# *PART TWO RESOLVING THE PROBLEM*

# 7 FACTORS AFFECTING PERFORMANCE

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DISASTERS

WIND | SURGE | FLOOD | FIRE | QUAKE | VOLCANO

↓

GENERATE FORCES ON BUILDINGS
AND THE ENVIRONMENT

↓

**RESISTED BY**

↑

KNOWLEDGE OF FORCES DEVELOPED

on

INDIVIDUAL LOAD AREAS

made up of many

CONNECTION DETAILS OF ELEMENTS

needing knowledge of

CAPACITIES OF FIXING ELEMENTS
NAILS, SCREWS, BOLTS, CLIPS, GLUES

and design skills in

COMPONENT FIXING & DESIGN OF
BUILDING CONSTRUCTION ELEMENTS

## 7.1 FACTORS AFFECTING PERFORMANCE

There are many factors that affect the performance of buildings and their construction methods in resisting forces caused by cyclones The principal factors to be considered are·

### 7.1.1 *Understanding the Forces*

There is, in the design and construction industry, and in the administration and political fields associated with building development, a general lack of understanding of the real forces caused by tropical cyclones

The actual forces are often three and four times greater than the forces envisaged by inexperienced personnel.

This is more prevalent where the capital city and major population bases are remote from the tropical cyclone regions.

### 7.1.2 *Type of Forces*

There is also a lack of understanding of the different types of forces involved, such as "structural" forces and "cladding" forces

Engineers are often involved in preparing designs for the structural loads on a building, but are seldom involved in the design, selection or detailing of the various claddings.

This is left to the architect or the building contractor or tradesmen to select and specify.

The forces on the claddings can be 50% greater than the forces on the structure.

Therefore, there is a need to educate the architects, builders and tradesmen to understand these forces and to devise better fixing methods to secure these claddings.

### 7 1.3 *Design*

The design of the building involves details of construction methods for connection of the building materials used

The designer should specify the materials to be used together with quality of materials and methods of connection.

Lack of knowledge or skill can affect performance.

Other factors that lead to poor design include.

- Pressure of work affecting quality control
- Using out of date codes or no code reference.
- Lack of in-service staff training and professional development

### 7.1.4 *Construction*

The contractor should purchase only quality approved materials and should provide experienced tradesmen to put them together. He should supervise the construction and be experienced in the details needed for cyclone areas

Lack of performance can be caused by·

- Volume of work
- Methods of employment of staff
- Lack of supervision.
- Inadequate quality control.
- Bad workmanship.
- Use of incorrect fasteners and fixings.
- Bad material supply

### 7.1.5 *Quality of Materials*

a. *Timber*

- Is timber graded to acceptable stress levels?
- Are the tradesmen familiar with these standards?
- Are joints exposed to the weather or covered?

b. *Concrete*

- Is the sand, aggregate and cement checked for quality?
- Is the formwork for concrete properly put together and supported?
- Is the reinforcement kept in its correct position?
- Is the concrete placed correctly and vibrated?

c. *Steelwork*

- Is steel free from rust?
- Is steel correctly supported and fixed?
- Does steel need to be galvanised?

d. *Roofer*

- Are the roof materials selected fit for the task?
- Will they carry the loads received by the codes?
- Is the method of fixing known and understood?

e. *Fixings*

- Are nails, screws, bolts and steel fixing plates galvanised?
- Are the nails used the correct size and length?
- Are thin metal plate connectors of the correct thickness?

### 7.1.6 *Supervision and Inspection*

Whilst the builder supervises his tradesmen, the professional consultant architects and engineers inspect the works from time to time.

It is essential that the inspectors are experienced in cyclone construction loads and methods of construction that will resist these loads.

Local authority inspectors also need to be aware of their responsibilities to achieve code performance.

### 7.1.7 Manufacturers

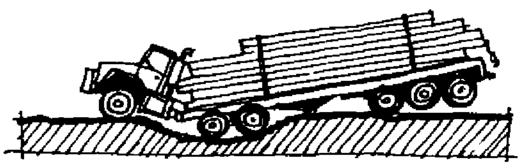
They should provide quality products to the industry, together with recommended methods of fixing that are proven to be adequate to resist the likely wind loads to be encountered.

They should inspect projects from time to time to monitor the effect of their fixing recommendations.

Lack of adequate instructions lead to failure

### 7.1.8 Transport Difficulties & Ordering

Specified materials unable to be delivered to remote sites or unavailable in the region where the building is to be erected



Specified materials too expensive.

Incorrect ordering of materials resulting in incorrect material or inadequate material arriving on site.

### 7.1.9 Debris

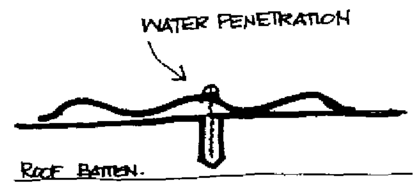
Damages caused by flying debris causing internal pressure to be activated.

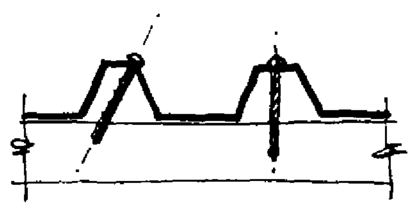
Builders should keep sites clear in cyclone season.

Debris damages can be controlled.

### 7.1.10 Workmanship

- Deficiencies occur in workmanship with insufficient sized washers on bolt fixings or insufficient screws or washers that are too small where the cladding material pulls through the fixing under severe loads or where bolts pull through timber
- Overdriving of lead head nails or roofing nails or over-drilling of screw holes.
- Deterioration of roofing timber by water penetration through screw or nail hole

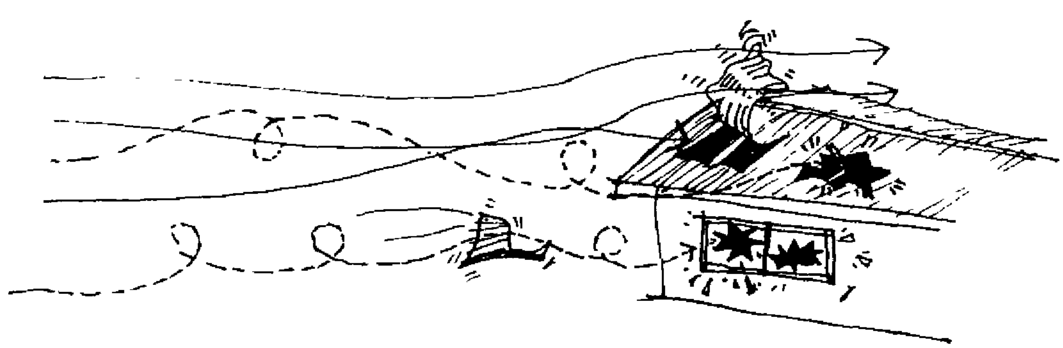


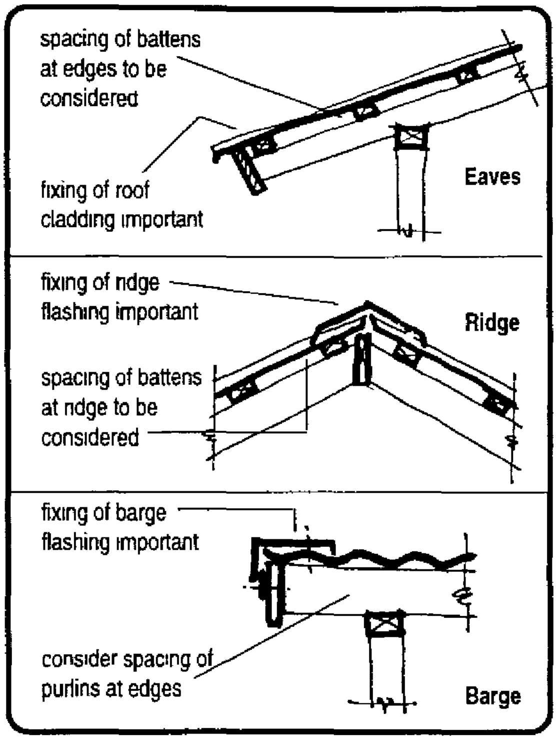
- Roof screws failing in torsion where not driven plumb. (especially in high rib roofing).

  Also, "creeping" can occur where long length roof sheeting shifts in position along the roof
- Awkward fixing locations, such as at chimneys or roof penetrations, changes in roof shape where it is difficult to apply the correct fixings at the cladding to roof frame or roof frame to roof structure.
- Lack of fixings in tile roofs where it is difficult to provide adequate fixings at the lowest three tiles and at ridges and valleys.

  It is important to fully investigate tile roofs in cyclone areas



Lack of attention to fixings at ridges, barges and eaves

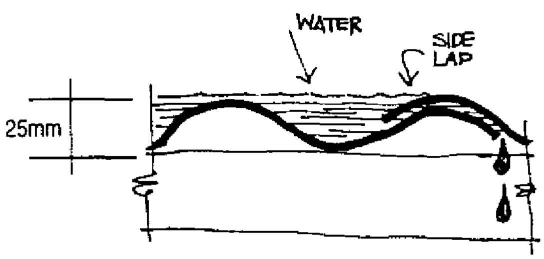



- Difficulties in providing fixings where roof insulation membranes are used on top of roof purlins or battens.

  This system also can prevent inspectors from viewing roof fixings and clips.

### 7.1.11 *Documentation*

- Using roof pitches that are too low where pans of roof sheeting can fill up with water under heavy rain with subsequent side flow of water under laps in roof sheeting and severe leaking to roof system causing consequential damages




  Use of undersize timber roof members for battens, rafters or purlins causing deflection.

  Expansion causes weakness at roof cladding fixings allowing water entry and deterioration of fixing and its strength by rotting, etc ..

- Using roof sheeting that is too thin, e g , galvanised iron or aluminium where sheets can tear away from fixings

- (Closer spacing of purlins or battens can reduce the loads to be resisted at each point of support)

## 7.2 POINTS TO PONDER

- The wind load acting on the site of a typical single level three classroom school 5.0 m high and 20 m long is sufficient to over-turn an unreinforced building.

- At 35 m/s (78 mph) (128 kph) the suction (uplift) forces on a roof are greater than the dead weight of the roof tiles and roof framing Therefore, above these wind speeds we can expect roof damage unless we take steps to "tie down" the roof and its cladding.

- If you use shutters for protection, you have to be home to close the shutters.

  If you live in the tropics where windows are much larger the shutters are larger and separately stored The occupants have to attend to the erection of these shutters, when the cyclone alert occurs.

- The force of the wind at 70 m/s (150 mph) (250 kph) is strong enough to move light concrete slabs.

The school is often the largest building in the village with no one to take care of it. People may always relate closely with their home and property but in some countries, they feel little responsibility to protect the government's school buildings.

## 7.3 PROBLEMS TO AVOID

### 7.3.1 *Examples of Typical Failures*

There are many failures in building construction in cyclone areas.

The most common are:

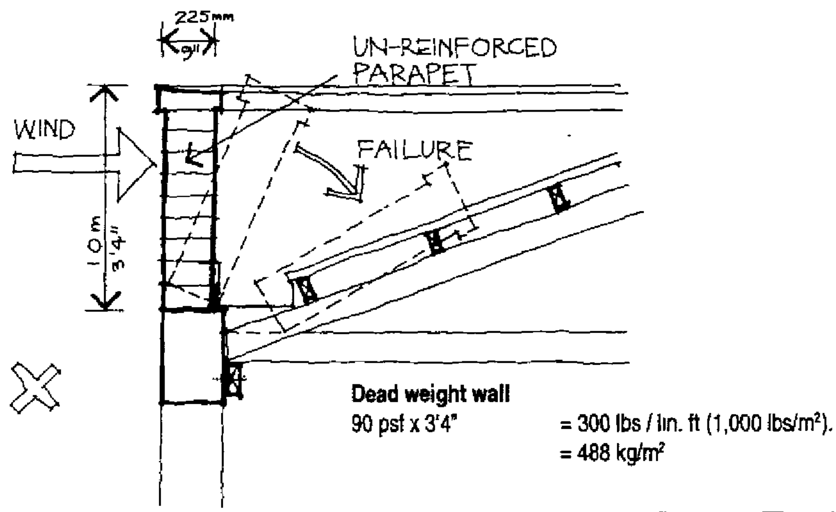
- Roof sheeting removed from purlins
- Roof sheeting and purlins removed from rafters
- Roof sheeting, purlins and rafters removed from wall frames (i.e., whole of roof structure removed).
- Roof structure removed, walls distorted
- Whole wall, roof removed or destroyed
- Whole structure intact but distorted due to inadequate bracing
- Failure of brick or block walls due to inadequate stiffening at tops of walls and inadequate vertical reinforcement.

Apart from these typical failures, there are other modes of failure that can cause damages

### 7.3.2 *Brick Parapets - Fixing*

The following diagrams describe situations where damages have occurred due to failure of a component or method of construction. The consequential damages caused by the collapse have been costed at many times the value of the damaged component.

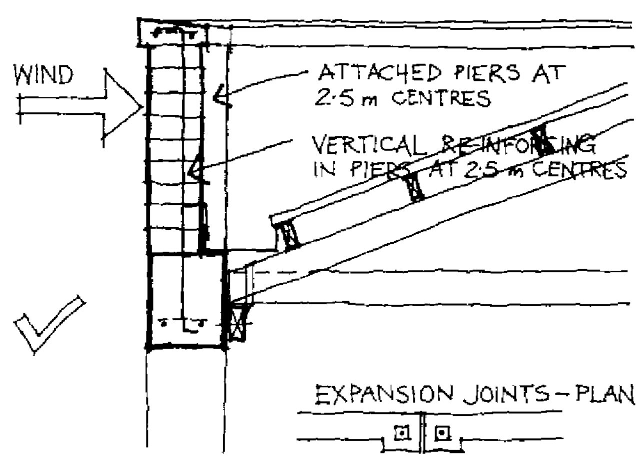
Un-reinforced brick parapet walls are dangerous and prone to collapse under wind loads.




Where the wall is laid above the beam as shown it is a vertical cantilever and will collapse at moderate wind forces. If a damp proof course is laid in the wall it is substantially weaker (up to 50%).

If the wall is 30 m long x 1.0 m high its weight is 14,650 kg and can cause damage to other parts of a building when it collapses.

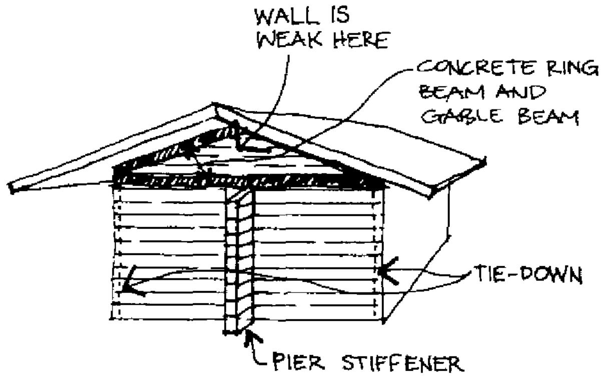
- The writer has seen an example where a 50 m long parapet as modelled above existed on the boundary wall of the second floor of a 6,000 m² city department store. When the brick parapet collapsed it fell onto a series of steel roof trusses, cracking the weld on 10 trusses with the shock load of impact. The bricks fell through the false ceiling to cause damage to the Fashion Department.



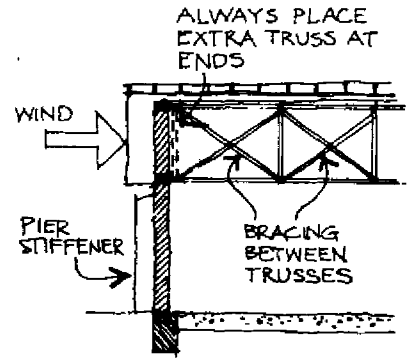

The wall should be topped with a concrete bond beam itself tied down to the base at regular centres and at edges of expansion joints and ends of wall panels.

Return walls or stiffening nibs should be provided at regular intervals (say 2.0 to 3.0 m apart).

Normal expansion joints should occur to avoid longitudinal expansion problems. Piers at joints should be reinforced vertically




METHODS OF GABLE WALL STIFFENING




SAVING THE LAST TRUSS MAY RESULT IN LOSING THE GABLE

### 7.3.3 *Gable Walls*

Gable wall designs continue to ignore the wind loads placed on the gable wall, especially at the apex of the gable. Many collapse throughout Asia and elsewhere. The gable end wall needs to have proper support. The practise of saving the cost of a truss against the wall is not warranted as the truss can, with bracing from other trusses, provide good lateral support to the top of the wall.

Long brick walls can also benefit from the addition of attached piers and concrete bond beams and columns.

Brick walls can gain lateral support from braced trusses. Always place extra truss at gable wall.

### 7.3.4 *Clip on Fascia Cladding*

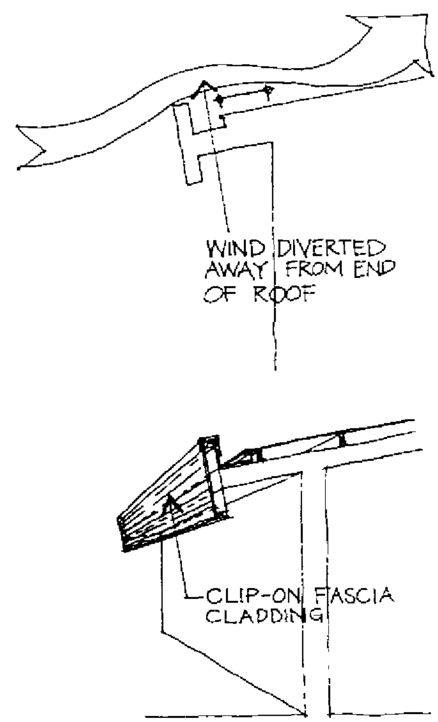
When fascias to roof systems are deepened as shown there is an advantage in distribution of wind load. The normal roof has a higher wind load at the eaves of 2.6 to 2 7 q compared to 1 6 to 1.7 q in the body of the roof

The introduction of a deep fascia (and hidden gutter) as illustrated, will divert the high pressure winds away from the eaves and allow a lesser wind pressure to impact some distance away from the eaves. This may even out the overall pressure on the roof to a more even wind suction load throughout. This will suggest that all roof fixings may be similar and is a detail worth considering.

However, the framing of this fascia (or barrier to divert the wind) should be well constructed.

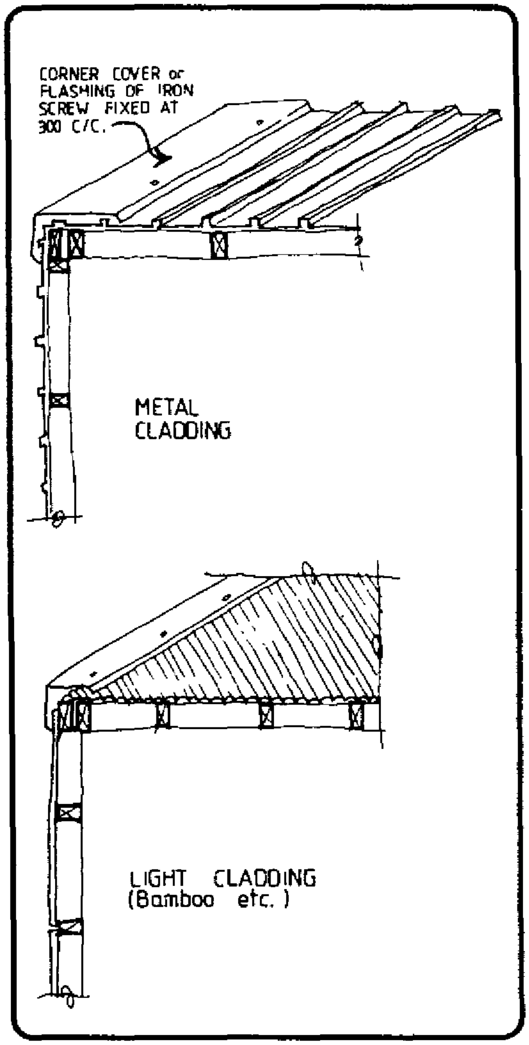
In addition, the cladding of the fascia and its flashings will need high quality fixing to its sub-frame by screwing of the sheet to the supports.

Current traditional sheet clipping systems have proven inadequate and will de-index under the wind loads, thus exposing the roof areas to progressive degradation. This failure occurred at a University in Australia in the 1971 Cyclone Althea.



### *7.3.5 Corner Protection to Cladding*

Removal of corner flashing and barge flashing led to loss of wall and roof cladding in the loft of a television studio with consequential loss of expensive control room equipment and two weeks "off air".




It is important to give protection to salient edges or corners in lightly framed buildings as it is at these corners where the turbulent wind pressures on the wall claddings are greatest (called the cladding load).

They are 50% greater than the structural wind loads (those wind loads for which the building's structural framework is designed by the Engineer)

Where the corner claddings are not properly considered, detailed cover moulds and / or flashings can be easily removed by the wind leading to progressive degradation of the adjacent cladding which is often lightly fixed behind the cladding

### *7.3.6 Platforms on Roofs*

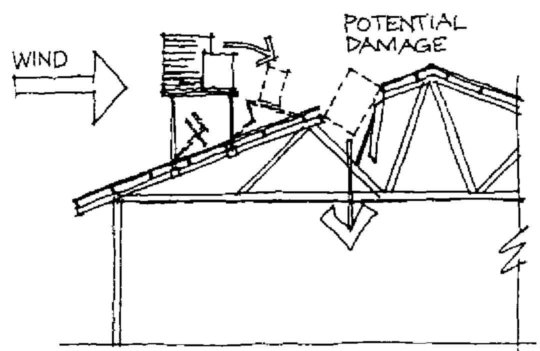
Many contemporary buildings save floor space by mounting equipment such as water tanks, solar hot water panels, air-conditioners and the like on the roof, often on frames built above roof level.

In the typical case of air-conditioning units, installers believe that the weight of the unit was sufficient not to worry about securing the unit to the frame or the roof structure.

In cyclones, wind loads will overturn these units which can fall through roof sheeting and damage the sheeting, framing, ceiling, lighting and stores, etc... in the building.

Subsequent rain and wind can cause consequential damage to the interior of the building and its equipment which can be many times the value of the building damage.

All roof mounted plant must be properly strapped and held onto adequate roof framing platforms mounted above roof sheeting and adequately supported through the roof to properly transfer loads.



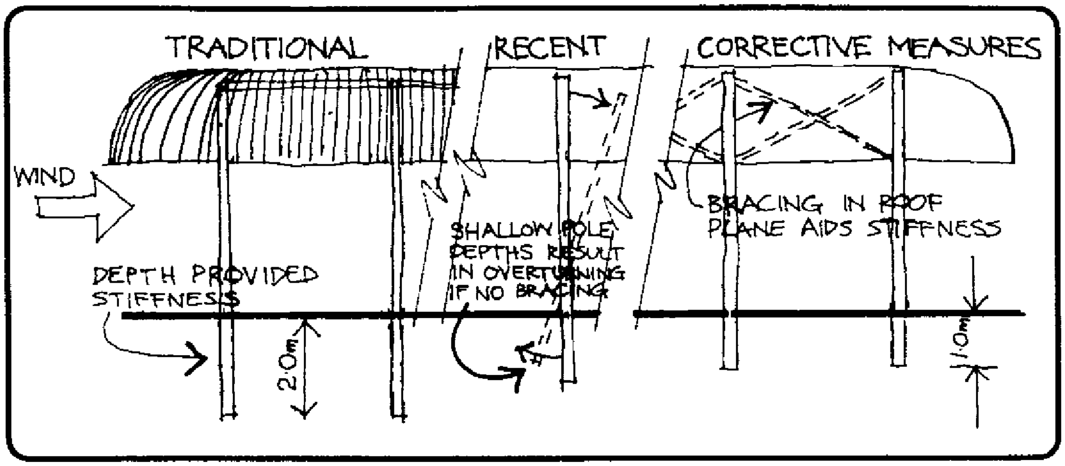

It is better in cyclone areas to avoid such roof mounted equipment

The case examined was a newspaper printing establishment where roof mounted air-conditioning equipment loosely mounted on a frame was blown off and fell through an asbestos cement roof. Among the damages was the loss of over 100 one ton coils of newsprint paper, a three months supply to the plant located in a remote area.

### 7.3.7 *Fale Construction*

In traditional fale or bure construction in the Pacific Islands, the poles were well treated and buried up to 2.0 m into the ground.

This system provided stiffness to the pole and avoided the need for roof plane bracing. The style became the custom.




In more recent times, poles have been installed at much shallower depths (presumably to save money), also without roof bracing. Many failures occurred due to the loss of integrity of the vertical cantilever previously adopted.

Where one system passes through a transition period into another system, we must identify the integrity of the original system and, if deleted, replace it with a new system of integrity

### 7.3.8 *Brick Wall Overturning*

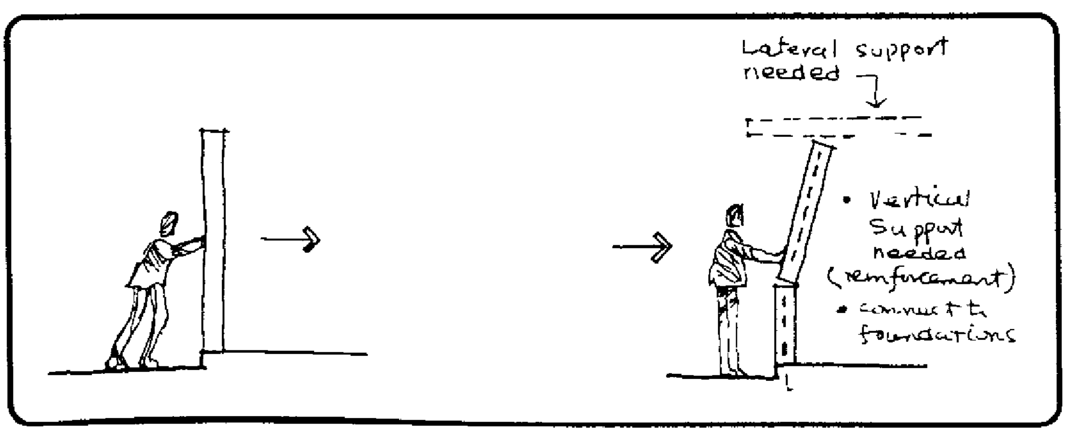
Brick walls are often erected, especially, in low rise one and two level buildings, with inadequate attention to their restraint and need for support.

In cyclone regions we see many screen walls and property boundary walls 1 m to 2 m in height which simply blow over

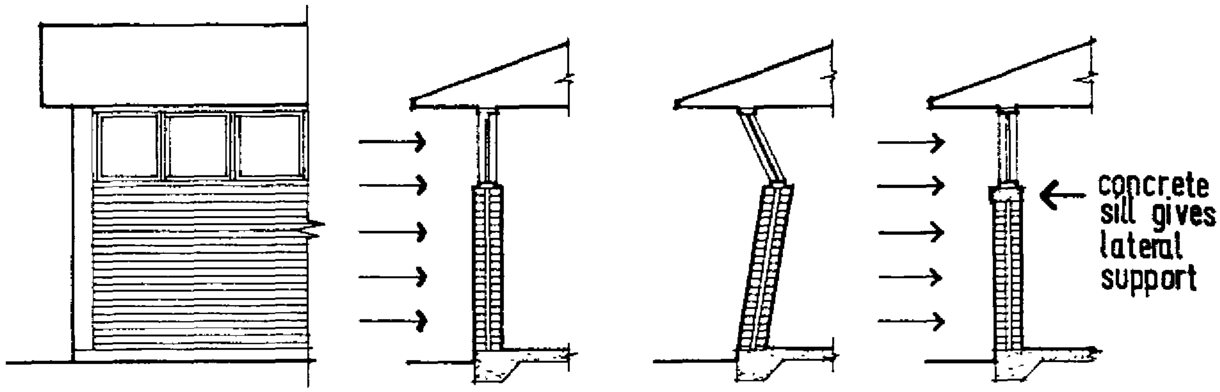
In buildings, it is often popular to separate concrete columns from brick walls to enable full height windows to be placed each side of the column for aesthetic reasons of delineation of the column and to let light into the building (see sketches on page 98). If there is no restraint or lateral support at the top of the wall then the wall is a simple vertical cantilever and can easily blow over

This, in fact, occurred in a University residential building in Townsville in 1971 where a series of 2.0 m wide 270 thick cavity walls 3.0 m high leaned inwards 300 mm during a cyclone.

The sketches following illustrate the problem and offer solutions.



### 7.3.9 Half Height Walls



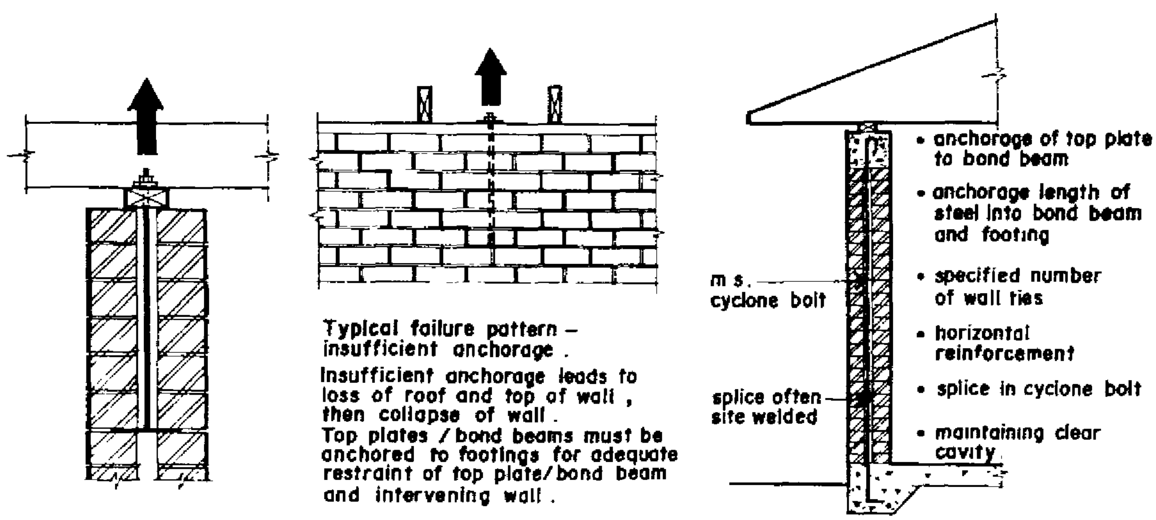

**Wall unstable as sill plate is not given adequate lateral support**

Long lengths of half height walls are often designed to allow long strips of windows for light and ventilation reasons. These can topple over in high winds unless they are restrained with attached piers, columns or stiffener posts and possibly a reinforced concrete sill tied between floor to roof supports

### 7.3.10 Inadequate Tie-Down

It is common practice in non-cyclonic areas to tie top plates down some 5 or 6 courses into brick walls. The 500 deep section of wall with a weight of about 250 kilograms is unable to restrain uplift forces of 1,500 kgs or more.

The holding down bolts to the top plates should extend right down to the foundations.

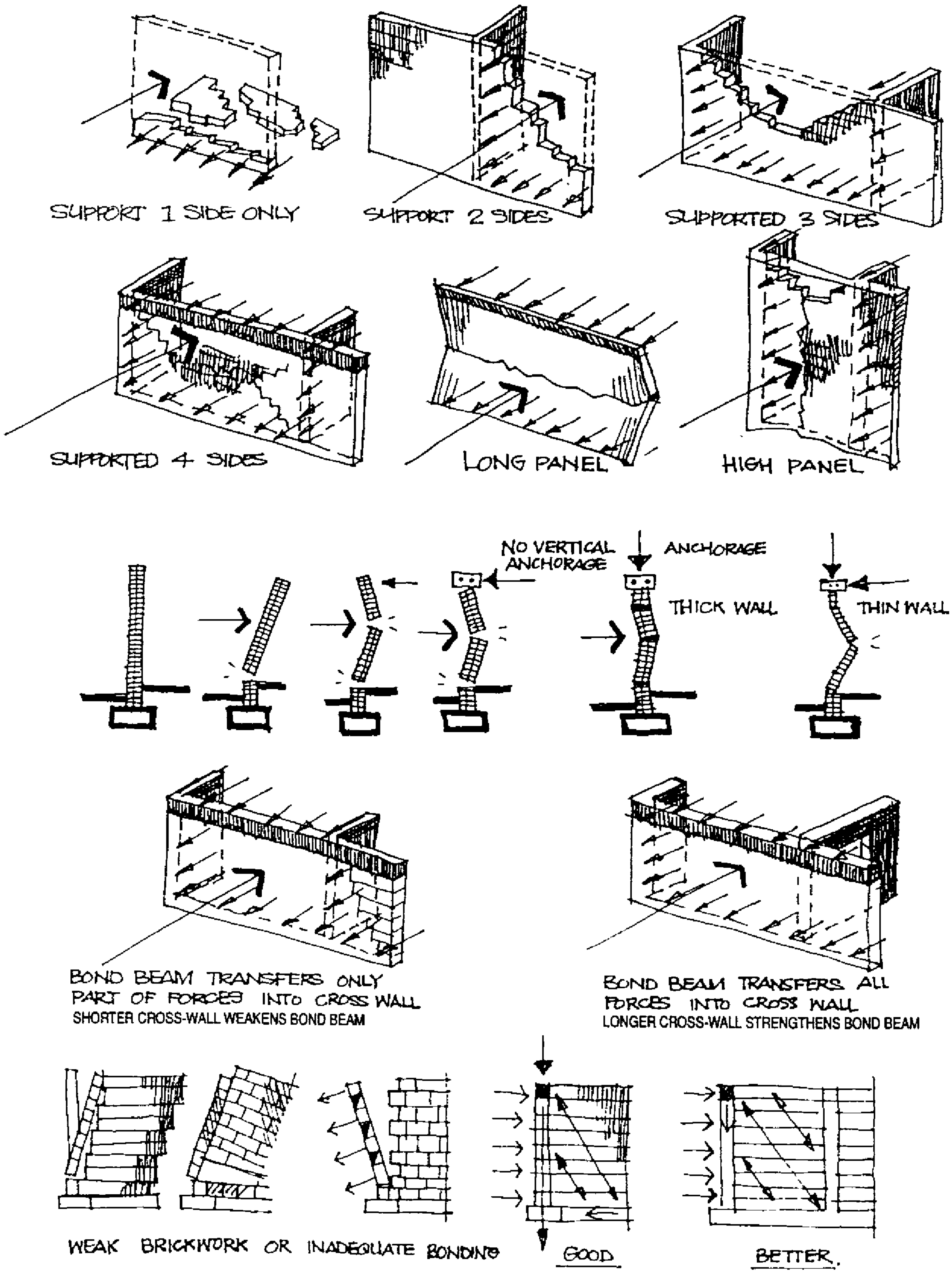



Points to watch for

**Common Problem Areas and Faults in Cavity Brick Walls**

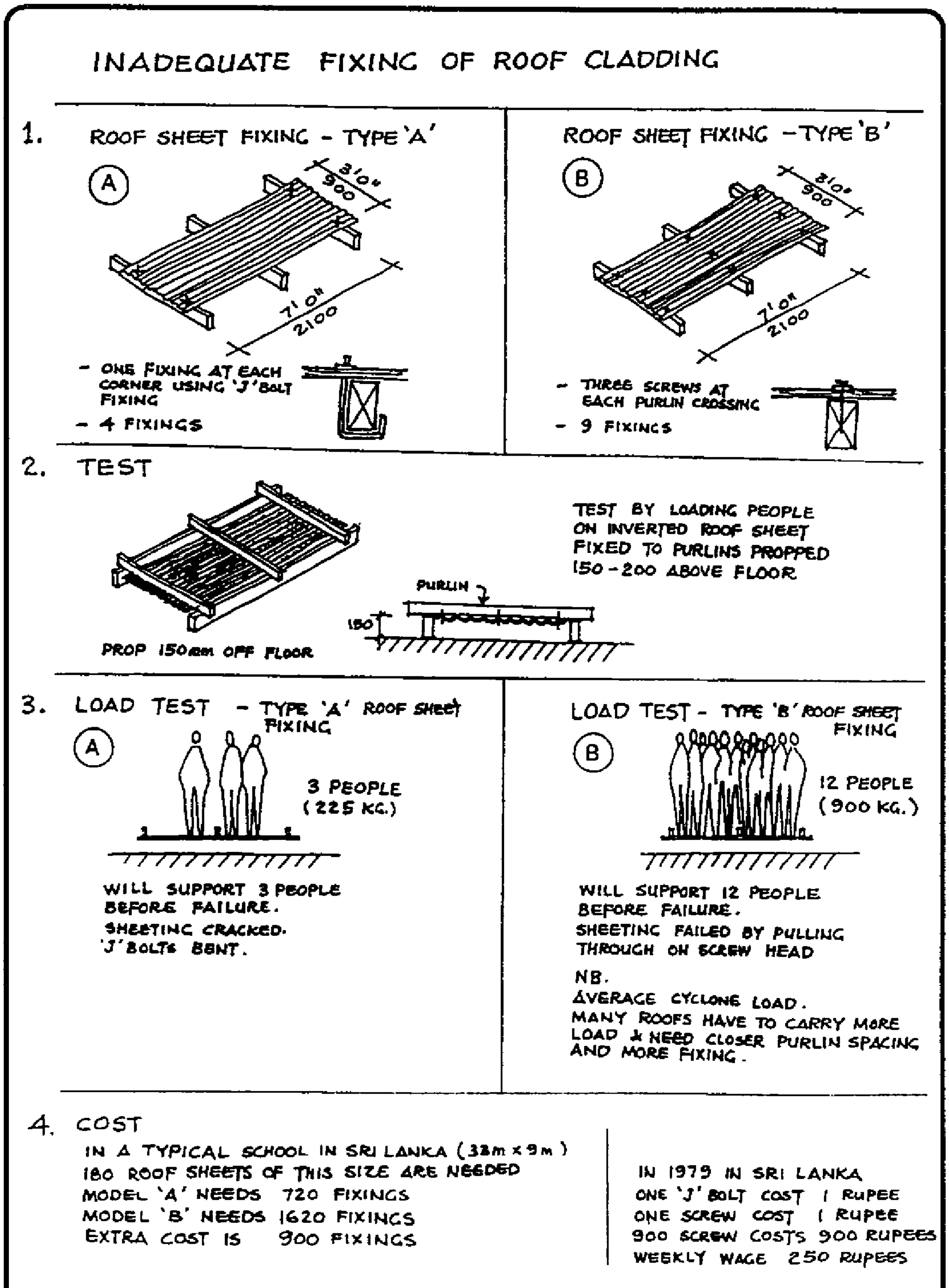
### 7.3.11 *Wind Action on Brick Walls*

The page of sketches illustrates the need for careful design of brick walls where length, height, size and reinforcement are critical factors if the wall is to resist nature's forces.

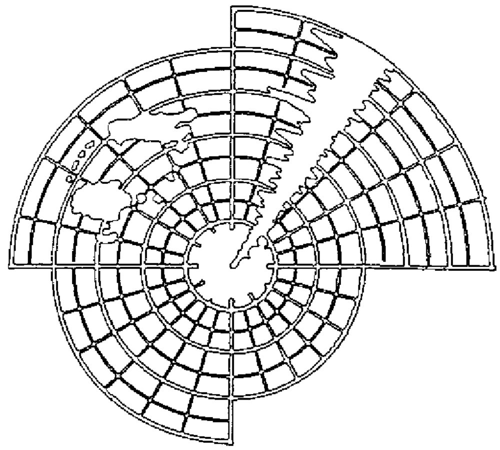


### 7.3.12 *Inadequate Fixing of Roof Cladding*

The above test was carried out on two occasions in 1979 in Sri Lanka after the 1978 cyclone. The impact of the testing was dramatic where the asbestos cement sheet cracked noisily on failure and the people loading the sheet fell 6" to the floor. The 'J' bolts (5–6 mm Ø) bent under the load of the 4 people.




ONE TRADESMAN'S PAY FOR LESS THAN ONE MONTH TO CARRY 4 TIMES THE LOAD



# 8 CALCULATION EXAMPLE — MODEL CLASSROOM BLOCK

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- 8.1.2 Variations in Wind Loads due to Ground Roughness and Wind Speed
- 8.1 3 Example of Wind Loads
  - (a) Wind Force
  - (b) Global Loads
- 8.1.4 Calculate Loads to Assist in Holding Down from Roof to Floor Slab (Model School)
  - (a) Roofing Batten to Rafter Connection
  - (b) Rafter to Wall Top Plate
  - (c) Top Plate to Foundation

## 8.1 SCALE OF WIND LOADS - EXAMPLE ON SCHOOL BUILDING

The same school building in the following four situations has to withstand different load conditions on each site.

### *8.1.1 Procedure*

The Basic Wind Speed (V) recorded can be translated into a Design Wind Speed ($V_S$) after applying factors for topography, site category or ground roughness, height, and importance of structure.

The Design Wind Speed is converted into a Dynamic Pressure (q).

The Dynamic Pressure is then converted by appropriate pressure co-efficients into a pressure ($p_e$) acting on any point on the surface of a building.

This pressure can be a positive pressure, acting toward a surface, or a negative suction from the surface.

The pressures or suctions are greater within 15% of corners of walls and edges of roofs. These wind pressures act over a surface to produce a wind force.

Internal wind forces add to the external suction forces to arrive at the total wind load or pressure.

This is then applied to a point or to whole surface areas such as walls or roofs.

The resulting pressures are those which should be considered in design.

Finally, it should be noted that the forces on the claddings, glazing and roofing (called Class A) are greater than the forces on the structure of the building (called Class B for building up to 50 m long or high) and Class C for the larger buildings.

Reference – British Code CP3 – 1972

### *8.1.2 Variations in Wind Loads due to Ground Roughness and Wind Speed*

**TABLE 16**
**DESIGN DATA FOR SCHOOL SITES**

| | | | | |
|---|---|---|---|---|
| Basic Wind Speed (V) | 50.0 m/s | 50.0 m/s | 50.0 m/s | 40 0 m/s |
| Height to Ridge (H) | 5.0 m | 5.0 m | 5.0 m | 5.0 m |
| Site Ground Roughness ($S_2$) | 1 | 2 | 3 | 3 |

| DESIGN WIND SPEEDS ($V_s$) | m/s | mph | m/s | mph | m/s | mph | m/s | mph |
|---|---|---|---|---|---|---|---|---|
| Class B – for structure | 41.5 | 93 | 37 0 | 83 | 32.5 | 73 | 26 | 59 |
| Class A – for cladding | 44 0 | 98 | 39.5 | 88 | 35.0 | 78 | 28 | 63 |

| DYNAMIC WIND PRESSURES (q) | kPa | psf | kPa | psf | kPa | psf | kPa | psf |
|---|---|---|---|---|---|---|---|---|
| Class B – for structure | 1.05 | 22.1 | 0.84 | 17.6 | 0.65 | 13.6 | 0.41 | 8.9 |
| Class A – for cladding | 1.19 | 24.6 | 0.96 | 19.8 | 0.75 | 15 6 | 0.48 | 10.2 |
| MAXIMUM WIND PRESSURES | | | | | | | | |
| CLASS B - STRUCTURE (q) | | | | | | | | |
| Wall Structure 1.6 q | 1.68 | 35.4 | 1.34 | 28.2 | 1 04 | 21.8 | 0.66 | 14.2 |
| Roof Structure 1.9 q | 1.96 | 42.0 | 1.60 | 33.4 | 1 24 | 25.8 | 0.78 | 16.9 |
| CLASS A - CLADDING (q) | | | | | | | | |
| Wall Cladding – General 1.6 q | 1.90 | 39.4 | 1.54 | 31.7 | 1 20 | 25.0 | 0.77 | 16.3 |
| Wall Cladding – Corners 1.9 q | 2.26 | 46.7 | 1.84 | 37.6 | 1.43 | 29.6 | 0 91 | 19.4 |
| Roof Cladding – General 1.9 q | 2.26 | 46.7 | 1.84 | 37.6 | 1 43 | 29.6 | 0.91 | 19.4 |
| Roof Cladding – Corners 2.7 q | 3.21 | 66.4 | 2.59 | 53.5 | 2 03 | 42.1 | 1.30 | 27.5 |

Statements:

1 On the type 3 site at basic wind speed 40 m/s, the loads are approximately half those on the type 2 site at 50 m/s.

2. On the type 1 site at basic wind speed 50 m/s; the loads are 25% higher than those on the type 2 site at 50 m/s.

3. The loads on the type 1 site at basic wind speed 50 m/s are 250% higher than those on the type 3 site at 40 m/s.

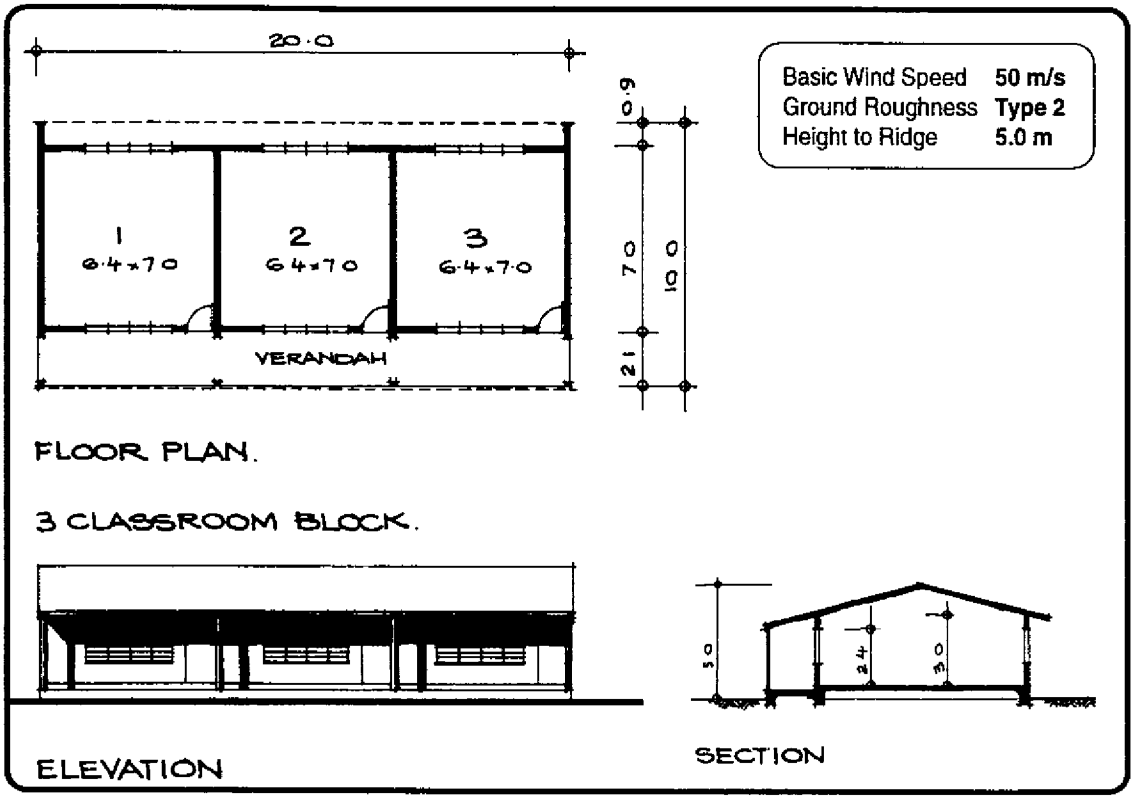
### *8.1.3 Example of Wind Loads*

How can we understand the wind loads involved in a cyclone? Hereunder are some examples, using as a model a simple 3 classroom block – 20.0 m long by 7.0 m wide, plus a 2 1 m wide balcony on one side.

#### *(a) Wind Force*

Assume the wind speed applies to the following areas:

| | | |
|---|---|---|
| Face wall area | 20 x 3 = | 60 m² |
| Face roof area | 20 x 10 = | 200 m² |

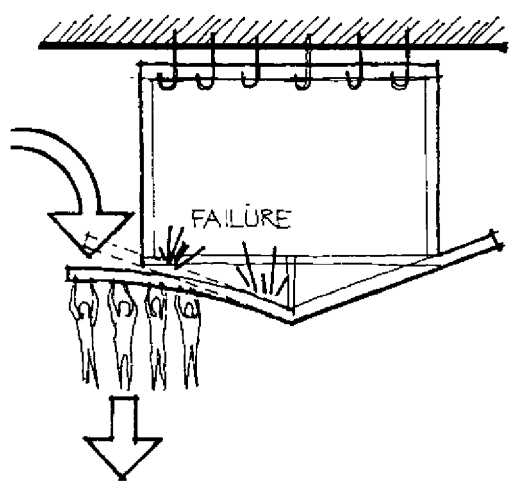



#### *(b) Global Loads*

| | | | | | | |
|---|---|---|---|---|---|---|
| Front wall area | 60 m² | x | 1.34 kPa = | 84 kN load | (18,600 lbs) | > 8 tonnes. |
| Roof area | 200 m² | x | 1.60 kPa = | 320 0 kN load | (72.628 lbs) | > 32 tonnes. |

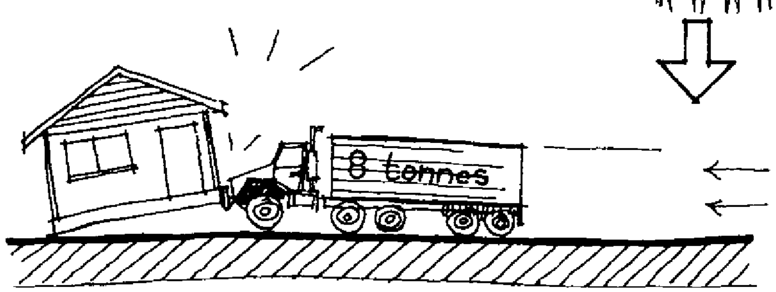
#### Roof Load

The total structure load on the roof is equal to two people per m² hanging on the roof. The cladding load tending to pull sheetıng off equals four people /m².




#### Wall Load

The total structure load on the wall is equal to the mass of eight (8) one-tonne trucks acting on the wall



### 8.1.4 Calculate Loads to Assist in Holding Down from Roof to Floor Slab (Model School)

Data taken from British Code Tables A – E (refer Section 5)

Ground Roughness **Site Category 2**, Height to Roof Ridge **5.0 m**, Wind Speed **50 m/s**

#### Pressure Co-efficients

| | | |
|---|---|---|
| Walls | 1.6 to 1.9 q | for Class A – Wall Claddings |
| | 1.6 q | for Class A – Wall Structure |
| Roof | 1.9 to 2.7 q | for Class A – Roof Cladding |

#### Wind Pressures

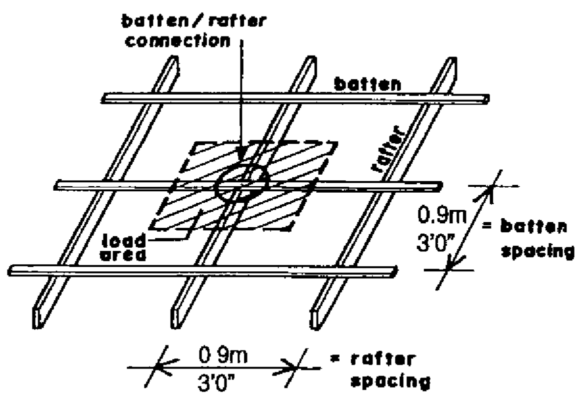
| | | | |
|---|---|---|---|
| Walls | 1.54 to 1.84 kPa | (31.7 to 37.6 lbf/ft²) | for cladding. |
| | 1.34 kPa | (28.2 lbf/ft²) | for structure. |
| Roof | 1.84 to 2.59 kPa | (37.6 to 53.5 lbf/ft²) | for cladding |
| | 1.60 kPa | (33.4 lbf/ft²) | for structure. |

Resistance capacities taken from Timber Research and Development Advisory Council of Queensland (1990): **TRADAC W50 Manual**, Australia

#### A. *Roofing Batten to Rafter Connection*

**A.1 Load Area**

0.9 x 0.9 = 0.81 m².
3'0" x 3'0" = 9 sq.ft.




**A.2 Load or Force**

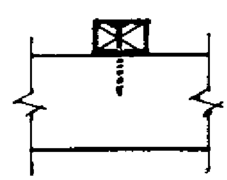
Class A Roof Load

| | | |
|---|---|---|
| 1.84 x 0.81 | = | 1.5 kN |
| 2.59 x 0.81 | = | 2.1 kN |
| 37.6 x 9 | = | 338 lbf |
| 53.5 x 9 | = | 482 lbf |

**A.3 Fixing Choices – Batten to Rafter**

*i. Screw fix*

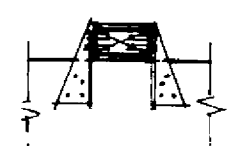
Strength 2.0 kN to 3.5 kN
(for timber grades F11 to F14).
Unseasoned timber 2.0 – 3.5 kN
Seasoned timber 1.4 – 2.5 kN.




*ii. Metal framing anchors*

2/metal framing anchors.
4/2.8 mm nails – each leg.

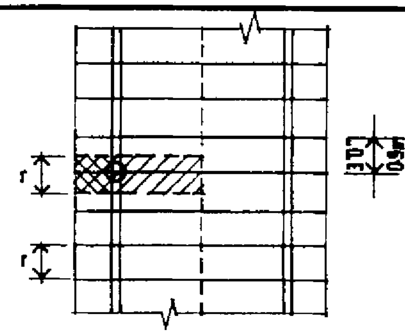
| | |
|---|---|
| Unseasoned timber | 2.5 to 4.0 kN. |
| Seasoned timber | 2.6 to 5.1 kN |



## B. *Rafter to Wall Top Plate*

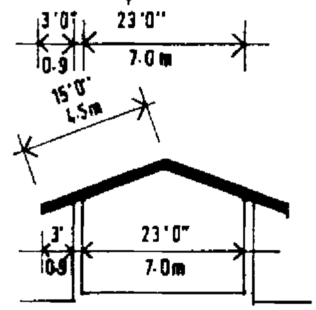
### B.1. Load Area

| | | |
|---|---|---|
| 44 x 0 9 | = | 3.96 $m^2$ |
| 14'6" x 3'0" | = | 43.5 sq.ft |




### B.2. Load or Force – Class B Structure

| | | |
|---|---|---|
| 1 6 kPa x 3.96 $m^2$ | = | 6 34 kN |
| 33.4 lbf/sq.f x 43 5 | = | 1,453 lbf |




### B.3. Fixing Choice

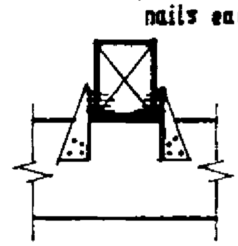
*i. Metal framing anchor*

4 Framing Anchors
4/2.8 mm nails each leg

Capacity – Max. 1820 lbs

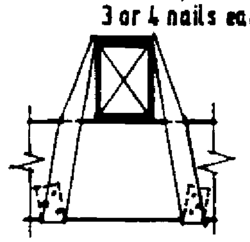
Capacity – Seasoned timber depending on timber quality — 4.7 to 7.5 kN

Capacity – Unseasoned timber depending on timber quality. — 4 7 to 9.3kN



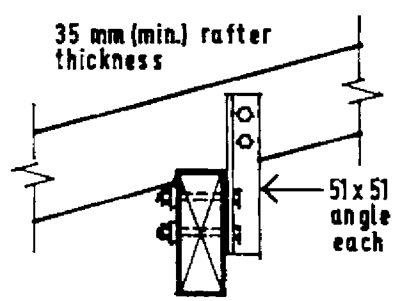

*ii. Metal cyclone strap*

One-strap 3/4 nails each end
Capacity – 7 2 kN




*iii. Steel angle and bolts*

50 x 50 x 5 MS angle with 2 x M10 bolts.
Capacity – Unseasoned timber 5.0 to 9 5 kN depending on timber quality.
Use better quality timber.



## C. *Top Plate to Foundation*

Vertical tie down bolts at 1.8 m or 6'0" cc.

### C.1 Load Area (Roof Uplift – Structure)

| | | |
|---|---|---|
| 1 8 x 4 4 | = | 7.92 $m^2$ |
| 6'0" x 14'6" | = | 87 sq.ft |

### C.2 Load or Force

Class B Structures

| | | |
|---|---|---|
| 1 6 kPa x 7.92 $m^2$ | = | 12 7 kN |
| 33 4 lbf/sq.ft x 87 sq ft | = | 2,906 lbf |

### C.3 Fixing Choices

*i. Half-Inch Tie-Down Bolt*

Capacity

| | | |
|---|---|---|
| One M12 Ø | = | 12 1 kN |
| One 1/2" Ø | = | 2,720 lbf |

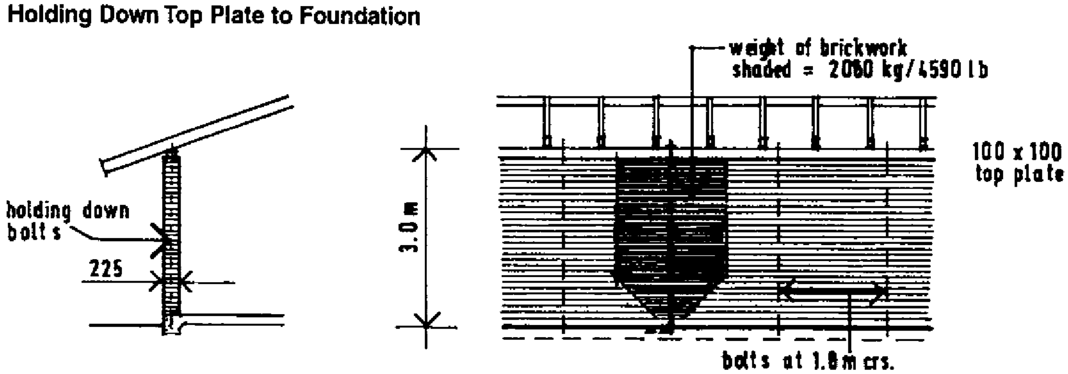
*ii. Five-Eighth Inch Bolt*

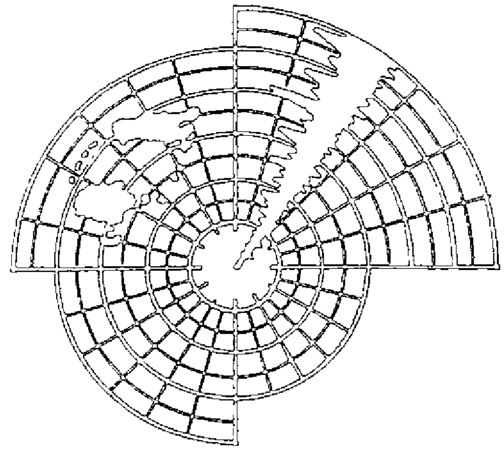
Capacity

| | | |
|---|---|---|
| One 16 Ø bolt | = | 22.6 kN |
| One 5/8" Ø bolt | = | 5,085 lbf |

Check size (depth) of top plate to support load between bolt supports (force above less dead load of roof) for span of 1.8 m and roof span of 4.4 m (suggest 100 x 100).

**Holding Down Top Plate to Foundation**





# 9 REPAIR AND REHABILITATION

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## 9.1 SOLVING THE PROBLEM

The problem of developing standard solutions and the details required to upgrade or maintain the integrity of an existing building is difficult because of the variety of shapes, designs, and construction techniques used in individual buildings.

Each case should be looked at independently and a solution worked out for that particular building.

The strong and weak points in each building need to be identified as the building construction methods used by different builders vary so much.

However, the following methods may be used as a guide when examining existing buildings which need upgrading.

The examiner must use his imagination when inspecting in order to identify quickly the global loads and the existing elements which can be tied together. Simple solutions are best. Simple lines of load transfer are preferred. A regular grid of support is better in appearance than scattered or haphazard supports

Try and get the support down to at least the floor to gain the advantage of the dead load or weight of the building. Do not forget that bracing can be provided by the existing wall and ceiling cladding in a lot of cases.

It is often possible to find solutions that are able to be carried out without vacating the building Even where basic structural integrity is not present it may be possible to superficially implant a structural system of load transferring elements into or onto the building to give it sufficient security. Each case should be examined individually as it is often possible to find creative solutions to the problem.

## 9.2 PRACTICAL SOLUTIONS

This section will provide sketches of construction details that offer practical solutions to the problem of the provision of resistance to cyclone forces.

It will be dealt with by dealing with the following elements.

- General methods of design.
- Wall construction and hold down methods.
- Roof framing and connections.
- Bracing and use of diaphragms
- Doors and windows.

It will also include case studies to illustrate where innovative, simple and economical methods were employed to save buildings from demolition or to extend their useful life.

As mentioned earlier, it is essential that the decision to demolish or rebuild is made by architects, engineers or building operatives experienced in the field.

The degree of partial demolition to provide access to enable strengthening procedures to be adopted is also an important decision where sound knowledge of construction and costing is needed

## 9.3 GENERAL METHODS OF DESIGN

The designer should be logical when designing for cyclones.

It is better to design a "framing system" to transfer loads from roof to foundation rather than simply allow construction to proceed on the "gravity system" where reliance on the dead load of the building materials is likened to the sticking together of many components to provide a link or chain of integrity (the "stitching" method).

Framing systems can consist of many varieties which may include.

- Pole construction where timber or concrete posts or poles are set deeply into the ground and cantilever up to the top plate level, (traditional Pacific Island method).

  **- Alternate**

- Brick walls bearing on concrete or stone foundations with bond beam at top of wall reinforced down to foundations at regular centres

  **- Traditional**

- Post and beam or portal frame construction in timber, concrete or steel with bracing walls of timber framing, brick or block

  **- Preferred**

  This system has been widely used for industrial and commercial work for many years and is, in the writer's opinion, the best and most economical method of providing the maximum security. A sketch of a simple system in timber frame is shown. The shape and pitch of roof may alter according to the designer's taste

All framing systems and all structures (including wall framing and roof framing) require to be braced in the plane of the wall or roof to set up a diaphragm action to resist racking forces.

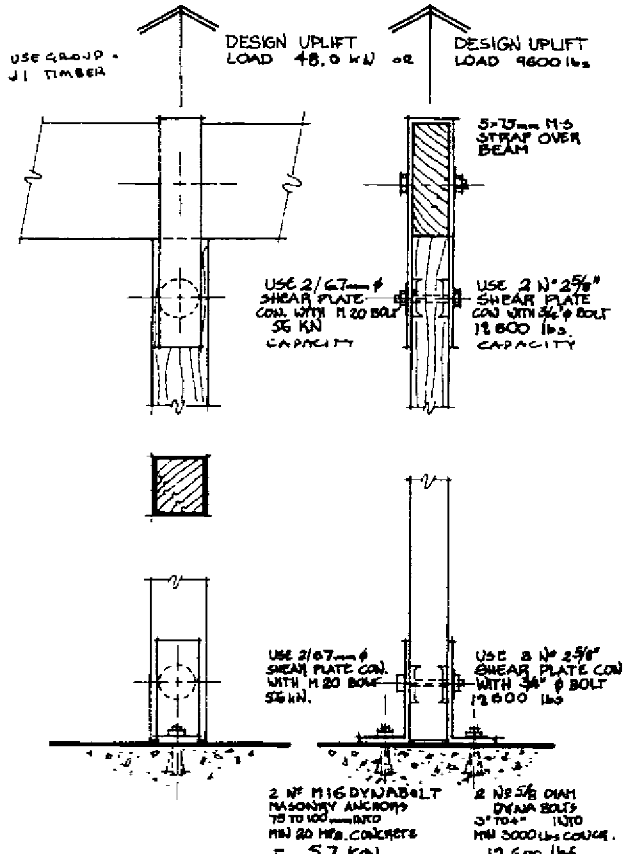
In addition, external walls need lateral support when spans along the length of the wall become too long for safety. These buttress type cross walls provide stiffness

All systems need vertical ties from the top to the bottom of all walls and therefore they need a continuous element at the top of the wall, a bond beam, ring beam, tie beam or top plate.

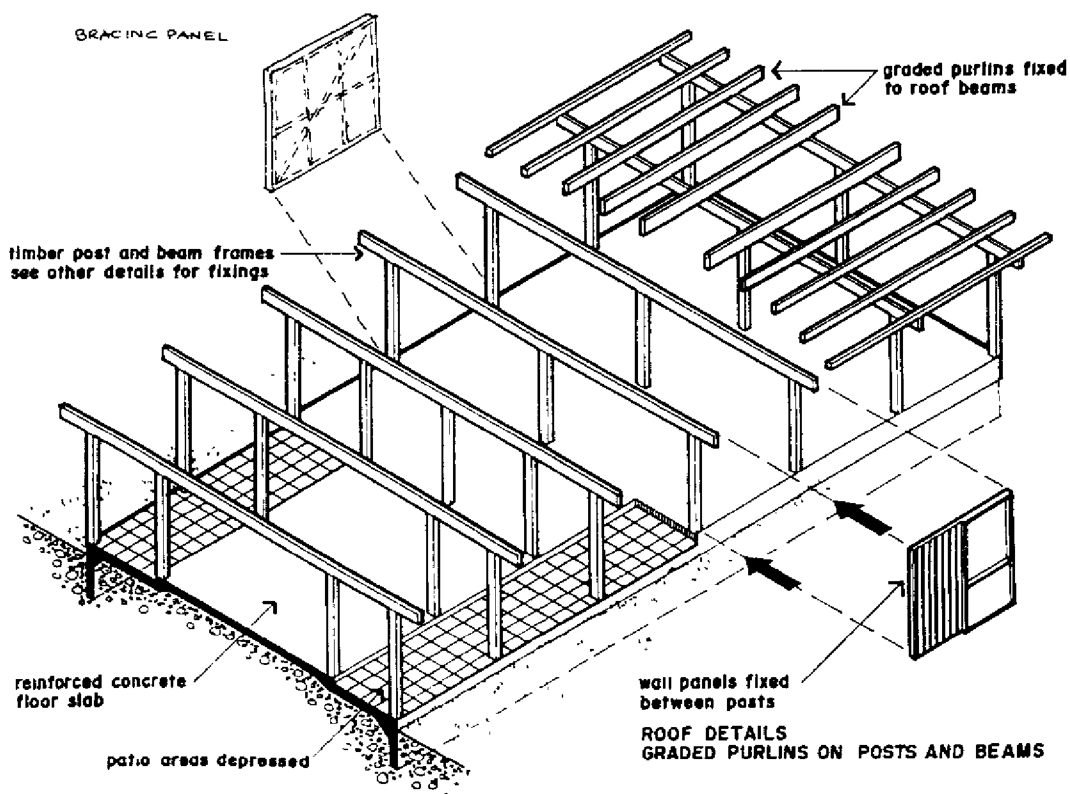
### 9.3.1 *Post & Beam*

The post and beam system has the advantage that there are fewer key joints or connections to inspect to ensure safety has been achieved than the case where the inspector has to examine practically every timber connection, in a stud wall for example, to ensure security of construction. Additional advantages are that the roof is pitched earlier than in conventional construction, offering shade during building, and a quicker completion

The strength in a simple timber post and beam design can be seen in the attached sketch where the post detail can transfer 57 kN or approximately 5.6 tonnes.




POST AND BEAM CONNECTIONS - FIXINGS.
(Can transfer 57 kN or approximately 5.6 tonnes)




ROOF DETAILS
GRADED PURLINS ON POSTS AND BEAMS

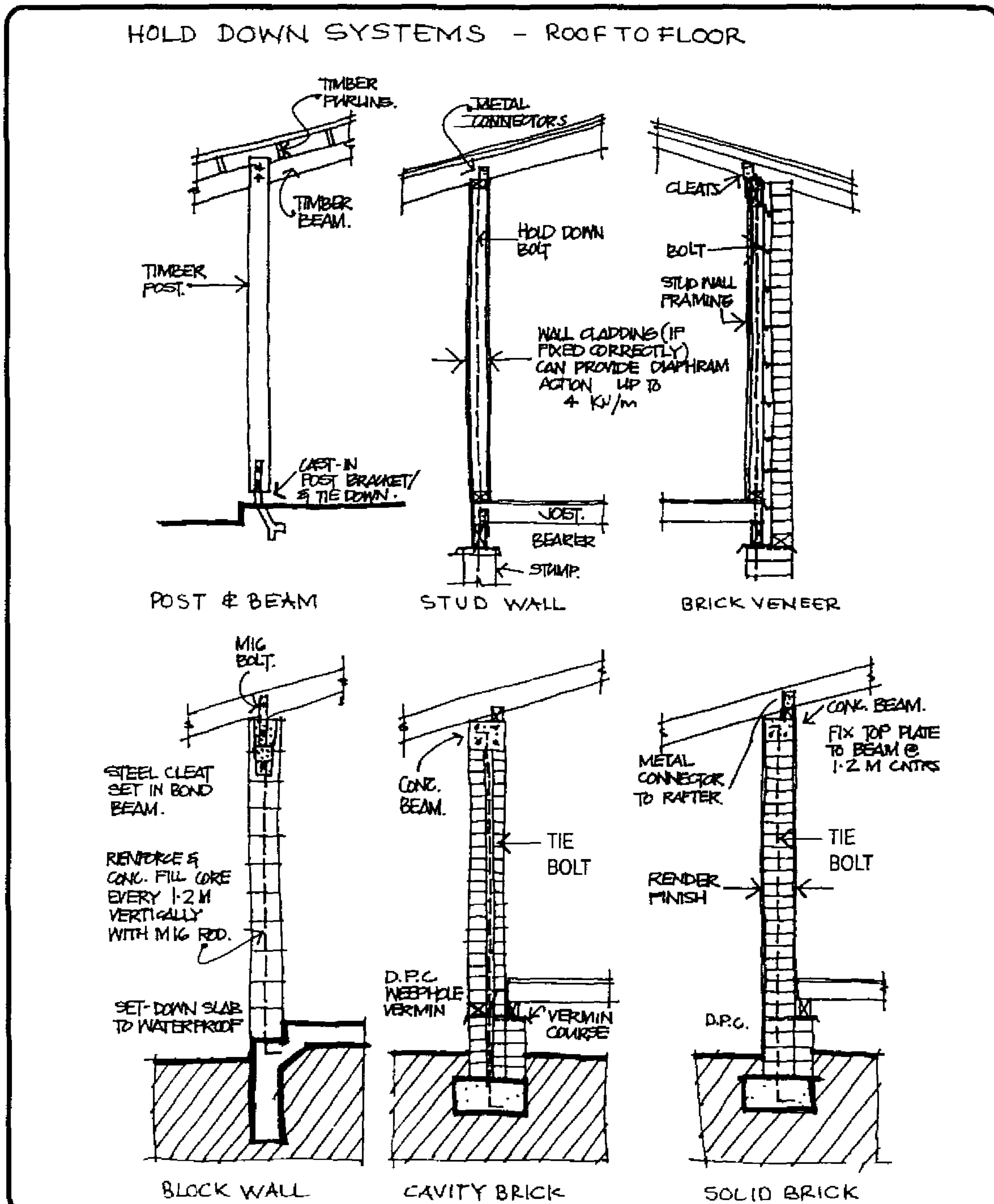
## 9 4 WALL CONSTRUCTION AND HOLD DOWN SYSTEMS

If existing buildings are selected for repair and rehabilitating, then weakness in wall construction requires upgrading by:

- Stiffening of wall where too thin for the length or height.
- Installation of bracing wall where walls are too long between supports.
- Installation of innovative "hold down" methods which transfer loads from roof plane to foundation such as the surface frame system

### 9.4.1 *Traditional Methods*

Traditional methods of holding down are illustrated hereunder



### 9.4.2 *Surface Frame System*

In existing buildings selected for rehabilitation it is often possible to surface mount structural frames to the external or internal walls to provide simple load transfer from roof frame level to foundation level.

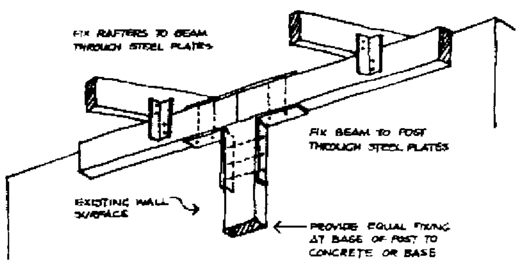
These systems need not detract from the aesthetic appearance and may even be seen as improvements

The following sketches show how a system can be applied to external walls.

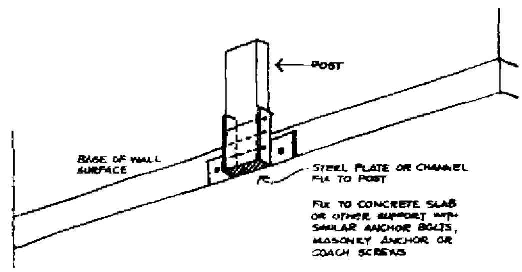
There is a need also to check if a frame system can be installed in corridors inside a building to provide tie down where the span between external walls is great.

External Walls

*FRAME BUILDING – USING TIMBER POST*



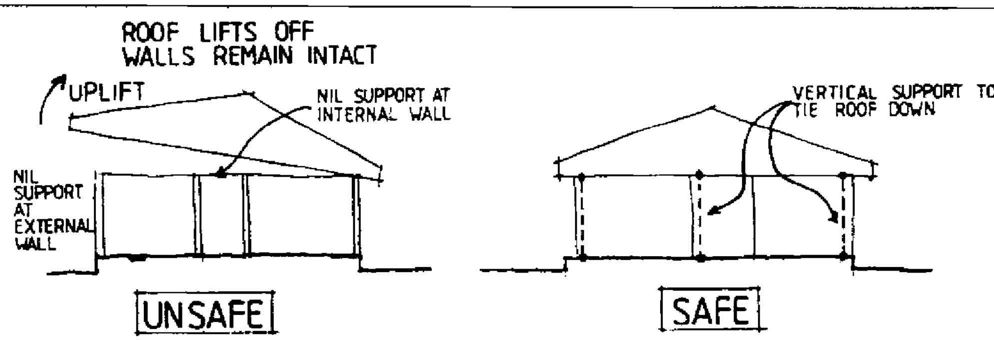

SURFACE MOUNTED POST & BEAM SYSTEM

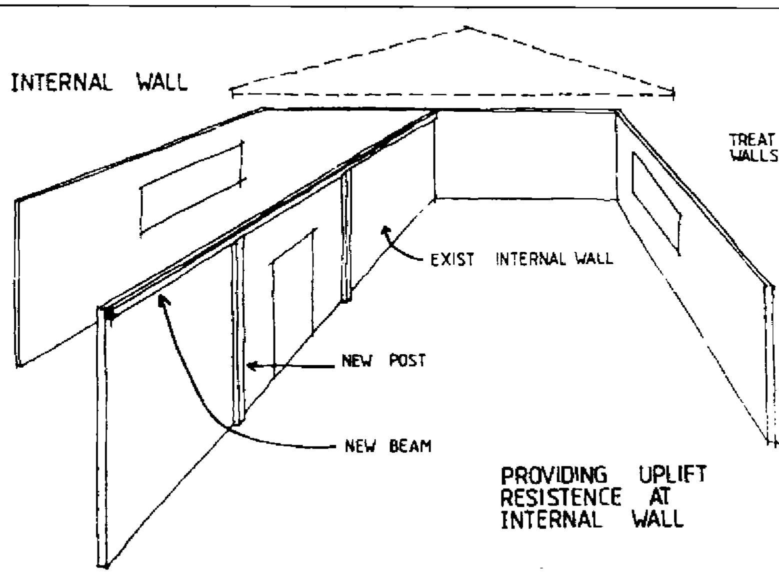



DETAIL AT BASE

## REINFORCEMENT DETAILS

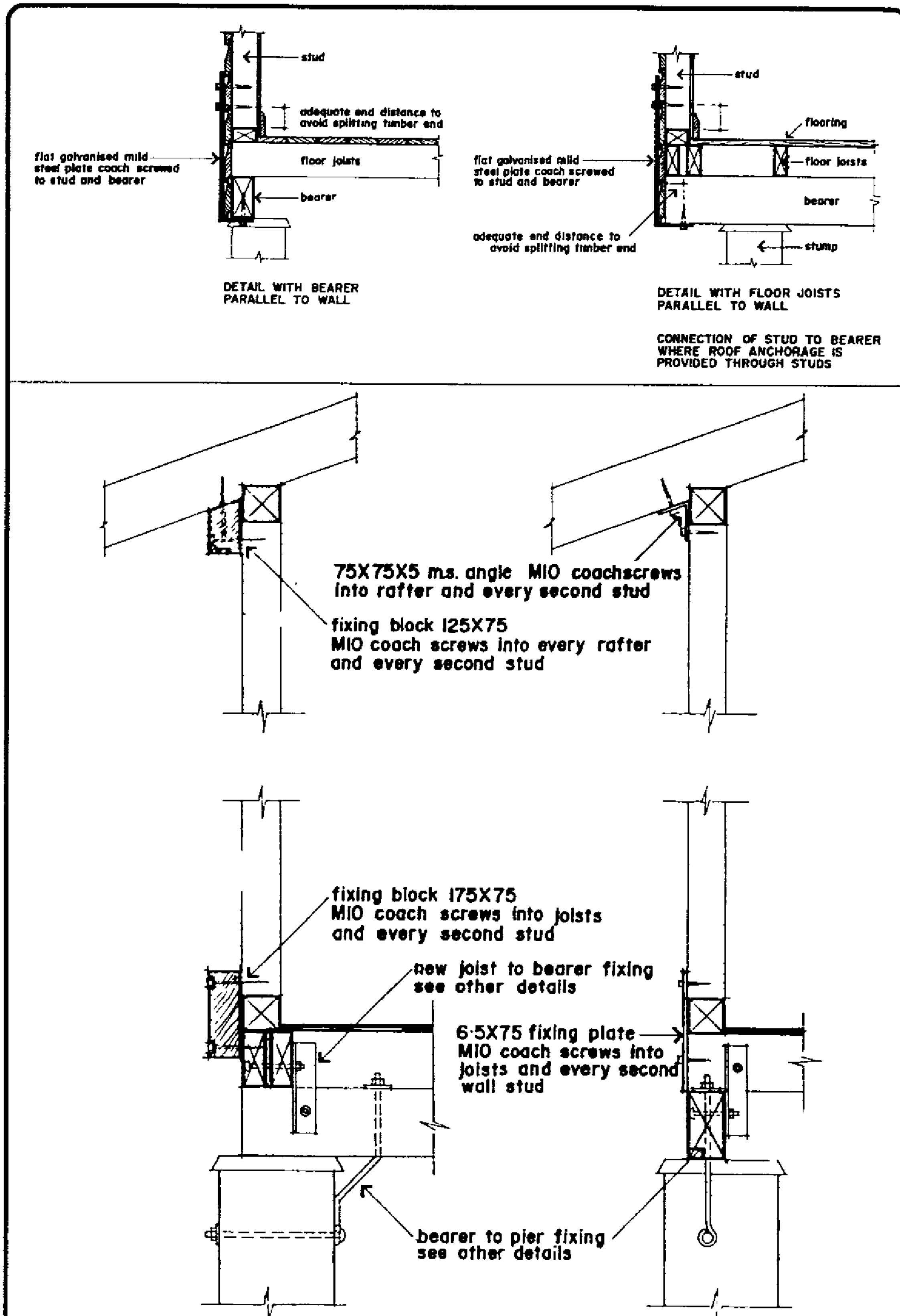
HOLD DOWN SYSTEMS
ROOF TO FLOOR



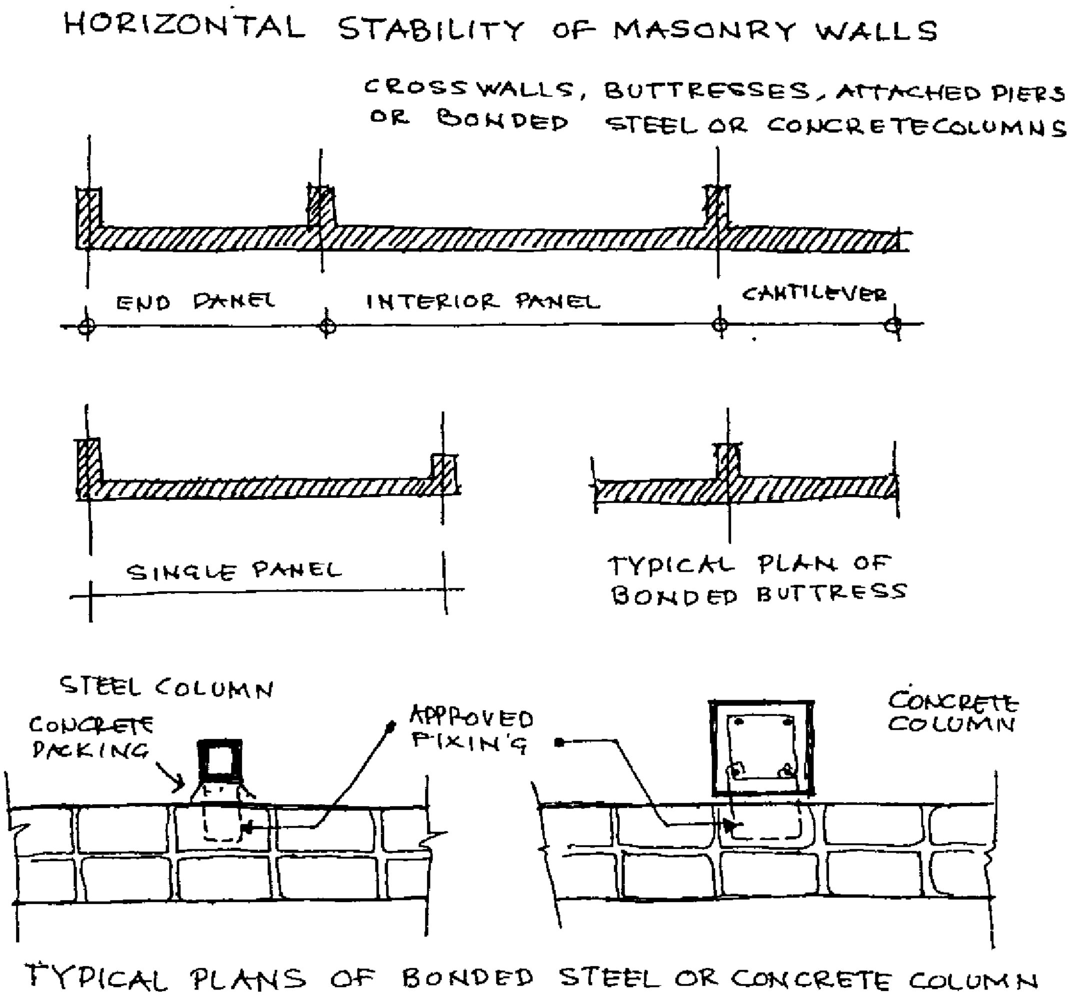

PROVIDING UPLIFT RESISTENCE AT INTERNAL WALL

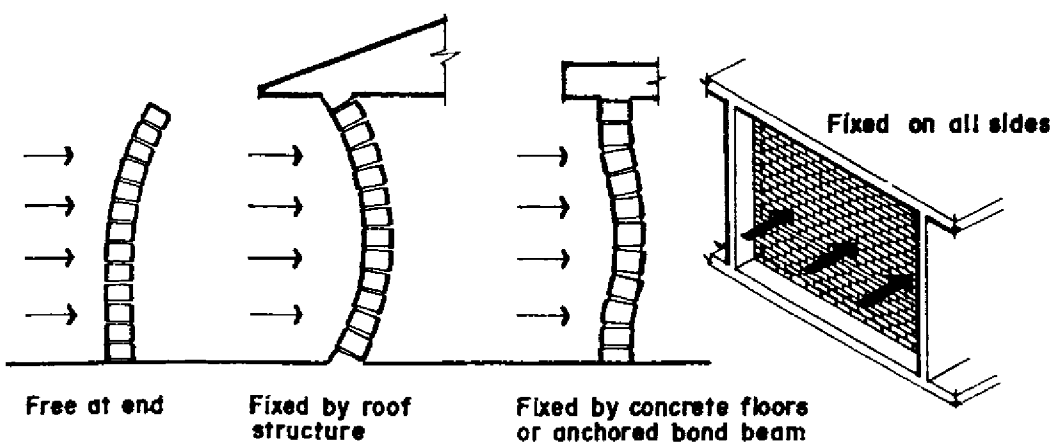
The spacing of the posts will depend on the load to be carried and the ability to find adequate fixings at the base to transfer the load.




RECTIFICATION TO EXISTING HOUSES TO PROVIDE HOLD-DOWN ANCHORAGE

*9.4.3* ***Masonry Walling***




ADVANTAGE OF FIXING AT TOP OF WALL, WITH ANCHORED BOND BEAM, AND AT CROSS-WALLS