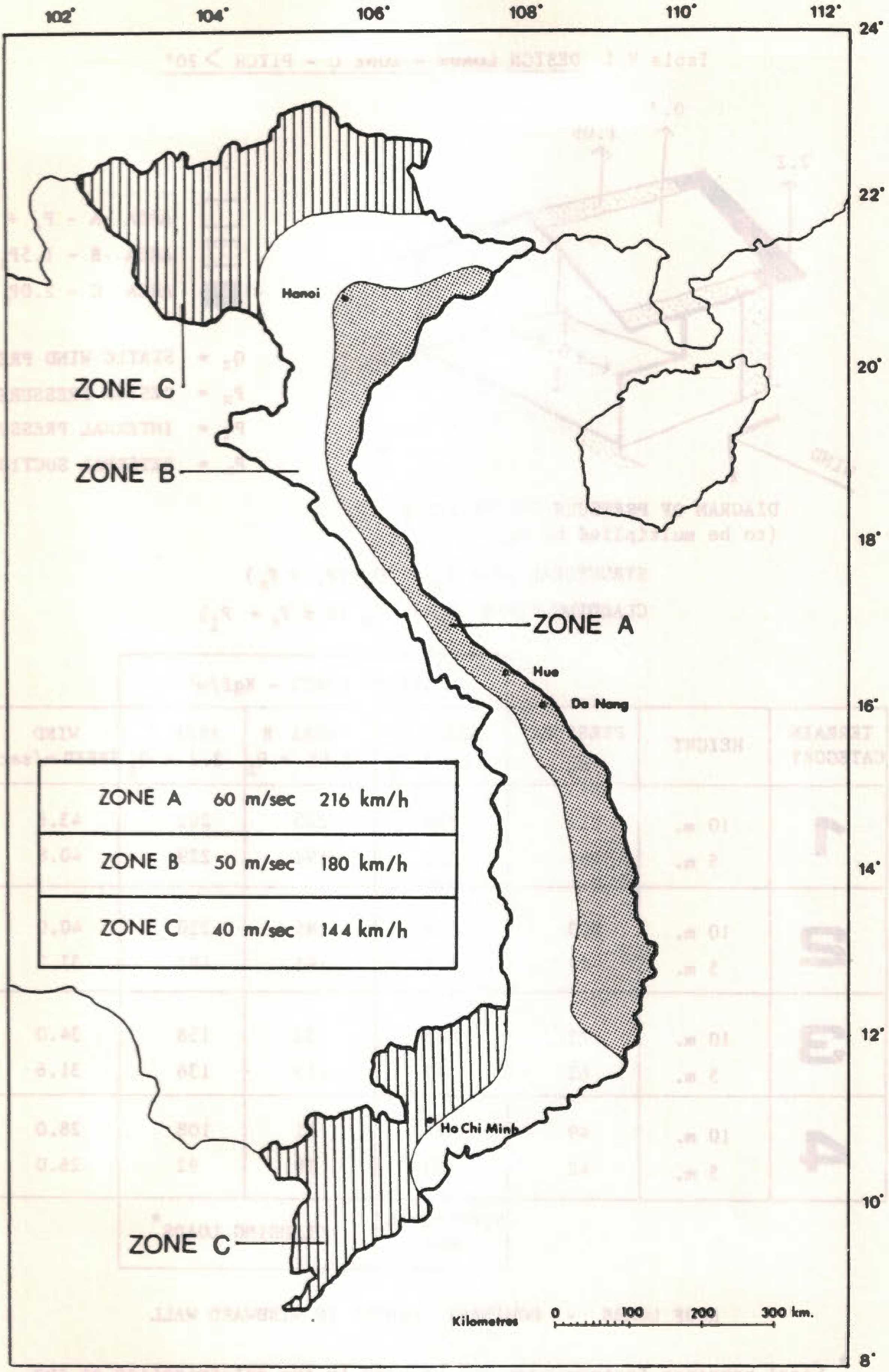


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Figure V.1 PROPOSED WIND ZONES FOR VIET NAM

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

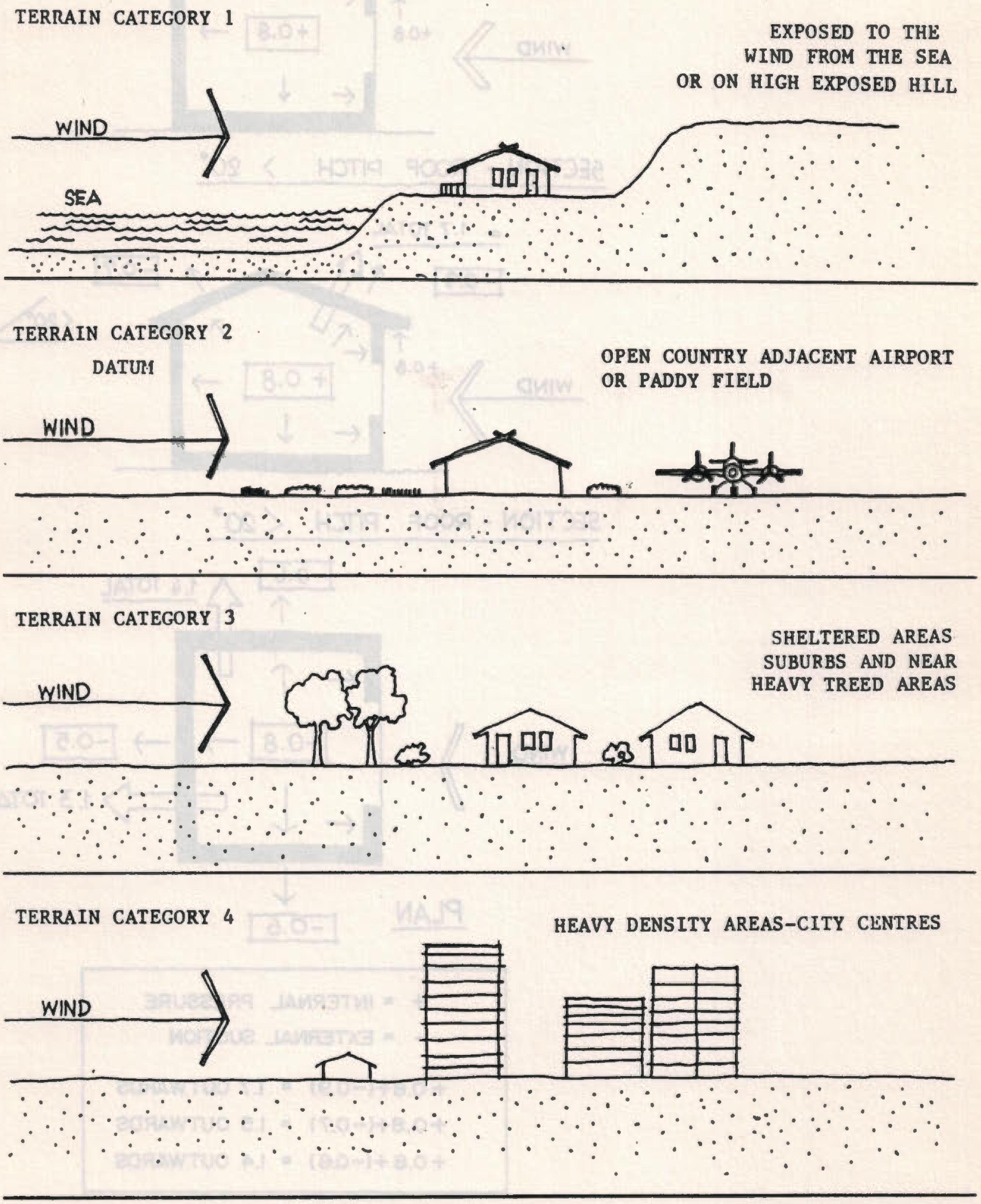
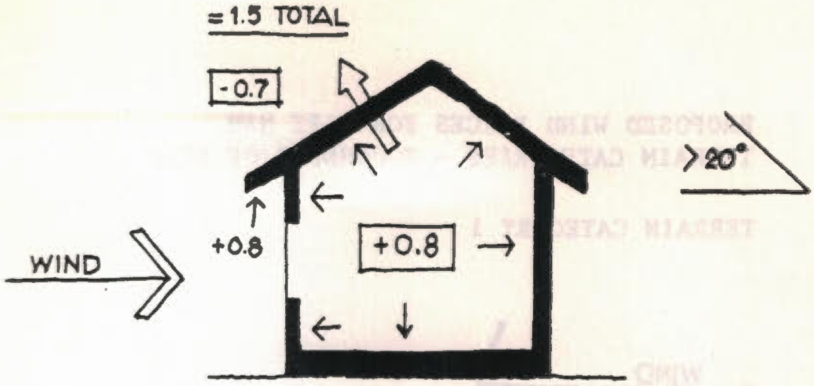
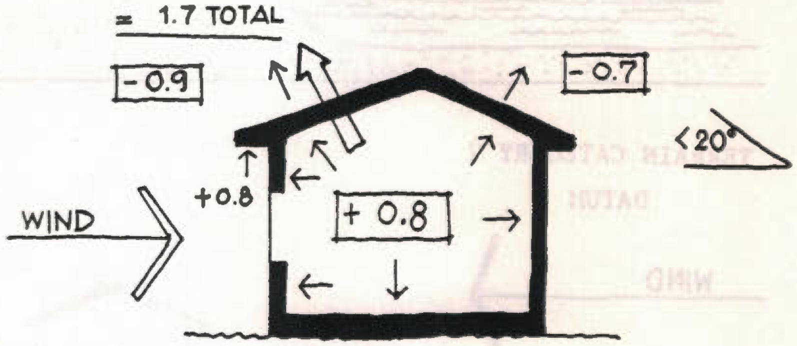


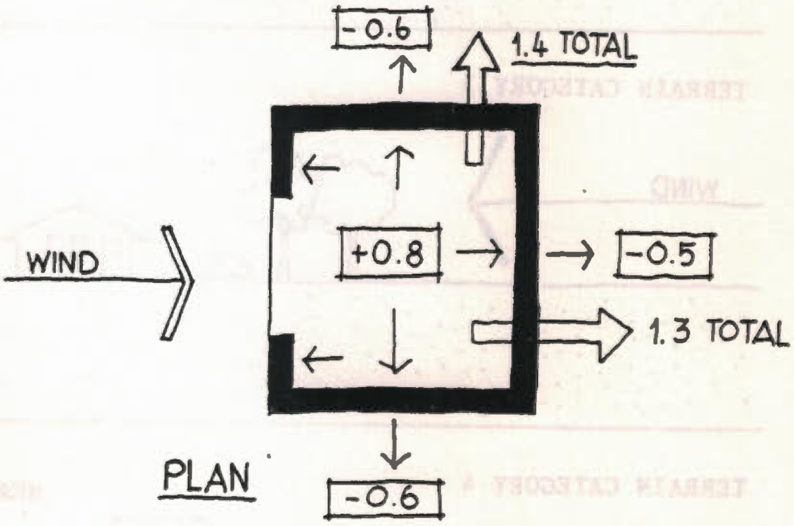
Figure V.2 DIAGRAM OF TERRAIN CATEGORIES



SECTION - ROOF PITCH > 20°



SECTION - ROOF PITCH < 20°



PLAN

\+ = INTERNAL PRESSURE

\- = EXTERNAL SUCTION

+0.8+(-0.9) = 1.7 OUTWARDS

+0.8+(-0.7) = 1.5 OUTWARDS

+0.8+(-0.6) = 1.4 OUTWARDS

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

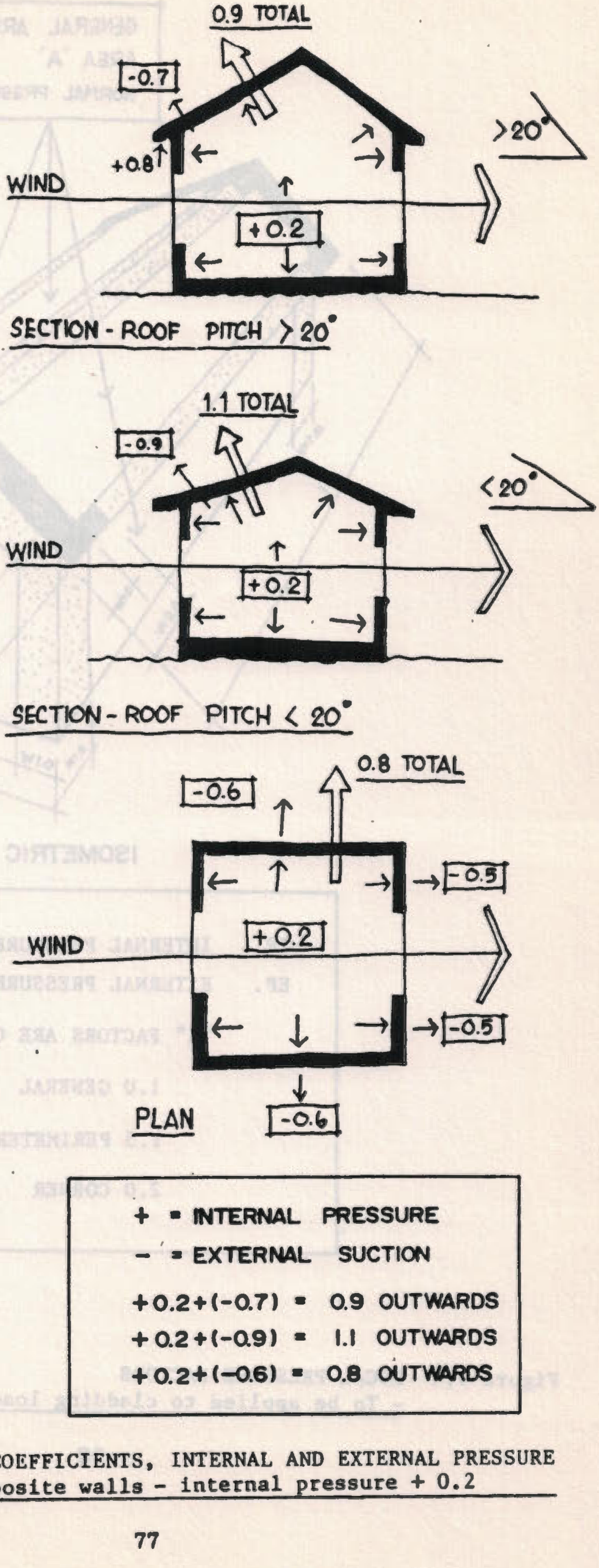
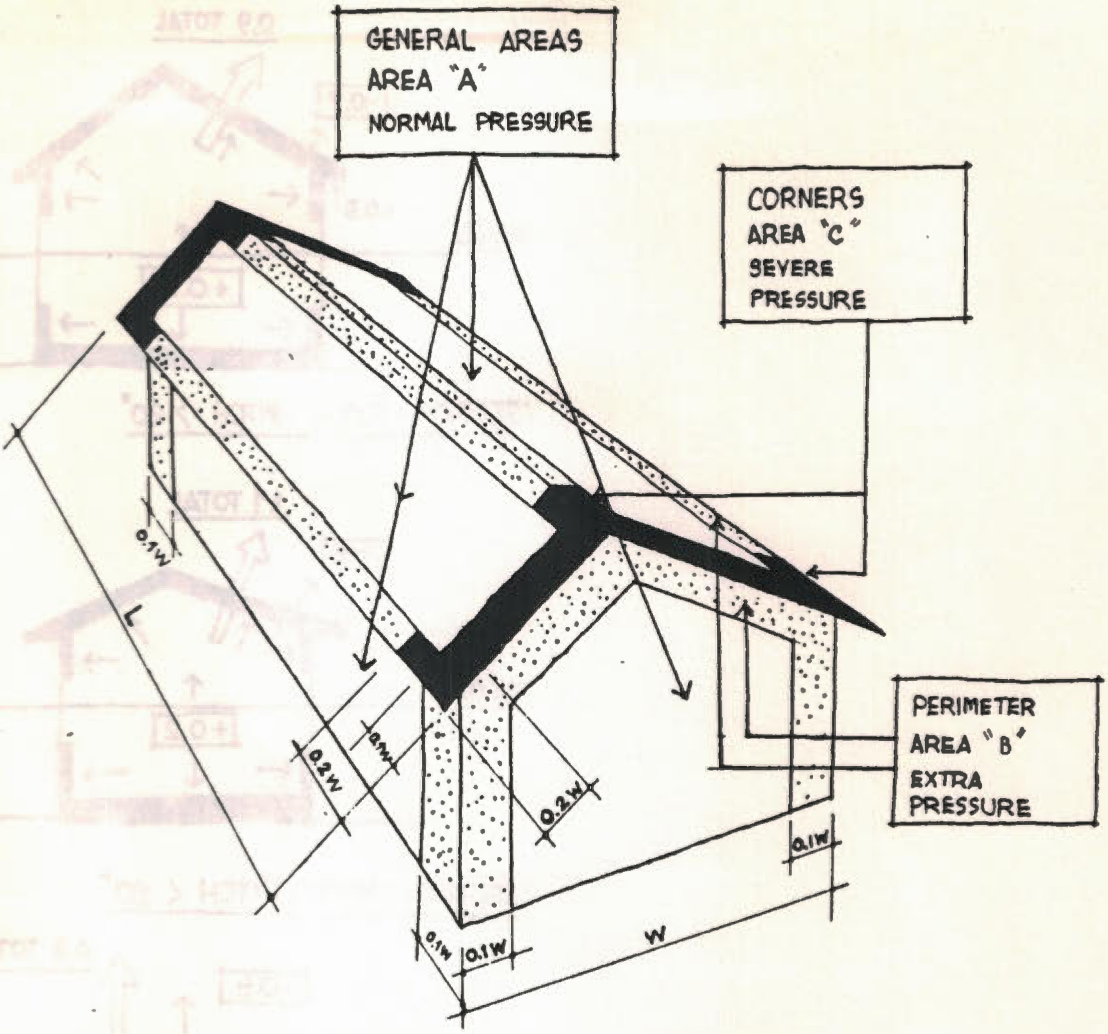


Figure V.3b STRUCTURAL LOAD COEFFICIENTS, INTERNAL AND EXTERNAL PRESSURE - Openings on opposite walls - internal pressure + 0.2



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>

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