5.3 BRIEF COMMENTARY ON WIND FORCE EFFECTS

5.3 1 Wind Speed

The wind moves over the ground at a certain speed normally referred to in metres per second (m/sec), kilometres 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 wind speed 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 wind speeds are normally those which occur at a height of 30'0" (10 0 m) above the ground on an open, inland terrain (site terrain category 2), such as at an airport, and are based on a 50 year return of the wind event. This is the international datum for wind speed and wind force calculation

5.3.2 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 30'0" (10 0 m) and thus taller buildings are subjected to higher wind speeds than are low buildings. A design factor for different building heights has been established.

5.3.3 Wind Zones

Due to various geographical features, cyclonic storms occur with predictable frequency in different locations. Cyclones are at their strongest over landfall and once they have travelled up to 30 miles 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 receive the strongest winds, strong winds and less strong winds

5.3.4 Site Terrain Category

The smoother the ground surface the less friction there is for the wind and therefore faster wind speeds result at smoother ground 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 has been developed and is shown on the diagrams

5 3.5 Wind Pressure

The wind speed can be converted into the pressures exerted on a plane surface normal to the wind. Tables cover 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.

5.3.6 Structural Wind Loads

Winds create both positive and negative pressures on buildings. The windward forces which are tending to push toward the surface of the building are considered to be *positive* external pressures Those pressures which are caused by the aerofoil effects of wind blowing around the walls or over the roofs create a partial vacuum or a net *negative* (suction) external pressure tending to pull away from the surface of the building

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

An opening can occur when a window breaks resulting in the immediate addition of the internal pressure to the external suction If the building is not designed for both of these pressures, the building could "explode" when the window breakage develops the internal pressure.

It is the resultant sum of the positive and negative pressures which determines the total force on any plane of a building's exterior

These outward bearing 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 give the pressures for buildings open on both sides or on one side.

As the wind passes over or around objects such as tress, ridges, fences, buildings, cliffs and valleys, 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 co-efficient for critical areas of buildings. Figures show the affected local areas of a building and gives these factors These loads are applied only in calculation of the forces on the cladding See also notes in paragraph 5 3.11. hereafter.

5 3.7 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.

5.3.8 *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 or be exceeded 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.

5.3.9 *Post Disaster Functions*

Important buildings, such as hospitals, police stations, post and telecommunications 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, post disaster buildings should be designed for 100 year event. The increase in design loads for the 100 year event is approximately 20%.

5.3.10 *Cyclonic Overload on Materials*

In considering the ability of building materials and their fixings that resist the cyclone 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 33%. Brickwork, on the other hand, will not recover after cracking.

5.3.11 *Special Notes on Cladding Loads*

The building structure has to resist the overall structural wind load applied to the total building and in this situation there is some load sharing by the total structure as the worst wind loads do not envelope the whole building at one time.

However the wind loads, fluctuating in speed and direction every 3-5 seconds create a dynamic cyclical pressure on the cladding on the buildings' walls and roofs

These loads are referred to as cladding loads. Dealing with the resistance of wind forces on claddings in low rise buildings is often left to the contractors and tradesmen.

It is only in recent decades that closer attention has been paid to these loads by professional Engineers, Architects, Researchers and Manufacturers.

The wind forces on claddings are most severe at edges and corners such as eaves, barges and ridges, often where inadequate fixings and protection expose weaknesses in cladding fixings.

Cladding loads in these areas can be 50% larger than the overall structural loads applied to the building as a whole.

It is important to design both claddings and their small fixings to resist these wind loads This involves study and understanding the real cladding loads, the nature and strength of the cladding material, the resistance of individual small fixings (such as nails and screws and bolts) and the batten or rafter spacings which affect the load area and consequent uplift forces.

The tables hereafter offer advice in resolving these wind loads.

5.4 PROCEDURE TO DETERMINE WIND LOADS

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

1. *Collect the Facts*

a) Identify national wind zone.
b) Identify wind speed.
c) Identify height of building and coefficient
d) Identify terrain category and coefficient
e) Identify topographical effects (hills, escarpments, valleys).
f) Determine design pressure.

2. *Determine the Wind Forces*

a) Identify building dimensions, length, height, width, shape and slope of roof.
b) Determine wind pressure co-efficients for wall and roof loads, both structural loads and cladding loads, and slope of roof.
c) Calculate structural loads
   - on walls.
   - on roof.
   - on windows.
d) Calculate cladding loads on walls and on roof

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

4. Design Construction Details & Connections

a) Decide on details.
b) Design resistance members.
c) Design fixing details
d) Decide on materials to be used
e) Specify workmanship required.
f) Check load areas and overturning moments.

5. Checklist of Key Points

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

a) The design wind applies to the wind speed at a height of 10 m on a terrain category 2 site (e.g. at 30'0" (10 m) on an airfield) and is based on a 50 year wind return.

b) 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.

c) If the building is higher than 30'0" (10 m) the design wind is higner If the site is more protected (in city areas) the design wind is less

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

e) This design pressure is increased or decreased by coefficients 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.

f) 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".

g) 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.

h) The cladding of the central wall and roof areas carry the same loads as the structural loads. 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 are pressures affecting the fixing of the claddings to their immediate supporting members and are referred to as "Cladding Load".

The accompanying table gives a listing of the force of aerofoil effect at different wind speeds.

5.5 AEROFOIL EFFECT

TABLE 5
AEROFOIL EFFECT — "WHEN ROOFS FLY"
MACKS WIND MOVEMENT CHART

VELOCITY	*TYPICAL MOVEMENT*	*VELOCITY (miles/hr)*
0.00 m/sec	Dead calm - birds fly	
0.23 m/sec	Leaf moves	0.50 mph
0.50 m/sec	Leaf flies	1 15 mph
0.75 m/sec	Paper flies	1.80 mph
0 – 5 m/sec		0 – 11 mph
5 – 10 m/sec	Loose aluminium sheets fly	11 – 22 mph
10 – 15 m/sec	Loose galvanised iron sheets fly	22 – 33 mph
15 – 20 m/sec	Loose fibre cement sheets fly	33 – 45 mph
20 – 25 m/sec		45 – 56 mph
25 – 30 m/sec	Loose concrete and clay tiles fly	56 – 67 mph
30 – 35 m/sec	Roof sheets fixed to battens fly	67 – 78 mph
35 – 40 m/sec	DC3 aircraft take off speed	78 – 90 mph
40 – 45 m/sec	Roof tiles nailed to battens fly	90 – 100 mph
45 – 50 m/sec	Garden walls blow over	100 – 112 mph
50 – 55 m/sec	Unreinforced brick walls fail	112 – 123 mph
55 – 60 m/sec	Major damage from flying debris	123 – 134 mph
60 – 65 m/sec		134 – 145 mph
65 – 70 m/sec	100 mm thick concrete slabs move	145 – 156 mph
70 – 75 m/sec		156 – 168 mph
75 – 80 m/sec	150 mm thick concrete slabs move	168 – 179 mph
80 – 85 m/sec		179 – 190 mph
85 – 90 m/sec		190 – 201 mph
90 – 95 m/sec		201 – 212 mph
95 – 100 m/sec	200 mm thick concrete slabs move	212 – 224 mph

5.6 WIND SPEED CONVERSION

TABLE 6
CONVERSION OF WIND SPEED TO FREE STREAM DYNAMIC PRESSURE

SPEED				*FREE STREAM DYNAMIC PRESSURE*			
m/sec	*knots*	*miles/hr*	*km/hr*	*lbf/ft²*	*kgf/m²*	*N/m²*	*kPa*
0.278	0.540	0.6212	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	1000.0	1.000
45 0	87 41	100.66	162.0	25.94	126.7	1241.0	1.241
50.0	97.12	111 84	180.0	32.03	156.4	1532.0	1.532
55.0	106 84	123.02	198.0	38.75	189.2	1854.0	1.854
60 0	116 55	134.21	216.0	46.12	225.2	2207 0	2.207
65.0	126 26	145.39	234.0	54.13	264.3	2589.0	2.589
70 0	135 98	156 57	252.0	62.73	306.5	3004.0	3.004
75.0	145.69	167.76	270.0	72.06	351.8	3448 0	3.448
80 0	155 40	178.94	288.0	81.99	400.3	3923.0	3.923
85 0	165 11	190.13	306.0	92.55	451.9	4429 0	4.429
90.0	174.83	201.31	324.0	103.80	506.7	4965.0	4.965
95 0	184 54	212 50	342.0	115.60	564.4	5532 0	5.532
100.0	194.55	223.68	360.0	128 10	625.5	6130.0	6.130

FORMULAE

$P = 0.613\,V^2$	N/m² (Pa)	(for V in m/sec)
$P = 0.0625\,V^2$	kgf/m²	(for V in m/sec)
$P = 0.00256\,V^2$	lbf/ft²	(for V in miles/hr)

where P = Free Stream Dynamic Pressure
V = Basic Wind Speed

STANDARD UNITS

m/sec	= metres per second
miles/hr (or mph)	= miles per hour
km/hr	= kilometres per hour
lbf/ft²	= pounds force per square foot
kgf/m²	= kilograms force per square metre
N/m²	= Newtons per square metre
kPa	= kiloPascals per square metre

5.7 WIND LOADS

Although damage to buildings during cyclones is often caused by a combination of wind and flood water, it is the effect of destructive high winds that concerns cyclone resistant design most.

Before proceeding to discuss the calculation of Design Wind loads on a building, it is of value to briefly discuss how the wind acts on a structure

When the wind is slowed down or changed in direction as it passes a structure, pressures are developed which act on the surfaces of the structure. These pressures may be positive or negative (suctions).

5.7.1 *Types of Force*

There are four main types of force induced in a structure by air moving past

(i) Dynamic free-stream reference pressure
(ii) Surface wind pressure distribution
(iii) Aerodynamic lift force
(iv) Aerodynamic drag force

(i) *Dynamic Free-Stream Reference Pressure*

Dynamic pressure is the free-stream pressure energy in the approaching wind.

(ii) *Surface Wind Pressure Distribution*

a) *Attached Flow* over windward surfaces can create both positive and negative pressures.

b) *Separated Air Flow* in the wake of a building always creates a negative pressure

(iii) *Aerodynamic Lift Force*

Aerodynamic lift force is the force acting on a building normal to the direction of the approaching air flow. The aerodynamic lift force is responsible for large uplift forces on roofs and cross-wind forces on tall buildings.

(iv) *Aerodynamic Drag Force*

Aerodynamic drag force is the force acting on a building in the direction of the approaching wind.

5.7.2 *Roofs*

Wind pressures on low pitch roofs experience negative pressures (or suctions) and will act upwards at right angles to the roof. Pressures will generally be highest near the windward edge of an area of roof.

TABLE 7
VERTICAL AND HORIZONTAL FORCES
% OF INCLINED FORCES

ROOF SLOPE DEGREES	*VERTICAL COMPONENT*	*HORIZONTAL COMPONENT*
5°	100%	9%
10°	99%	17%
15°	97%	26%
20°	94%	34%
30°	87%	50%
40°	77%	64%

On a gable roof, barges, verges, eaves and corners experience strong negative pressures, whilst on a hip roof, the ridge and ridge hips carry the strong negative pressures (suction)

The inducement of suction, particularly on the front edge of the roof does not require any opening in the building to generate it. Consequently, it is possible for a roof to be sucked off without any openings in the building at all

The slope of the roof significantly effects the proportion of vertical uplift forces to horizontal forces acting on a roof. Low pitched roofs of 0° to 10° experience almost 100% suction, whilst in roofs of 30° pitch or more, the roof experiences a significant percentage of dynamic pressure tending to hold the roof on, but the turbulent area moves from the eaves to the leeward side of the ridges.

5.7.3 *Walls*

Pressures on walls vary with wind direction and may range from positive (pressure) to negative (suction)

By introducing openings into the front of a building, an internal pressure is produced. This compounds the suction forces on the roof.

5.8 DIAGRAMS OF THE EFFECTS OF WINDS

The following diagrams illustrate the effects of the wind on a building and shows how the wind affects the various walls and roof slopes.

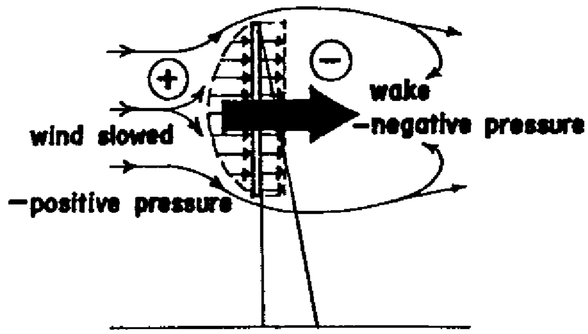
The wind forces create pressure loads on some walls and roof slopes and suction loads on others

In addition, internal pressure is acting on the walls and ceilings internally. If a door or window is open or broken then these internal forces change from pressure to suction in some cases.

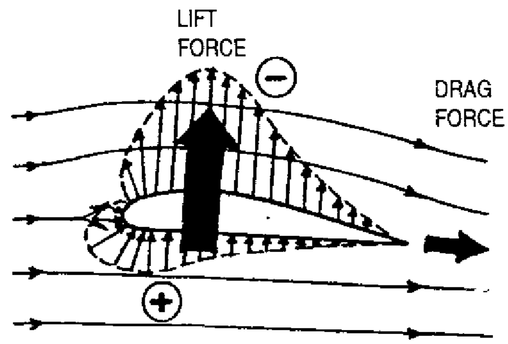
All of the above forces are acting on the building simultaneously and in addition, the size of the forces fluctuate rapidly depending on the size, speed, direction and pressure of the cyclone itself

The final few diagrams show the resistance mechanisms required to resist the wind forces actions on the building elements. More detail discussion on these connections will be provided in later sections in this paper.

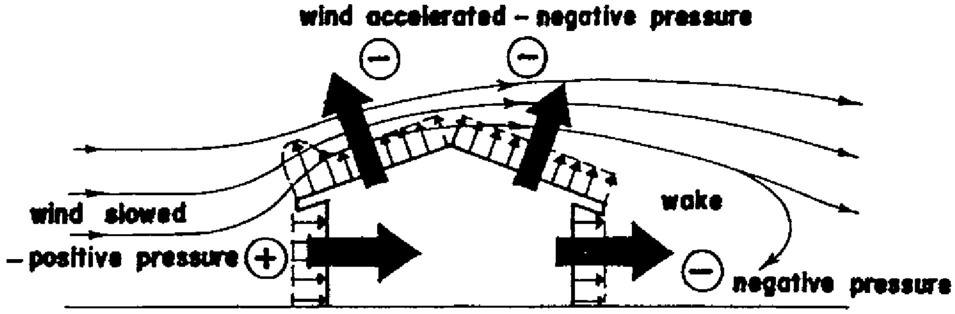
WIND ACTION ON BUILDINGS AND ROOF STRUCTURE



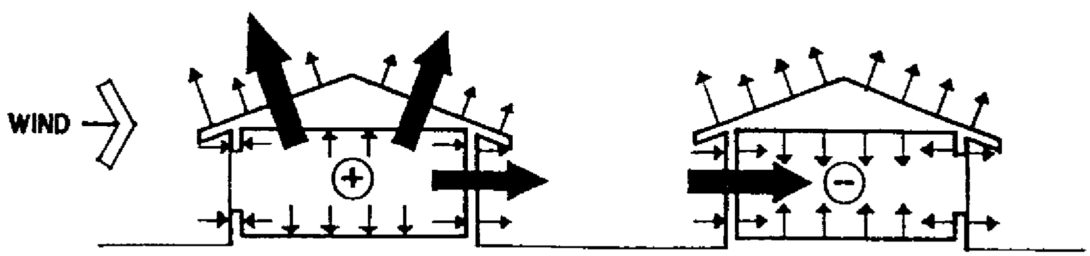
HOARDING — experiences drag force and overturning



AEROPLANE WING — experiences lift force and little drag force

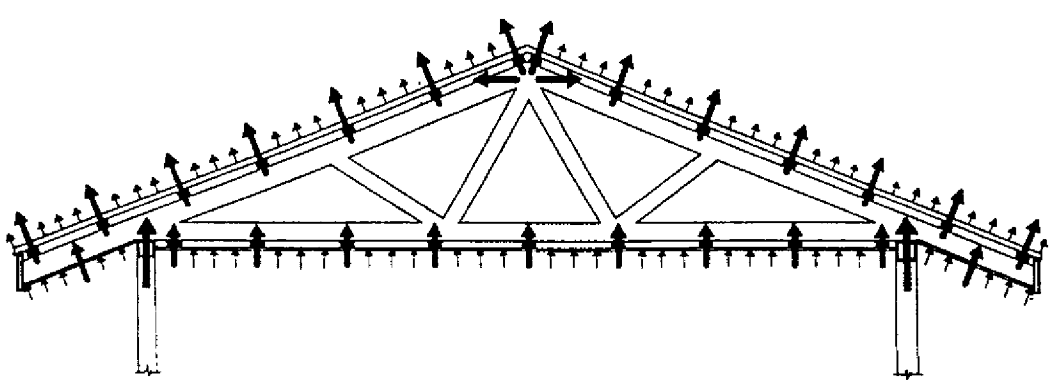


HOUSE — lift forces, drag forces, overturning forces

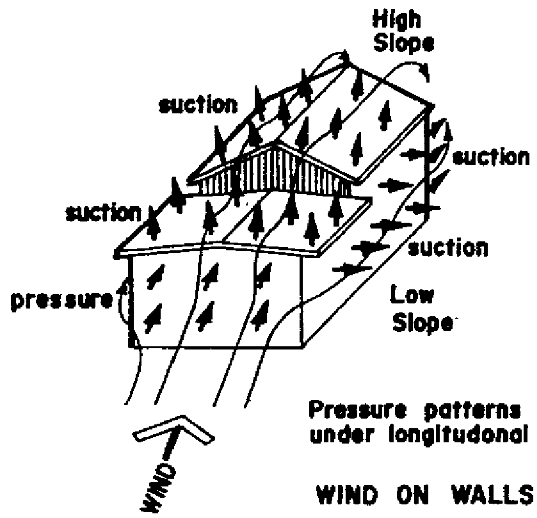


opening in windward wall
—positive internal pressure

opening in leeward or side wall
—negative internal pressure

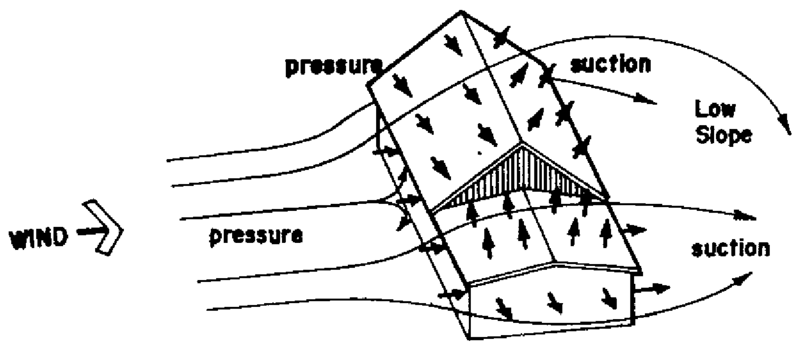


WIND ACTION ON BUILDINGS



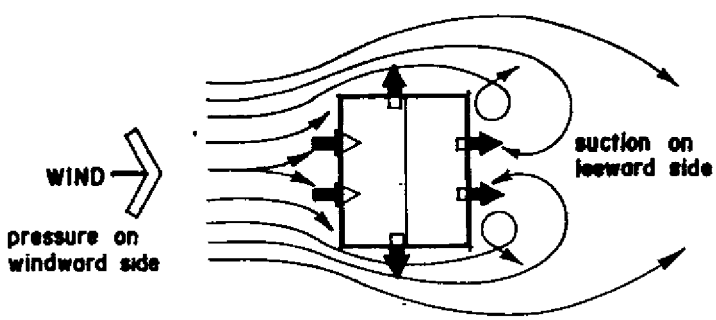
Pressure patterns on a building under longitudonal wind.

WIND ON WALLS

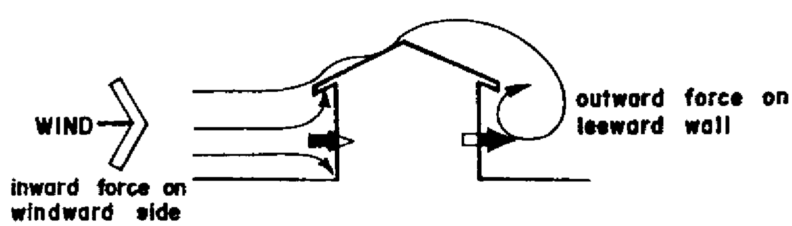


Pressure patterns on a building under lateral wind.

WIND ON WALLS

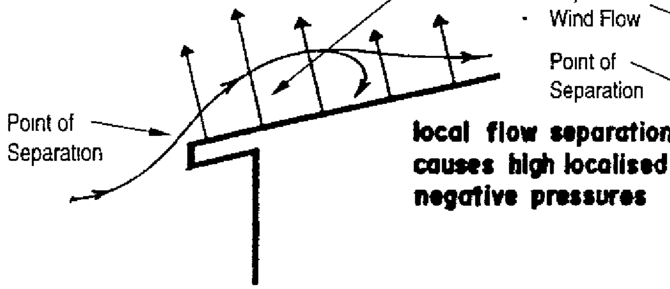


Plan of air flow around a building.

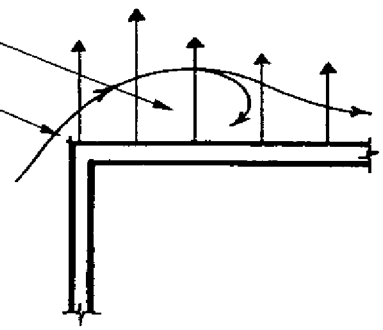


Elevation of air flow over a building.

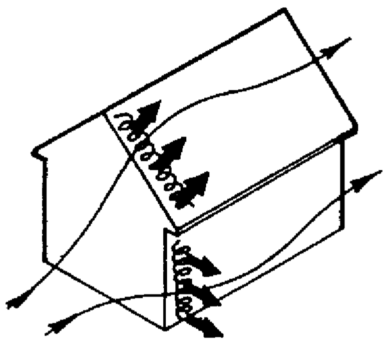
LOCAL EFFECTS AND TURBULENCE



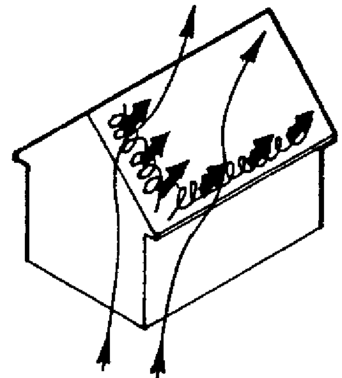
Roof Edge



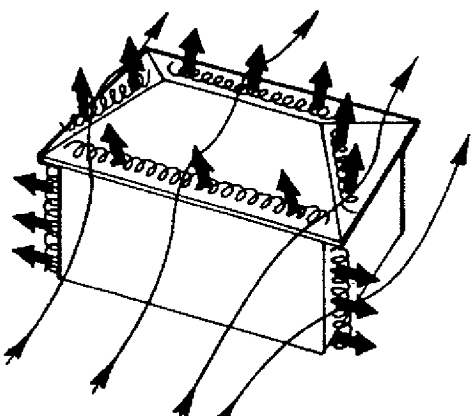
Wall Corner



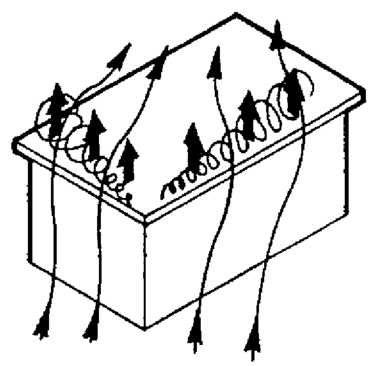
wind flow end on – gables and corners experience locally stronger uplift forces



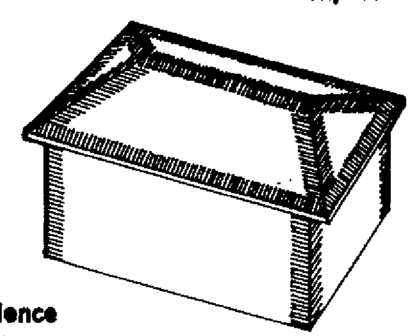
wind flow onto corner – gables and eaves experience locally stronger uplift forces



wind flow onto side – eaves ridge and hips experience locally stronger uplift forces



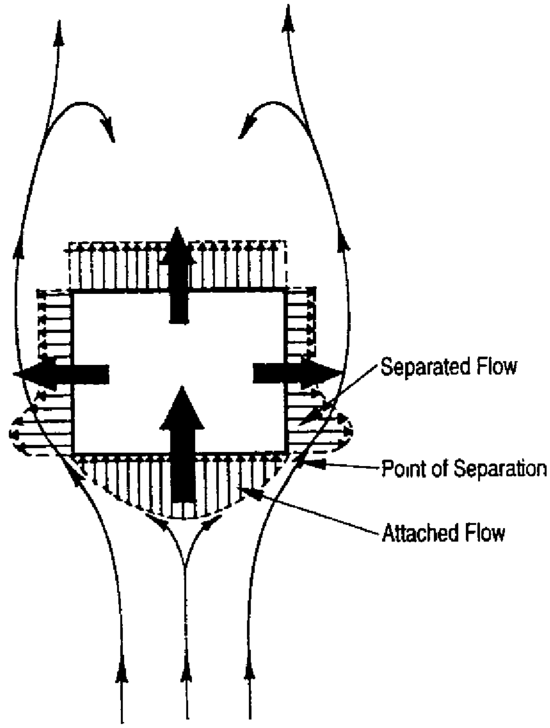
wind flow onto corner of flat roof – eaves and barges experience locally stronger uplift forces

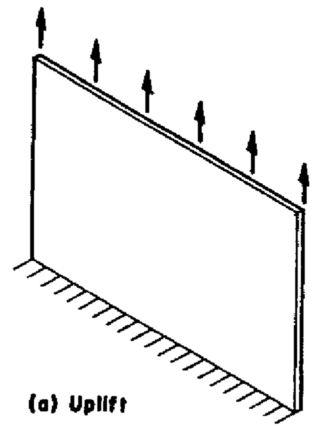


regions of roof and walls that experience higher local uplift forces

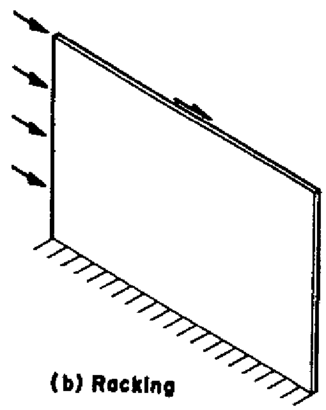
EFFECTS OF TURBULENCE AT EDGES AND CHANGES IN ROOF SLOPE

WIND ACTION ON WALLS

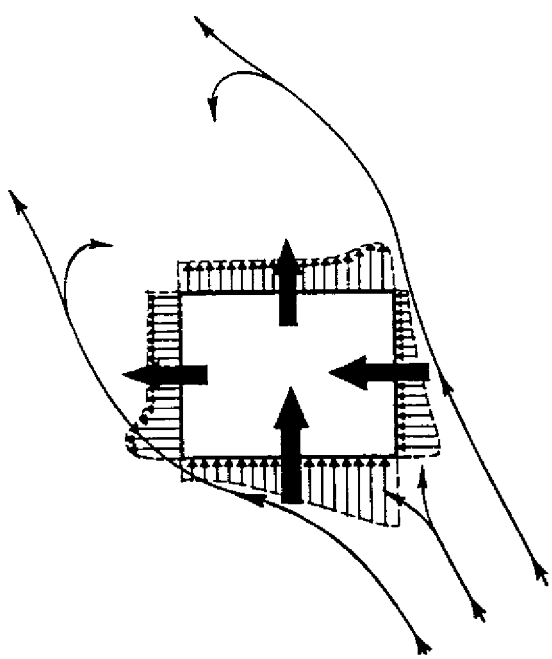


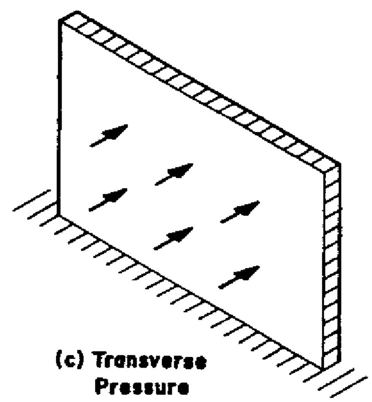


(a) Uplift

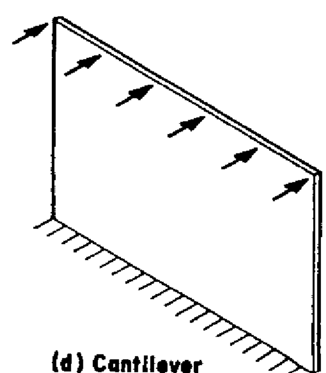


(b) Racking



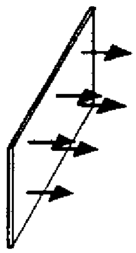


(c) Transverse Pressure

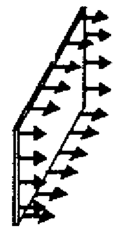


(d) Cantilever Loading

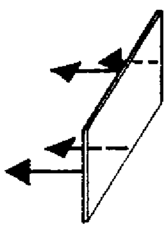
SUCTION PRESSURE ON WALLS



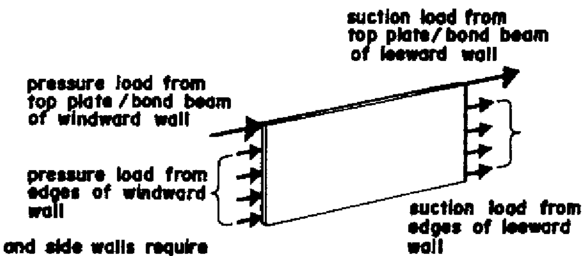
Suction on side and leeward walls sucking cladding off and wall out.



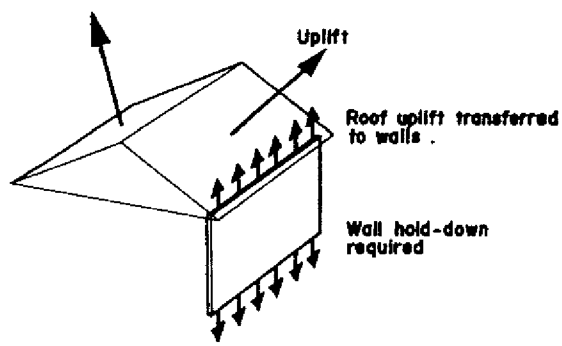
Suction loads transferred to wall edges : eaves, floor, intersecting walls.



Leeward and side walls require holding back at ceiling line, floor line, crosswalls.

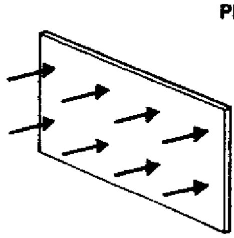


RACKING FORCES ON CROSSWALLS

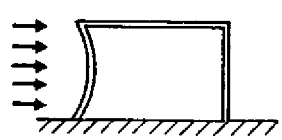


UPLIFT FROM ROOF TRANSFERRED THROUGH WALLS
(Through connection in walls if no tie rods direct from rafters to footing.)

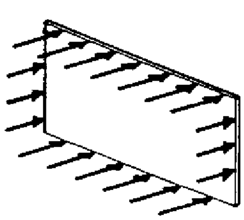
PRESSURE ON WALLS



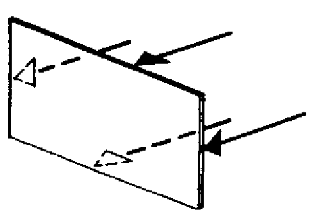
Pressure on windward walls blowing cladding and wall in.



Windward wall bends under wind load : held at edges.

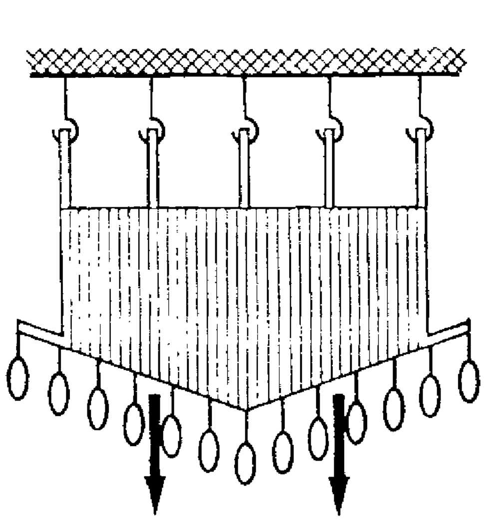


Windward wall load transferred to wall edges : eaves line, floor line, intersecting walls

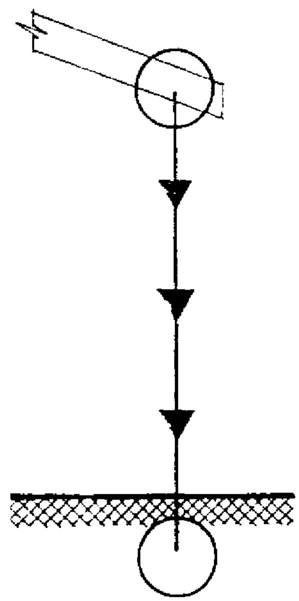


Windward wall requires support from ceiling line, floor line, crosswalls.

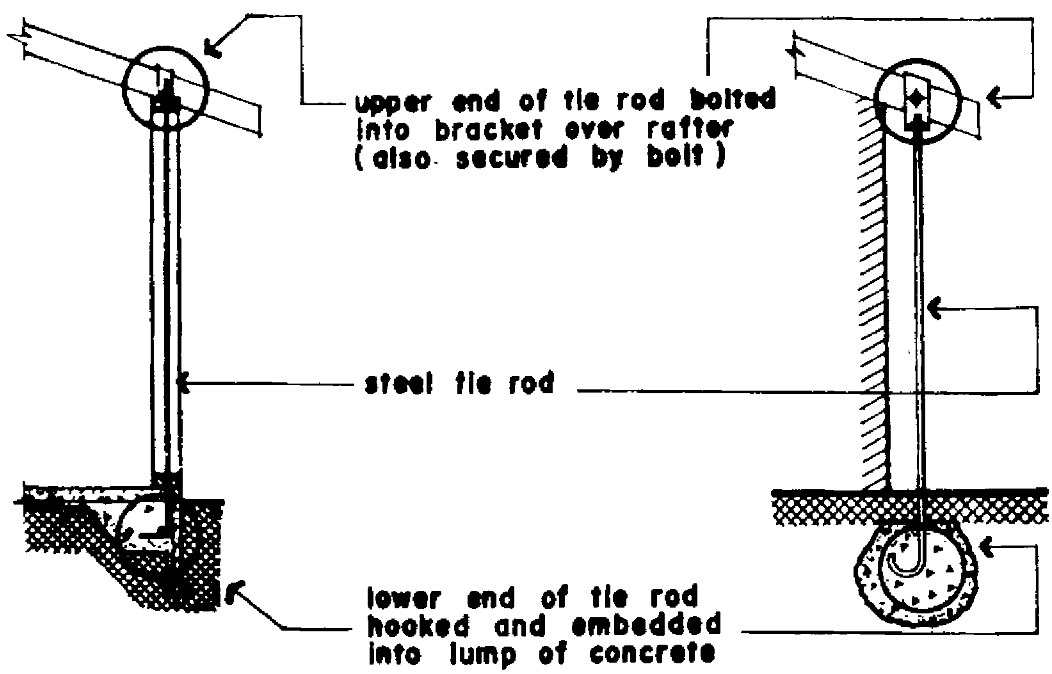
SIMPLE ROOF HOLD-DOWN SOLUTIONS



Uplift forces on a roof are equivalent to hanging bags of cement at close centres from the roof battens, with the house inverted and suspended from its footings.



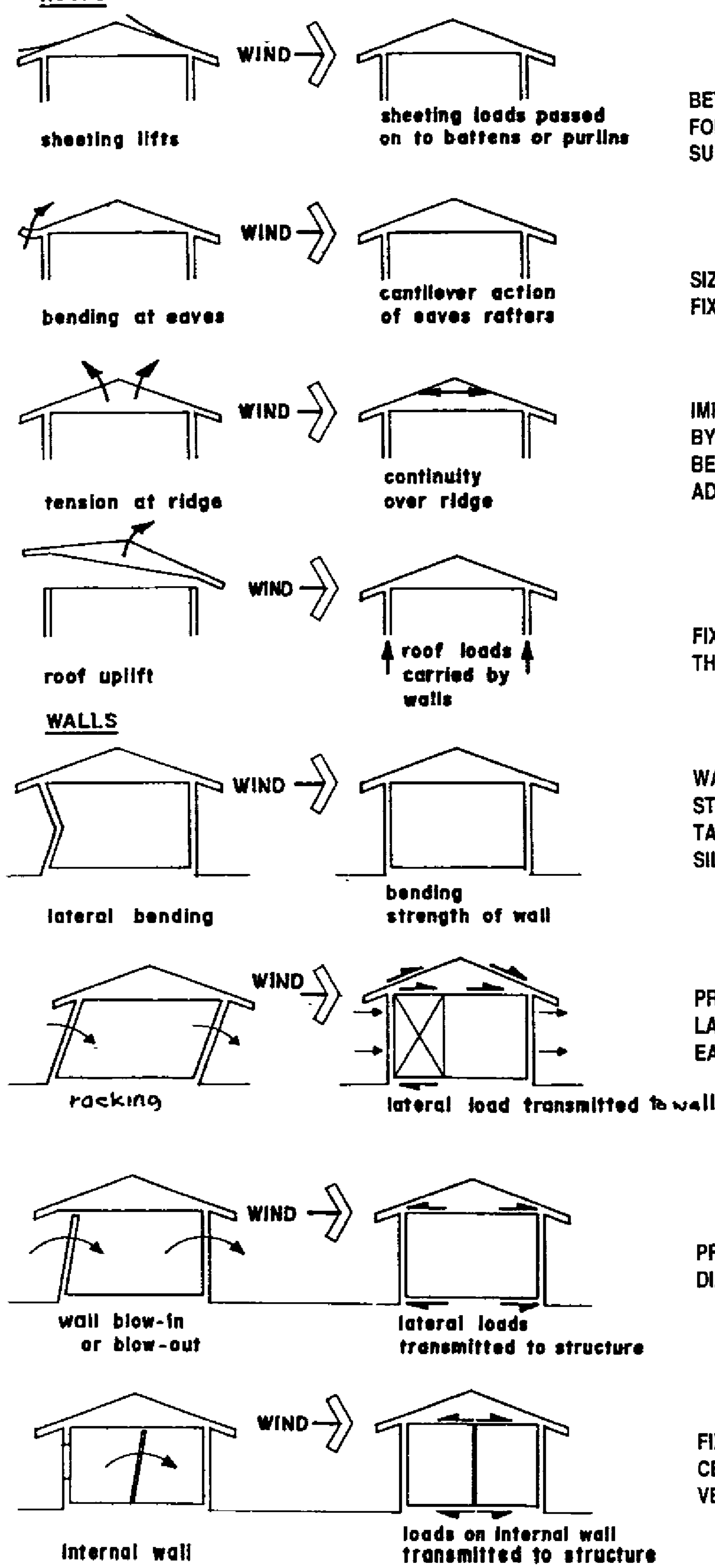
The roof rafters must therefore be strongly anchored to the ground.



Steel rod bolted over rafter and embedded into concrete footings.

CONCRETE WEIGHT EQUALS NETT UPLIFT LOADS

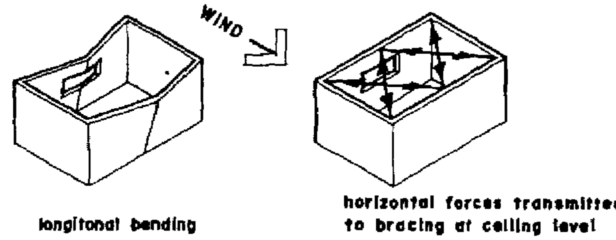
WIND ACTION | **RESISTANCE MECHANISM**



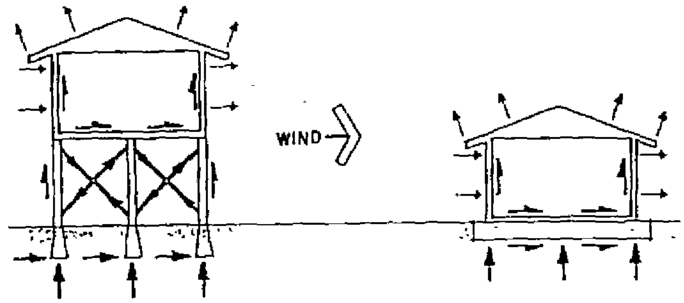
- BETTER FIXING NEEDED FOR ROOF SHEETING TO SUPPORTS
- SIZE OF RAFTER AND FIXING TO BE ADEQUATE
- IMPROVE FIXING AT RIDGE BY BETTER FIXING BETWEEN RAFTERS AND ADEQUATE ROOF FRAMING
- FIX ROOF FRAMING DOWN THROUGH WALLS
- WALL STRUCTURE TO BE STIFF FOR FULL HEIGHT. TAKE CARE AT WINDOW SILLS AND WINDOW HEADS
- PROVIDE ADEQUATE LATERAL BRACING ON EACH AXIS
- PROVIDE ADEQUATE DIAPHRAGM ACTION
- FIX INTERNAL WALLS TO CEILING TO AVOID VERTICAL CANTILEVERS

WIND ACTION

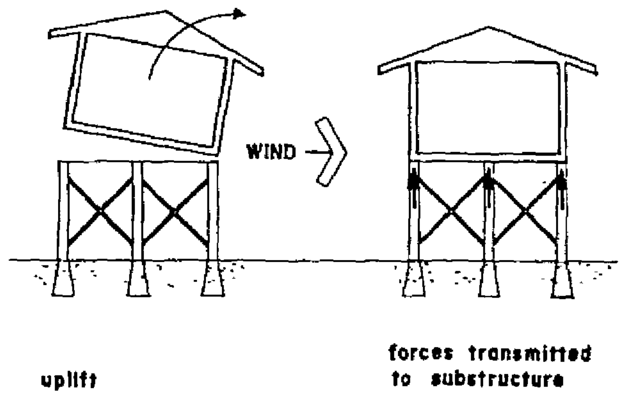
DIAPHRAGM NEEDED AT CEILING OR BEAM SUPPORT TO WINDWARD WALL



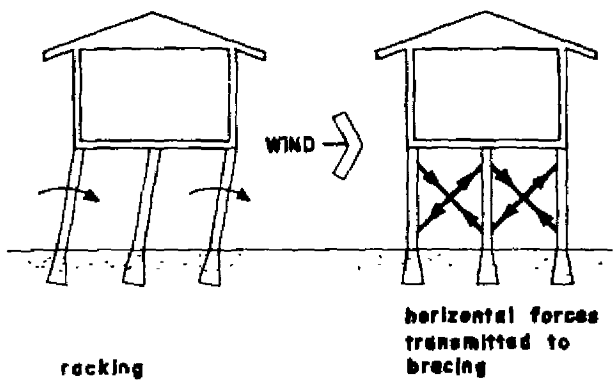
LINES OF TRANSMISSION OF WIND FORCES FOR BOTH DOUBLE AND SINGLE STORY BUILDINGS



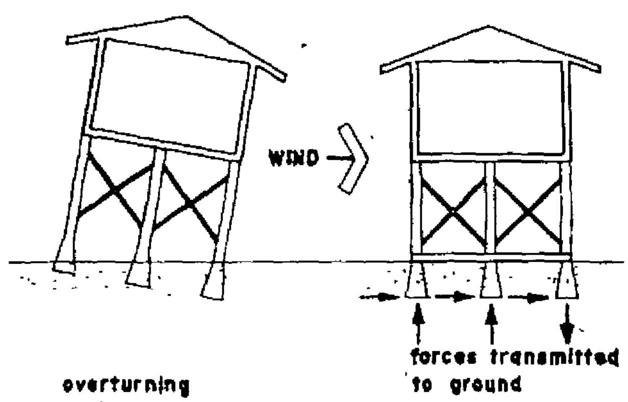
PROVIDE ADEQUATE FIXING OF UPPER STOREY TO SUB-SUPPORTS



BRACE SUB-FRAME



DESIGN ADEQUATE FOUNDATIONS AND CONSIDER FLOOR SLAB TO UNDERCROFT



5.9 SITE EXPOSURE – TERRAIN CATEGORY OR GROUND ROUGHNESS

Dispersal of Tropical Cyclones over tropical oceans is rare Most are absorbed in to the middle or upper atmosphere or alternatively, gradually weaken over land mass.

Cyclonic winds normally lose intensity once the cyclone has passed over the coastline. The degree of this loss of intensity depends on many factors not the least of which are:

a. The degree of exposure, and;

b. Surface 'roughness', (Cyclonic winds lose intensity much faster over terrains littered with many permanent obstructions than over flat open plains)

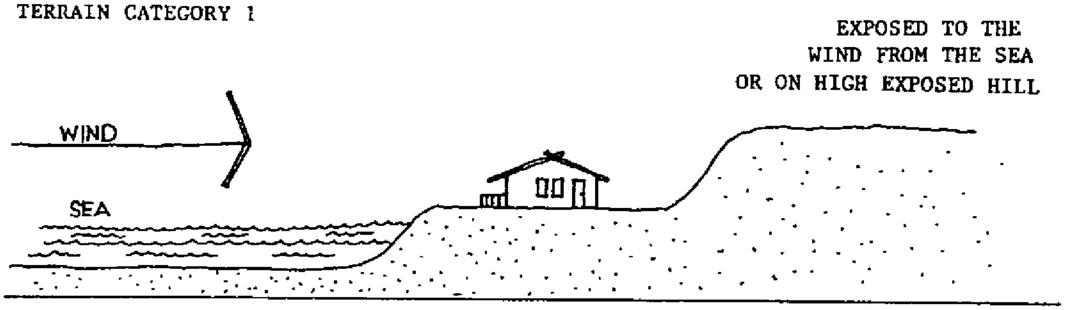
So as to facilitate design, different types of terrain and collections of buildings are categorized in what are termed 'terrain categories'

Terrain Category One

'Exposed open terrain with few or no scattered obstructions and in which surrounding objects are less than 1.5 metres high'. (Open sea coast, flat treeless plains)

TERRAIN CATEGORIES – ROUGHNESS OF SITE

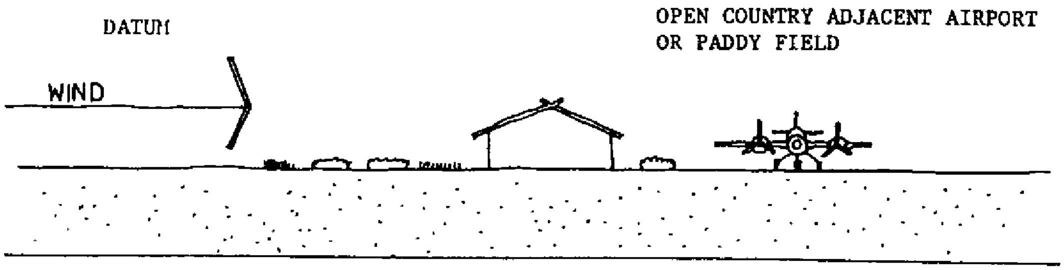
TERRAIN CATEGORY 1



Terrain Category Two

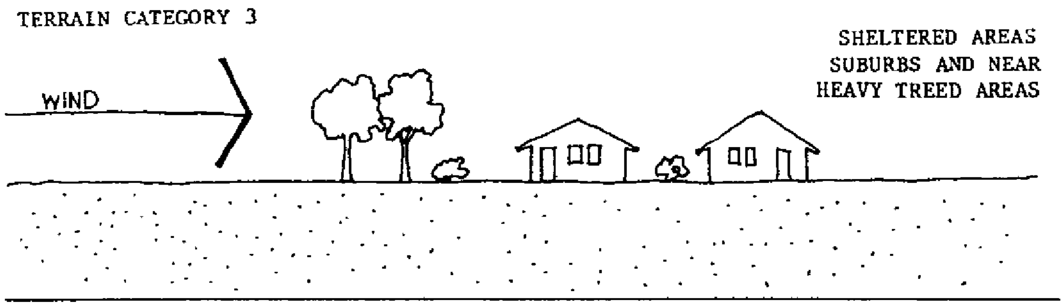
'Open terrain with well scattered obstructions having heights generally 1.5 to 10 metres' (Airfields, open park land, sparsely built up outskirts of town)

TERRAIN CATEGORY 2



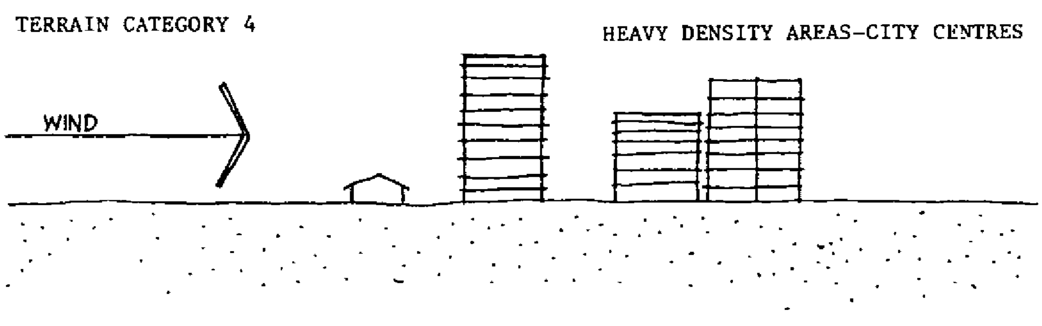
Terrain Category Three

'Terrains of numerous closely spaced obstructions being the size of domestic houses'. (Well wooded areas, suburbs and towns)



Terrain Category Four

'Terrains of numerous large, high closely spaced obstructions'. (Such as those found in dense city centres.)



The purpose of this categorisation is to obtain a multiplying factor (itself relative to building height) for each terrain category (available in tabulated form ... "British Wind Code CP3" Section 5 10) by which the basic wind velocity is multiplied to obtain the Design Wind Velocity

5.10 DESIGN LOADS

There are three types of specific loads that affect a structure:

(i) Dead loads,
(ii) Live loads, and,
(iii) Loads applied to a structure during the course of a natural disaster (such as strong wind, flood and earthquake). For the sake of this paper we shall confine our comments to wind loads

5.10.1 Dead Loads

The load due to the weight of the structure is called the dead load

Dead load = cladding + battens + rafters + stud walls + flooring + bearers + posts + footing (and so on).

Examples of typical dead loads for some structural materials are set out in the accompanying Table 8.

(The following table was onginally prepared by Engineer David. H. Lloyd)

TABLE 8
TABLE 'A' - DEAD LOADS

ELEMENT	*UNIT OF FORCE PER SQM (KN/sq.m))*	*TOTAL OF CONTRIBUTING UNITS OF FORCE PER SQM (KN/sq.m)*	*TOTAL OF CONTRIBUTING ELEMENTS IN POUNDS PER SQUARE FEET*
FLOORS			
TIMBER 20 mm T&G hardwood boards on 100 x 50 mm joists at 450 mm cc on 100 x 75 mm bearers Average Load. T&G Boards. Joists. Bearers.	0 259 kN/sq.m 0.115 kN/sq.m 0.014 kN/sq m	0.388 kN/sq.m	(8 2 psf)
CONCRETE 100 mm RC slab. 150 mm RC slab	2.40 kN/sq.m 3.60 kN/sq m		(50 psf) (75 psf)
ROOFS			
0 80 mm (22 g) GI sheet on 100 x 50 mm rafters at 450 mm cc - GI sheet including Joint Laps. Rafters	0 096 kN/sq.m 0.115 kN/sq.m	0.211 kN/sq.m	(4.4 psf)
0.80 mm Aluminium sheet on 100 x 50 mm rafters at 450 mm cc. Aluminium sheets. Rafters.	0 029 kN/sq.m 0.115 kN/sq.m	0.144 kN/sq.m	(3.0 psf)
Corrugated AC on 100 x 50 mm rafters at 450 mm cc. AC Rafters.	0.134 kN/sq.m 0.115 kN/sq.m	0 249 kN/sq m	(5 2 psf)
Terra Cotta Tiles on 100 x 50 mm rafters at 450 mm cc with 50 x 25 mm tile battens. Tiles. Rafters. Battens.	0 575 kN/sq.m 0 115 kN/sq.m 0.024 kN/sq.m	0.714 kN/sq.m	(15 psf)
Concrete Tiles on 100 x 50 mm rafters at 450 mm cc with 50 x 25 mm battens at 300 mm cc. Tiles. Rafters. Battens.	0.527 kN/sq m 0.115 kN/sq m 0.024 kN/sq.m	0.666 kN/sq m	(14 psf)
CEILING SYSTEMS			
(Excluding Timber Framing) 10 mm Fibrous Plaster. 13 mm Gypsum Plasterboard. 5 mm AC sheeting. Suspended Acoustic tiles.	0 086 kN/sq.m 0.215 kN/sq.m 0.072 kN/sq m 0.033 kN/sq m		(1.8 psf) (4.5 psf) (1 5 psf) (0 7 psf)
WALLS			
(Area in wall, not plan area). 75 x 50 mm studs at 450 mm centres + 6 mm AC both sides. 75 x 50 mm studs at 450 mm centres + 13 mm gypsum board each side. 110 mm brick per skin. 200 mm hollow concrete block.	0 320 kN/sq.m 0.330 kN/sq.m 2.151 kN/sq.m 1 912 kN/sq.m		(45 psf) (40 psf)

5.10.2 Live Loads

The loads applied either continuously or periodically to a structure are called live loads.

Live loads = Furniture + people + machinery (and so on)

Examples of typical live loads applicable to school buildings to follow on table

TABLE 9
TABLE 'B' - LIVE LOADS

SCHOOLS AND UNIVERSITIES	*UNIFORMLY DISTRIBUTED*		*CONCENTRATED LOAD*	
Building Element	*Load kPa*	*psf*	*Load kN*	*lbs*
Assembly Rooms	4.0	80	2.7	54
Class Rooms	3.0	60	2.7	54
Corridors	4.0	80	4.5	90
Dining Rooms	2.0	40	2.7	54
Kitchen	5.0	100	—	
Dormitories				
1 and 2 storeys	1.5	30	1.8	
over 2 storeys	2.0	40	1.8	
Gymnasiums	5.0	100	—	
Laboratories	3.0	60	6.7	
Toilet Rooms	2.0	40	1.8	

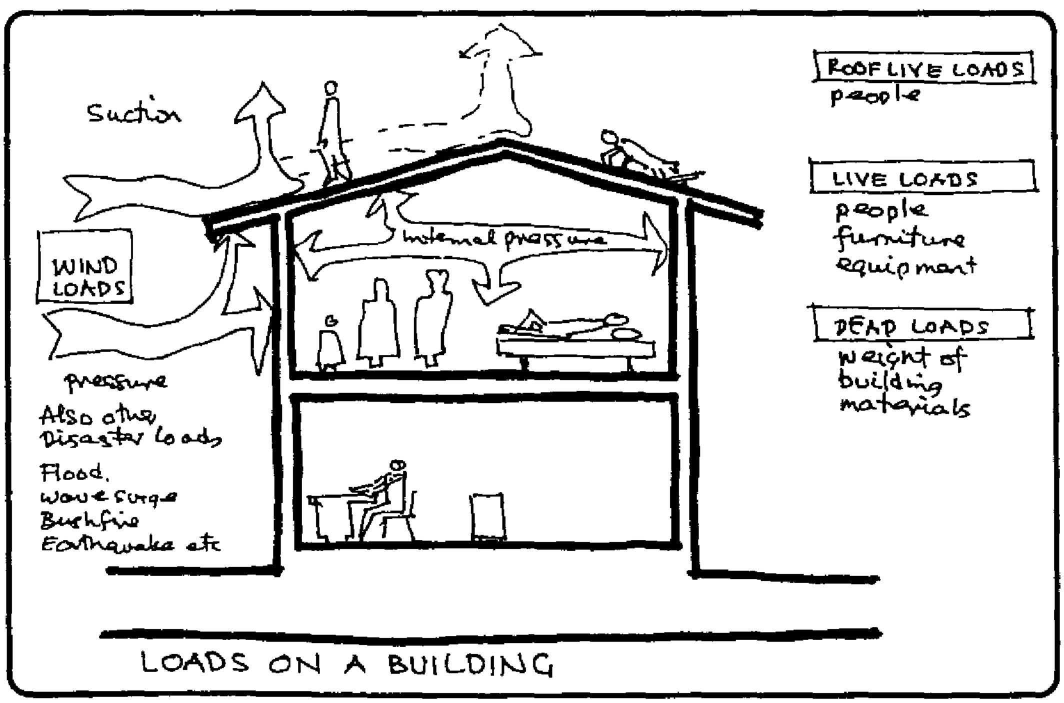
5.10.3 Minimum Live Roof Loads

The minimum live roof load is the load due to maintenance and construction and not due to the wind.

TABLE 10
MINIMUM LIVE ROOF LOADS

	ON ROOFS LARGER THAN 14 SQ.M	*ON ROOFS LESS THAN 14 SQ.M*
LIVE LOAD	= 0.25 kPa (5lb/ft^2)	= (1.8/A) x 0.12 kPa

A = the plan projection of the surface area of the roof in square metres.



5.11 BRITISH WIND LOAD TABLES

Following is a copy of the procedure for the calculation of Design Wind loads for selected locations. The procedure is an interpretation of the British Standards Institution Code BSI-CP3, Chapter V, Part 2, September 1972

Ideally, the calculations should include all external walls and both the windward and leeward slope of the roof. But, since the windward slope of the roof and the side walls generally experience the greatest negative pressures, any building designed to withstand pressures experienced in these locations will more than adequately withstand those on the leeward slope or remaining external walls.

5.12 WIND LOADS ON BUILDINGS

5.12.1 British Standards Institution

"Basic data for the Design of Buildings, Chapter V – Loading," BSI - CP3, Chapter V, Part 2, September 1972.

This paper is attempting to provide simple tables that are useful in calculating forces on simple buildings, that is; buildings of domestic scale one, two and perhaps three levels in height.

This should cover the majority of buildings on the planet and perhaps well over 90% of the residential buildings.

These buildings are those which receive the least professional input from Architects and Engineers who may be involved in less than 8% / 10% of the design of these buildings which house 100% of the world's population.

5.12.2 Formulae, Coefficients & Symbols

(a) Design Wind Speed, V_S

Factors for:

- Topography S_1 = shape (mostly 1.0)
- Ground roughness variations S_2 = site category & height
- Statistical factor S_3 = mostly 1 0

Design Wind Speed: $V_S = V \,.\, S_1 \,.\, S_2 \,.\, S_3$

(V = 3 second gust at height 10 m at one in 50 year return period in open country or in terrain equivalent to an airport).

(b) Conversion of Design Wind Speed to Dynamic Pressure, **q**

Dynamic Pressure $q = k.V_s^2$ (of approaching wind).
Surface Pressure $P = C_p.q$ (pressure coefficient x q).

Total Force: $F = (C_{p_e} - C_{p_i}) \,.\, q \,.A$

(Sum of internal and external pressure coefficients by dynamic pressure for the area concerned).

(c) Load on Building, **F**

Load (Force): $F = C_f \,.q \,.A$

(Force co-efficient by dynamic pressure by frontal area).

5.13 BRITISH WIND CODE CP3 – CHAPTER V – PART 2 – 1972

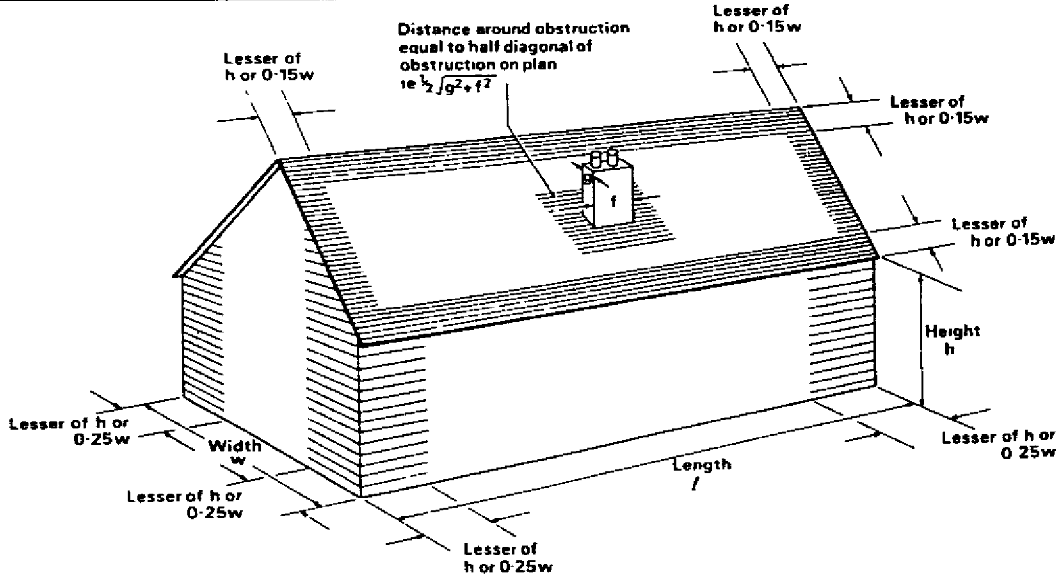
Symbols

V	=	Basic Wind Speed	b	=	breadth
V_S	=	Design Wind Speed	d	=	depth
P	=	Pressure on surface	h	=	height
P_e	=	external pressure	l	=	length
P_i	=	internal pressure	w	=	width
q	=	Dynamic Pressure	a	=	angle
C_f	=	force coefficient	S_1	=	topography factor
C_p	=	pressure coefficient	S_2	=	ground roughness factor
C_{p_i}	=	internal pressure coefficient	S_3	=	statistical factor
C_{p_e}	=	external pressure coefficient	F	=	force
A	=	Area of the surface			

k = 0.613 in SI Units (N/m² & m/sec).
k = 0.00256 in Imperial Units (psf & mph).

Note. For these tables, the values for S_1 and S_3 are both assumed to be equal to 1 0

(Tables prepared and converted to V = 50 m/s by Mr. Rod Buchanan BE (Hons), MIEAust, RPEQ, CPEng & K J Macks, AM, Hon.D Eng, ASTC)



AREAS WHERE HIGH SUCTIONS ON THE CLADDING MUST BE ALLOWED FOR
(Diagram Source: Newberry & Eaton 1974:44)

Table A ***DESIGN WIND SPEEDS & DYNAMIC PRESSURES***

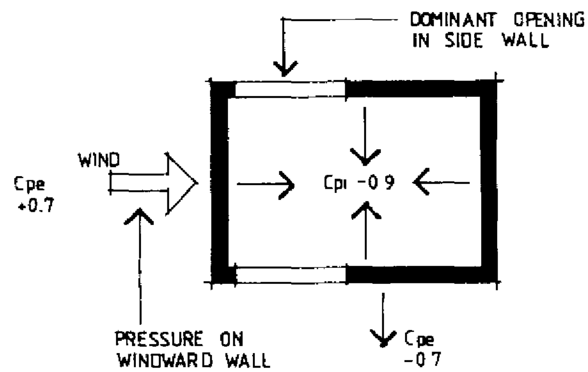
Conversion from Design Wind Speeds to Free Stream Dynamic Wind Pressures

TABLE 11
DESIGN WIND SPEEDS & DYNAMIC PRESSURES V = 50 m/s

GROUND ROUGHNESS CATEGORY	*HEIGHT*	*CLASS A - CLADDING*					*CLASS B - STRUCTURE*				
		S_2	*Vs*		*q*		S_2	*Vs*		*q*	
			m/s	*mph*	*kPa*	*psf*		*m/s*	*mph*	*kPa*	*psf*
1	15	1.03	51.5	115	1.63	34.0	0.99	49.5	111	1.50	31.4
1	10	1.00	50 0	112	1.53	32.0	0.95	47 5	106	1.38	28.9
1	5	0 88	44.0	98	1.19	24.8	0.83	41 5	93	1.06	22.0
1	3	0 83	41.5	93	1.06	22.0	0.78	39.0	87	0.93	19.5
2	15	1.00	50.0	112	1.53	32.0	0.95	47.5	106	1.38	28.9
2	10	0.93	46 5	104	1.33	27.7	0.88	44.0	98	1.19	24.8
2	5	0 79	39 5	88	0 96	20.0	0.74	37.0	83	0 84	17.5
2	3	0 72	36.0	81	0.79	16.6	0.67	33.5	75	0 69	14.4
3	15	0.88	44.0	98	1.19	24.8	0.83	41.5	93	1.06	22.0
3	10	0.78	39.0	87	0.93	19.5	0.74	37.0	83	0.84	17.5
3	5	0.70	35.0	78	0.75	15.7	0 65	32.5	73	0.65	13.5
3	3	0 64	32 0	72	0 63	13 1	0 60	30.0	67	0 55	11.5
4	15	0.74	37.0	83	0.84	17.5	0.69	34.5	77	0.73	15.2
4	10	0.67	33.5	75	0.69	14.4	0.62	31.0	69	0.59	12.3
4	5	0.60	30.0	67	0.55	11.5	0.55	27.5	62	0.46	9 7
4	3	0 56	28.0	63	0 48	10.0	0.52	26 0	58	0 41	8.7

Table B ***MAXIMUM WIND PRESSURES – WALL STRUCTURE – CLASS B***

MAXIMUM WIND PRESSURES – WALL STRUCTURE – LOADING CO-EFFICIENTS



$$P = (Cp_e - Cp_i).q$$
$$P = (+0.7-(-0.9)q = \mathbf{1.6q}$$

TABLE 12
MAXIMUM WIND PRESSURES - WALL STRUCTURE CLASS B

GROUND ROUGHNESS CATEGORY	*HEIGHT*	*DYNAMIC PRESSURE* *q*		*WIND PRESSURE* *P = 1.6 q*	
		kPa	*psf*	*kPa*	*psf*
1	15	1.50	31.4	2.40	50.2
1	10	1.38	28.9	2.21	46.2
1	5	1 06	22.0	1 69	35.3
1	3	0.93	19.5	1 49	31.2
2	15	1.38	28.9	2.21	46.2
2	10	1.19	24.8	1.90	39.7
2	5	0 84	17.5	1.34	28.0
2	3	0.69	14.4	1 10	23.0
3	15	1.06	22.0	1.69	35 3
3	10	0.84	17.5	1.34	28.0
3	5	0 65	13.5	1.04	21.6
3	3	0 55	11.5	0.88	18 4
4	15	0.73	15.2	1.17	24.4
4	10	0.59	12.3	0.94	19.7
4	5	0.46	9.7	0.74	15.5
4	3	0.41	8 7	0 66	13 8