IS 15498 (2004): Guidelines for Improving the Cyclonic Resistance of Low Rise Houses and Other Buildings/Structures [CED 57: Cyclone Resistant Structure]

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भारतीय मानक

कम ऊँचाई वाले आवास और अन्य भवनों/निर्माणों की चक्रवाती प्रतिरोधिता को बेहतर बनाने की मार्गदर्शिका

Indian Standard

GUIDELINES FOR IMPROVING THE CYCLONIC RESISTANCE OF LOW RISE HOUSES AND OTHER BUILDINGS/STRUCTURES

ICS 91.120.99

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

October 2004

Price Group 7

Cyclone Resistant Structures Sectional Committee, CED 57

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Cyclone Resistant Structures Sectional Committee had been approved by the Civil Engineering Division Council.

Cyclonic storms form far away from the sea coast and gradually reduce in speed as they approach the sea coast. Cyclonic storms generally extend up to about 60 km after striking the coast. Cyclones associated with high speed winds followed by heavy rains and accompanied by surge have been causing untold misery to the populace and wide spread devastation of properties in the coastal belts of India. The frequency of cyclonic storms is more along the east coast as compared to the west coast of India. The coastal regions of Tamil Nadu, Andhra Pradesh, Orissa and West Bengal on the east coast and Gujarat on the west coast are cyclone prone. Damage to houses is most responsible for loss of life and thus the need to have greater emphasis on the safety of houses. Due to this, need has been felt to evolve national standard for design and construction of cyclone resistant structures so as to ensure desirable level of safety. The provisions given in this standard are intended to reduce the damage to buildings and structures in the event of a cyclone.

This standard covers the guidelines regarding planning, design and construction aspects for improving the cyclonic resistance of low rise houses and other buildings/structures.

The composition of the Committee responsible for formulation of this standard is given in Annex B.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

GUIDELINES FOR IMPROVING THE CYCLONIC RESISTANCE OF LOW RISE HOUSES AND OTHER BUILDINGS/STRUCTURES

1 SCOPE

This standard covers the guidelines regarding planning, design and construction aspects for improving the cyclonic resistance of low rise houses and other buildings/structures.

2 REFERENCES

The standards listed in Annex A contain provisions, which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards as given in Annex A.

3 CYCLONIC WIND FIELD

3.1 Cyclones are vortices in the atmosphere having a core called the eye of extreme low pressure and light winds, surrounded by strong winds having nearly circular contours of equal pressure called isobars. The circulatory system is in the anti-clockwise direction in the northern hemisphere. The radial distance from the centre of the eye to the region where the maximum tangential wind velocity occurs is called the radius of maximum winds (RMW). The wind speed falls off gradually beyond this region and the approximate wind velocity distribution is given by:

$$V(r) = V_o \left(\frac{r_o}{r}\right)^{\alpha}$$

where

$V(r)$ = velocity of wind at a radial distance, r ;

r_o = radius of maximum wind (RMW);

V_o = velocity of maximum wind; and

α = a power law exponent varying between 0.4 to 0.6.

NOTE — r and r_o are to be measured from the centre of the eye of the storm.

3.2 In the interior region to the radius of maximum wind the velocity distribution may be assumed as linear varying from zero at centre of eye.

4 CYCLONIC WIND SPEED FOR DESIGN OF BUILDINGS AND STRUCTURES

It is known that higher wind speed occurs during cyclones compared to non-cyclonic storms. Further, there is a greater degree of turbulence in such storms and the probability of occurrence during the life time of a structure is also large. Therefore, structures are subjected to greater risk under cyclonic storms. To account for the enhanced risk, an enhancement factor 'f', whose value is equal to unity for dwellings, 1.15 for industrial buildings, and 1.30 for structures of post-cyclone importance shall be considered while determining the design wind speed. The design wind speed V_d at any height z in m/s shall be taken as:

$$V_d = f\, k_1\, k_2\, k_3\, V_b$$

where

f = enhancement factor for cyclonic risk;

k_1 = probability factor (risk coefficient);

k_2 = terrain, height and structure size factor;

k_3 = topography factor;

V_b = basic wind speed; and

z = a height or distance above the ground.

The values of k_1, k_2, k_3, and V_b shall be as specified in IS 875 (Part 3).

NOTE — In the design of special structures, such as, chimneys, overhead transmission line towers, etc, specific requirements as specified in the respective Codes may be followed.

5 PRESSURES AND FORCES

5.1 The pressures and forces, both global and local, shall be computed using the coefficients given in IS 875 (Part 3) for various types of buildings and structures.

5.2 Unless measures have been taken to ensure that doors and windows would stay in position during a storm, failure of the closing element over the largest opening shall be considered for computing the percentage opening (permeability) in addition to any fully vented openings.

6 GUIDELINES FOR PLANNING

Though the cyclonic storms always approach from the direction of the sea towards the coast, the wind velocity and direction relative to a building remain random. Hence, reduction coefficients for directionality and orientation of buildings in a preferential direction are not feasible. The general guidelines on planning include:

a) As far as possible, the building shall be founded on good ground. Part of the building on good ground and partly on made up ground shall be avoided [*see* Fig. 1 (a)].

b) Regular plan shapes are preferred. Re-entrant corners are to be avoided [*see* Fig. 1 (b)].

c) For individual buildings, a circular or polygonal plan is preferred over rectangular or square plans but from the view point of functional efficiency, often a rectangular plan is commonly used. Where most prevalent wind direction is known, a building should be so oriented, where feasible, that its smallest facade faces the wind.

d) A symmetrical building with a compact plan-form is more stable than an asymmetrical building with a zig-zag plan, having empty pockets as the latter is more prone to wind/cyclone related damage [*see* Fig. 1 (c)].

e) In case of construction of group of buildings with a row type or cluster arrangement, cluster arrangement can be followed in preference to row type. However, in certain cases, both may give rise to adverse wind pressure due to tunnel action and studies need to be conducted to look into this aspect [*see* Fig. 1 (d)].

f) Long walls having length in excess of 3.5 m shall be provided with cross walls or integrated pilasters [*see* Fig. 1 (e)].

g) Buildings are not to be located in low-lying areas as cyclones are invariably associated with floods.

h) In hilly regions, construction along ridges should be avoided since they experience an accentuation of wind velocity whereas valleys experience lower speeds in general [*see* Fig. 1 (f)].

j) Except in case of buildings with large span with sloped roofs, roof pitches having a slope less than 1 in 3 shall be avoided [*see* Fig. 2 (a)].

k) Hipped roofs are preferred to gabled roofs for non-engineered and semi-engineered buildings as the peak suction pressures for all angles of attack are lower in the former case, and may be taken as 80 percent of those on pitched gabled roof in the absence of more detailed information [*see* Fig. 2 (b)].

m) The percent of the total opening in the cross-section of the frontal wall shall be less than 50 percent of the width of the wall. Opening in load bearing walls should not be within a distance of $h/6$ from the inner corner for the purpose of providing lateral support to cross walls, where h is the storey height up to eave level [*see* Fig. 2 (c)].

n) While planning a lay-out for group housing, if the inter-building spacing is less than twice the width of the building considerable shielding is available for the interior buildings though the first two columns/rows attract larger forces compared to a stand alone building.

p) In regions where storm surges lead to coastal inundation, buildings should be located at higher ground levels. If high ground is not available buildings may be constructed at raised earthen mounds suitably surrounded by retaining walls. Alternatively, buildings may be constructed with stilts with no masonry up to maximum surge level. Suitable bracings may, however, be provided in case of multiple hazard zones, particularly due to earthquake, to avoid failures arising out of large variations in stiffness between stilt and higher floor levels.

7 GUIDELINES FOR NON-ENGINEERED CONSTRUCTION

All construction though using the conventional building materials but made intuitively without carrying out a proper structural design and or constructed without adequate control at site, with respect to both materials used and construction practices employed, may generally be termed as non-engineered construction. All construction in low strength masonry or clay mud and similar other forms of biomass with fall under the category of non-engineered construction. The measures suggested

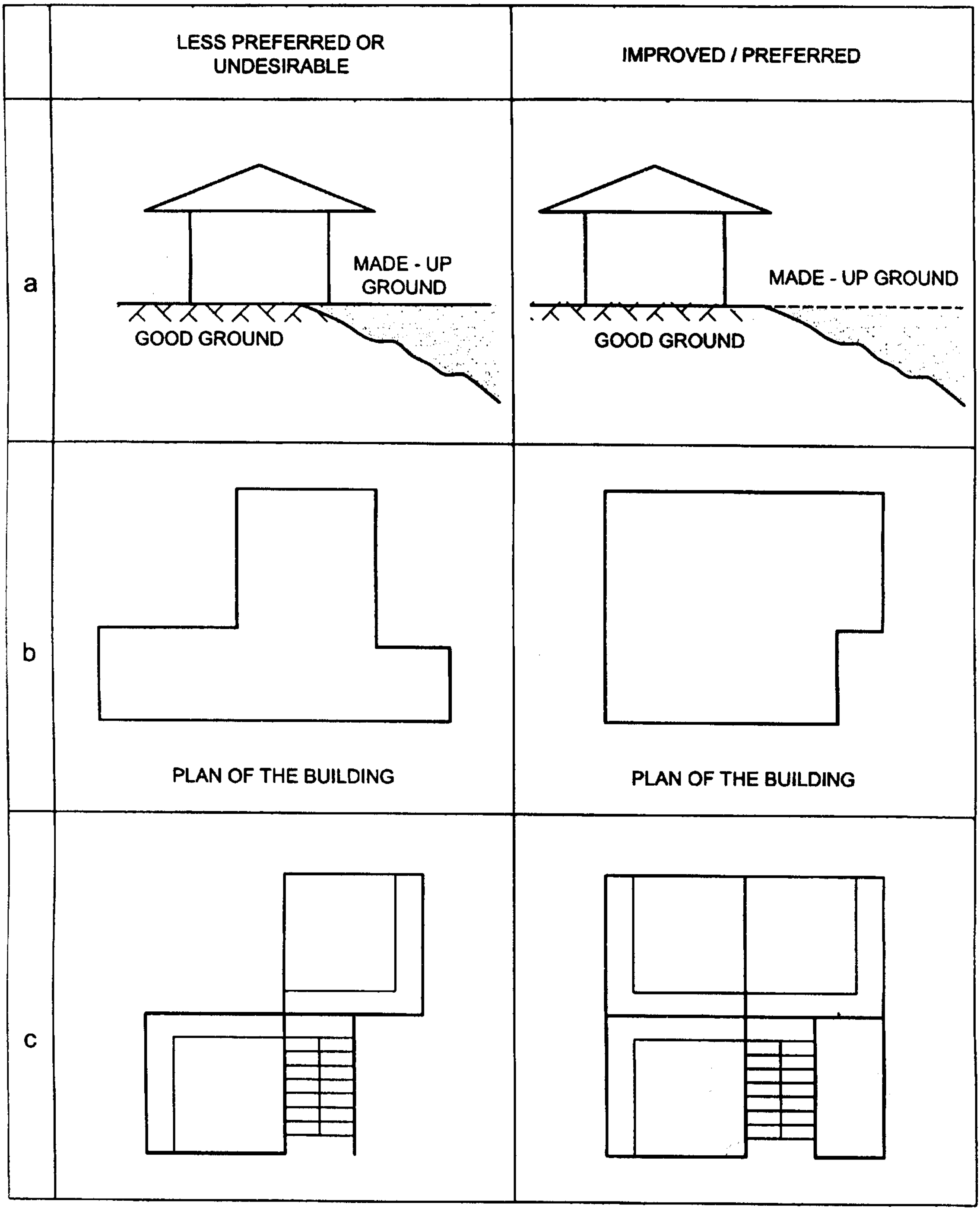


FIG. 1 IMPROVEMENTS FOR BUILDING LAYOUTS TO REDUCE DAMAGES DUE TO CYCLONES (*Continued*)

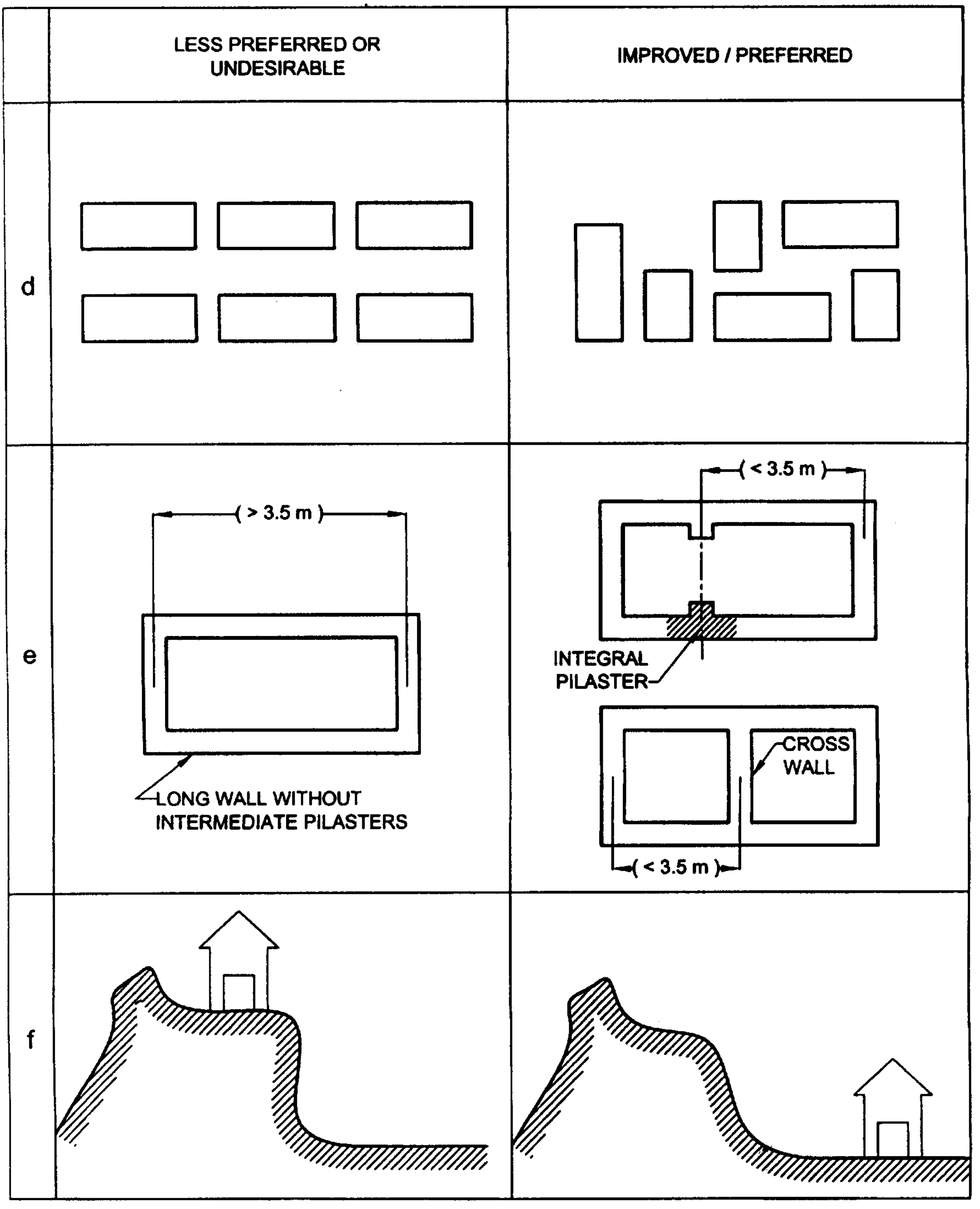


FIG. 1 IMPROVEMENTS FOR BUILDING LAYOUTS TO REDUCE DAMAGES DUE TO CYCLONES

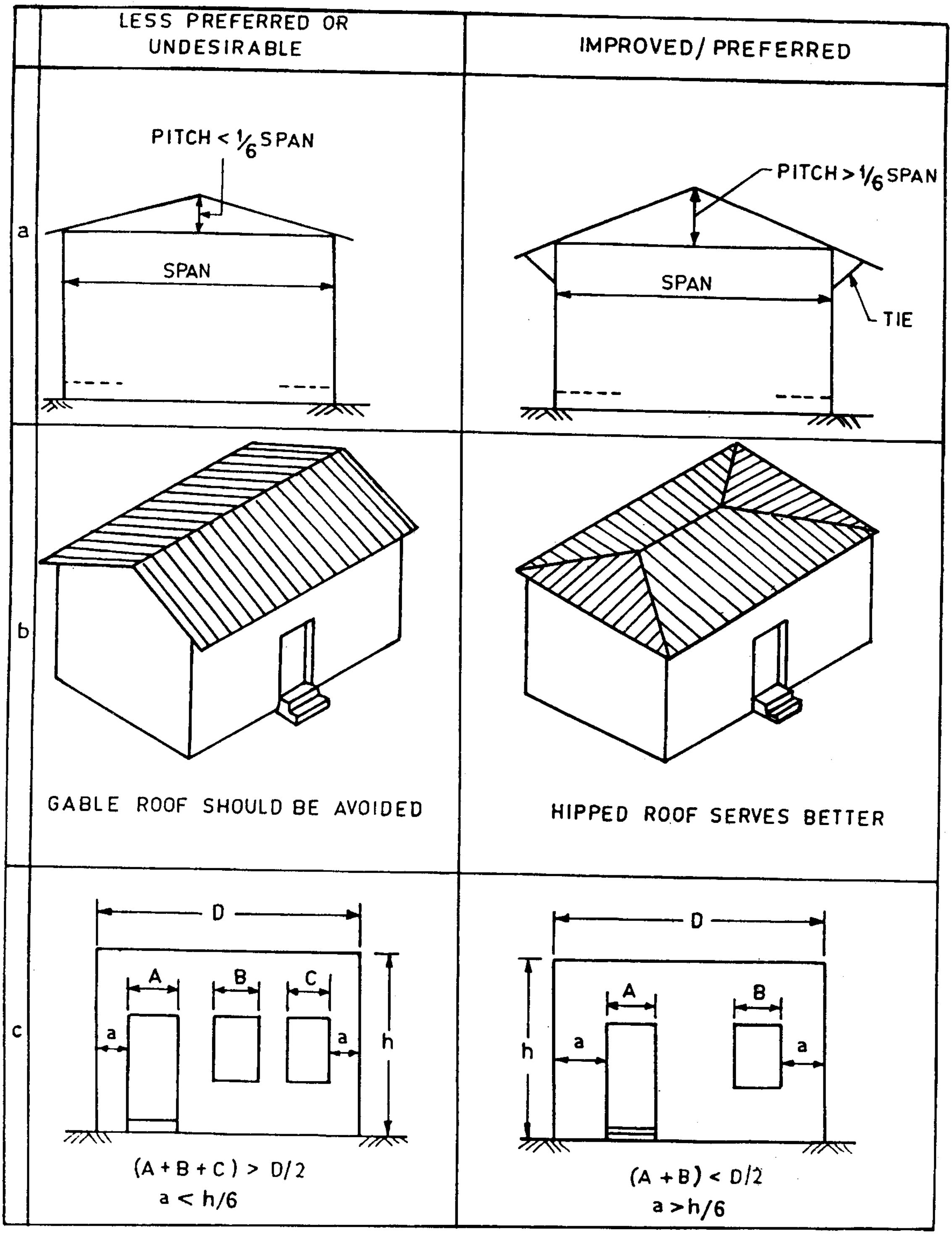


FIG. 2 IMPROVEMENTS FOR ROOFS AND WALLS OF BUILDINGS TO REDUCE DAMAGES DUE TO CYCLONES

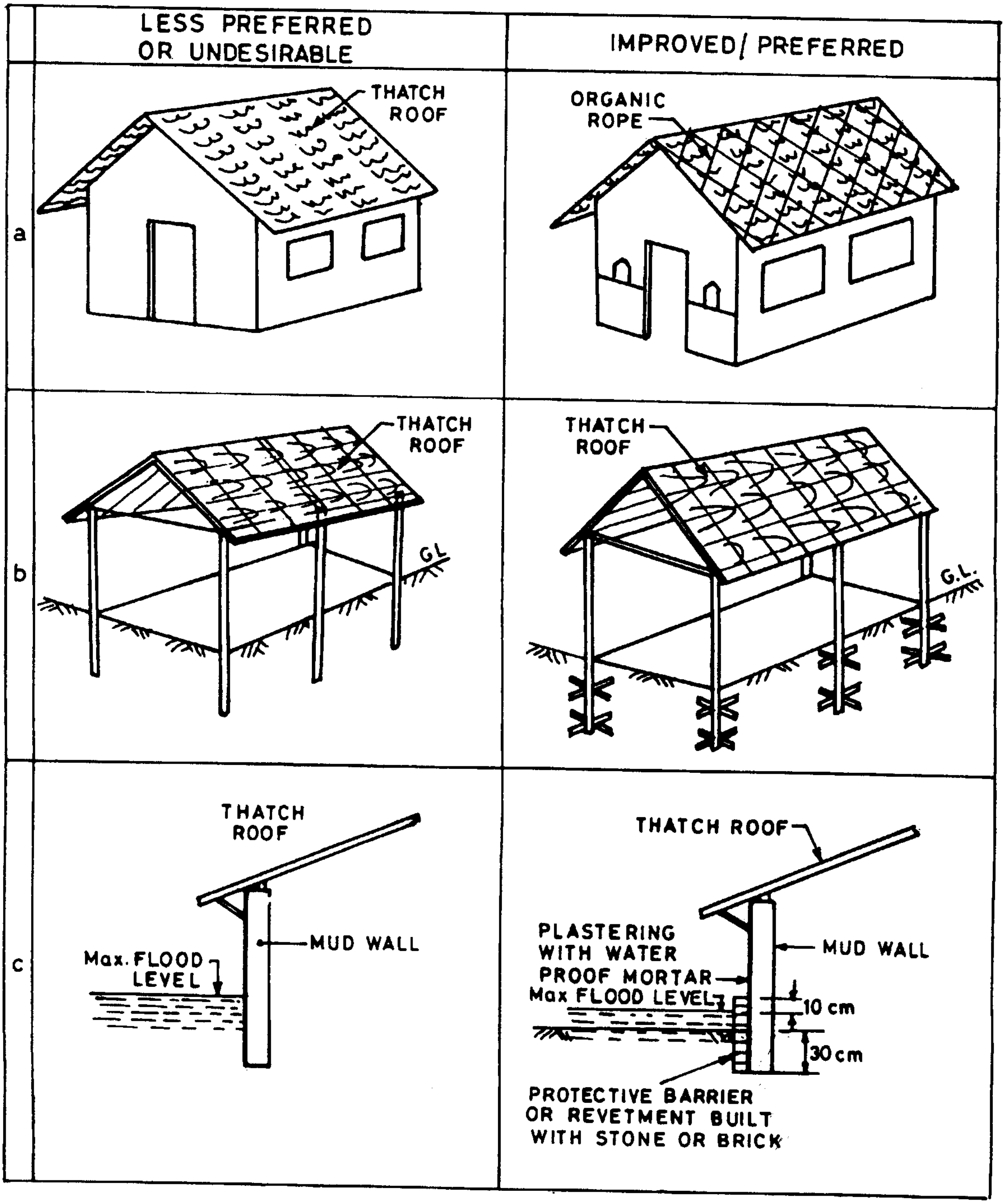


FIG. 3 IMPROVEMENTS FOR THATCHED ROOFS AND MUD WALLS TO REDUCE DAMAGES DUE TO CYCLONES

here-in enhance the cyclonic wind resistance to significantly higher levels, but still lower than semi-engineered and engineered buildings covered in **8** and **9**.

a) The aerodynamics of flow around buildings, leads to large suction pressures on the roof. To reduce problems due to flying-off of thatched roof, it may be held down to the frame work of the roof or the building envelope using organic ropes. As organic ropes have short life, the holding down ropes alone may be changed every year prior to the most probable month of occurrence of cyclones. Diagonal pattern of rope is preferred [*see* Fig. 3 (a)].
b) The overhang of the roof beyond the wall shall be limited to 450 mm. In case it exceeds this value, the projected portion of the roof may be properly tied back to the wall framework.
c) All the posts buried below ground level shall be painted with a coat of coal tar up to the level of maximum flood discharge.
d) The main posts shall be firmly anchored to the ground using suitable anchor poles. The minimum depth of anchorage for the main posts shall be 900 mm and the minimum length of anchorage bars shall be 450 mm with a minimum bearing area of 22 500 mm^2. Each post shall have four anchor poles, as shown in Fig. 3 (b) at two levels at least at 500 mm interval in different directions.
e) As mud wall is erodable, protection barrier or revetment built with stone or brick shall be built up to the maximum flood level, and plastering with special water proof clay or cement/lime mortar on outer surface is essential [*see* Fig. 3 (c)].
f) In case of sloped roof, triangular frames as shown in Fig. 4 may be located with a maximum spacing of 2.0 m. The members of this triangular frame shall be sufficiently strong to hold back the cross runners. Suitable connections shall be ensured between various elements of this frame using metal straps, bolt and nuts, and steel flats to enable better integrity for the structure as a whole (*see* Fig. 5 and Fig. 6).
g) The main triangular frames are to be firmly connected to anchorage elements/bond beams at the level of the eaves. The anchorage elements in turn are to be connected to the main posts of the wall using U bolts.
h) Brick work in weak mortars and random rubble masonry can be used for the walls. In these cases, the bond beam/anchorage beam provided on top shall be anchored to the foundation using mild steel rod properly encased in cement mortar. Alternatively if continuous lintel is provided with reinforced concrete or wood with sufficient height of brickwork/rubble masonry, the roof can be anchored to the continuous lintel. The total downward load due to weight of masonry and roof shall have a factor of 1.50 over the total uplift force on roof. The total area of anchorage reinforcement provided shall be twice that required for transmitting the uplift force.
j) Discrete anchorage of roof into brick/rubble masonry can be accomplished through anchorage reinforcement. An angle of dispersion of two verticals to one horizontal may be assumed. The shear strength of masonry shall be neglected in any computation, and the effective weight of masonry above shall be 1.5 times the uplift force at the given anchorage based on simplified load-flow pattern.

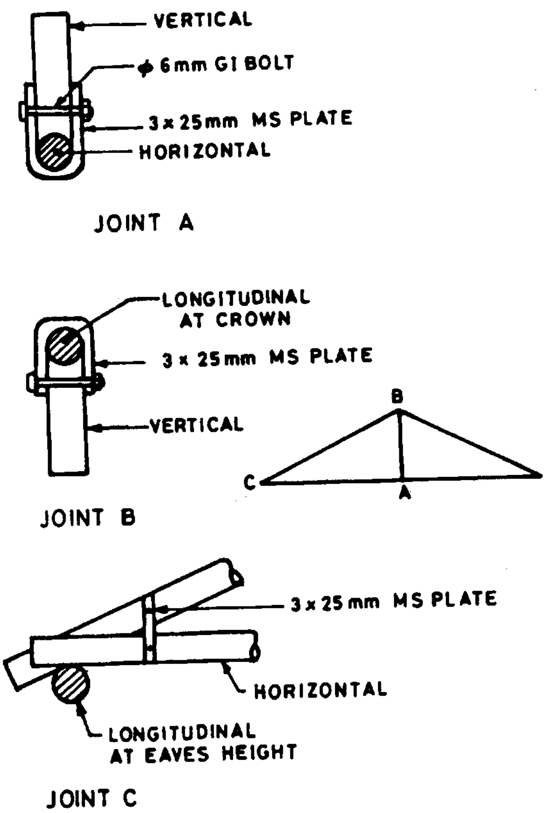


FIG. 4 TYPICAL JOINT DETAILS

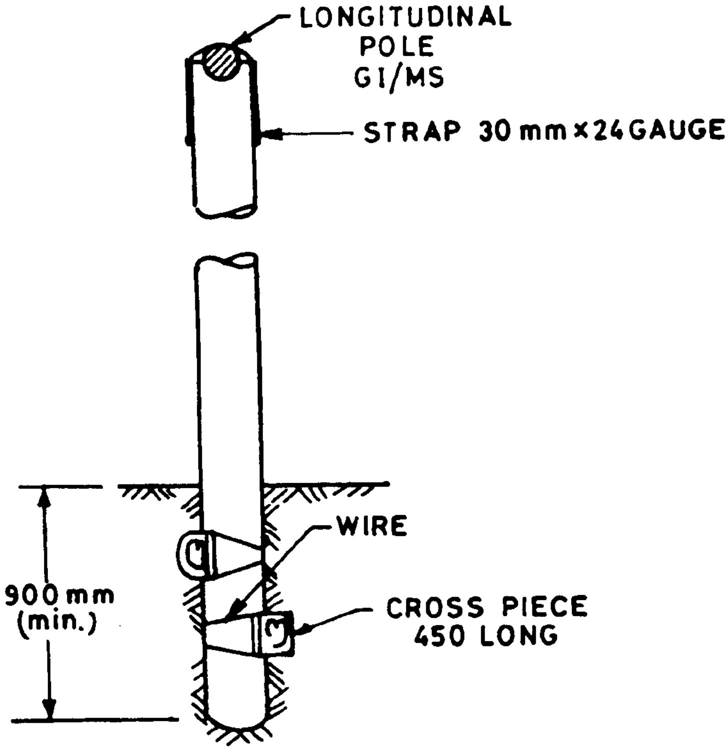


FIG. 5 ANCHORAGE TO FOUNDATIONS IN THATCHED BUILDINGS

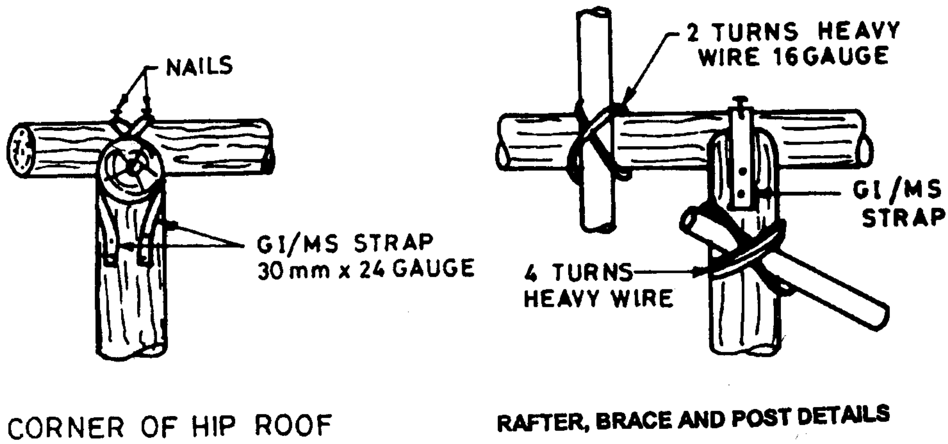


FIG. 6 CONNECTIONS USING WIRES AND STRAPS IN THATCHED BUILDINGS

8 GUIDELINES FOR SEMI-ENGINEERED CONSTRUCTION

Semi-engineered buildings are buildings which have certain elements structurally designed, such as, roof slabs and foundations but certain elements not properly designed such as walls of masonry buildings and in which the supervision may be through Engineering staff or otherwise. The following guidelines are useful in detailing semi-engineered buildings:

a) To achieve a certain measure of restraint for tiled roofs provide concrete or masonry restraining bands at a spacing of approximately 1.2 m to 1.5 m. These bands may preferably be located over wooden rafters forming integral part of the truss system. In case the bands are connected to the purlins U bolts may be used and suitably anchored over the reinforcing rod. The dimension of the band may be about 100 mm × 50 mm. The restraining bands shall have at least one

10 mm diameter bar placed inside the band. Typical details of improvements to tiled roof are given in Fig. 7. Hip, valley and ridge tiles shall be firmly embedded in continuous band of cement mortar. If nailing holes are available in these tiles, nails can be inserted through these into the mortar bed and these can effectively serve as shear connectors.

b) The tiled roof system shall be securely fixed to a bond beam. The bond beam in turn is to be connected to the foundation by holding down bolts. The holding down bolt shall be designed with a factor of safety of 2.0.

c) Wherever asbestos sheets are used for roof cladding, U bolts are preferred when compared to J bolts. The numbers of U bolts at various locations are indicated in Fig. 8.

d) In case hollow concrete block masonry is used for walls the designed reinforcements can be taken through the hollow concrete block forming a pilaster with reinforcement as shown in Fig. 9. The spacing of such pilasters shall not be greater than 3.0 m. The reinforcements are to be anchored well into the foundation and integrated with lintel band and bond beam (*see* Fig. 10).

e) Good connections are required among the various wooden elements in the roof and wall. Typical details shown in Fig. 11 and Fig. 12 may be adopted with modifications to suit the structural scheme. The important requirement is that the uplift force on the roof is to be safely transmitted to the foundation. The connections must have adequate strength to transfer the uplift force.

f) If strong wall made of good quality brick work is provided, the roof can be anchored to the continuous lintel band through cyclone bolts.

9 GUIDELINES FOR ENGINEERED CONSTRUCTION

Engineered buildings are buildings designed by Architects and/or Engineers and properly supervised by Engineering staff during construction, such as, reinforced concrete and steel framed buildings. Public buildings, such as, schools and hospitals, cyclone shelters, etc, have to be carefully engineered.

In a cluster of buildings having similar heights and where the inter building spacing is less than 2 times the width of an individual building the following enhancement/shielding factors are to be considered:

a) For corner buildings located on the periphery of the building clusters, the pressure loadings shall be enhanced by a factor of 1.50.

b) For all interior buildings a shielding factor of 0.80 can be considered.

c) The roof pressures on corner buildings of the outer rows shall be enhanced by a factor of 1.50 in industrial sheds.

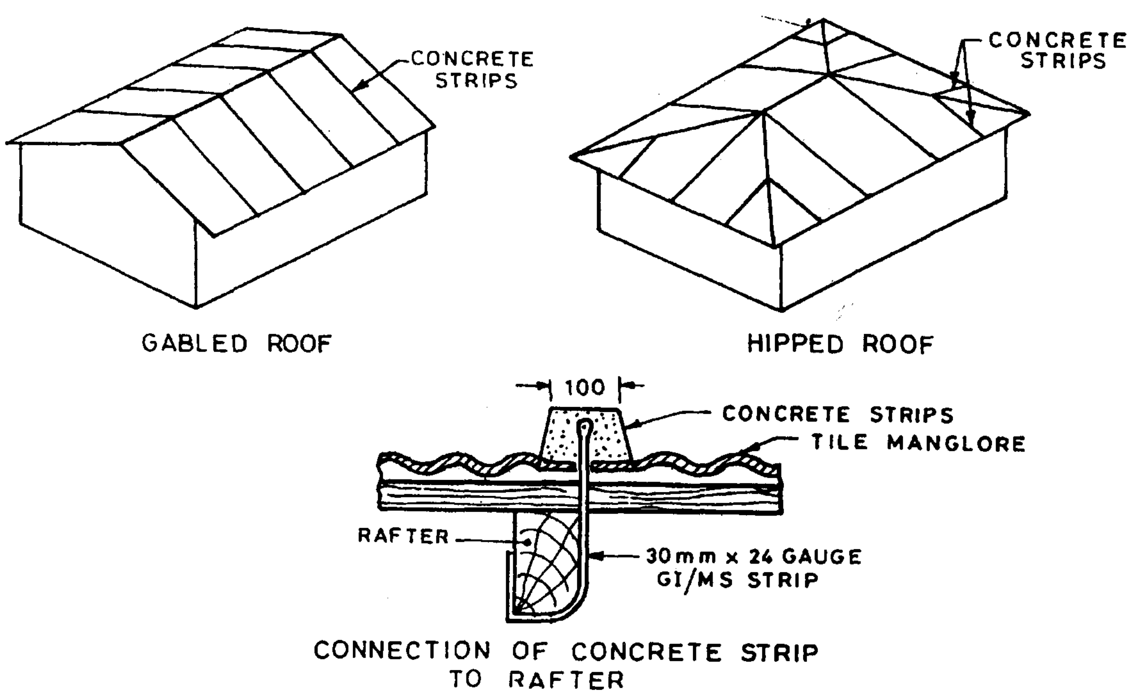
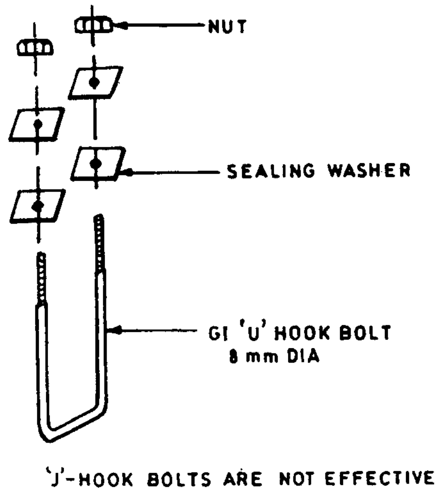
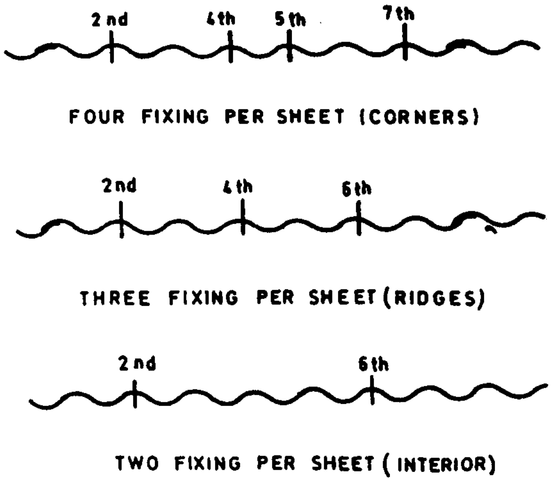


FIG. 7 IMPROVEMENTS TO TILED/AC SHEETS ROOF TO REDUCE DAMAGES DUE TO CYCLONES

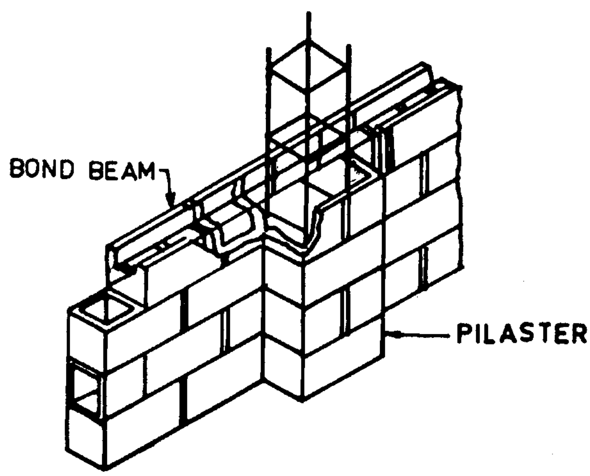


U-HOOK BOLTS AND WASHER ASSEMBLY ARE RECOMMENDED



LOCATION OF HOOK BOLTS

FIG. 8 DETAILS OF BOLTS



REINFORCED CONCRETE MASONRY PILASTER WITH CONTINUOUS BOND BEAM

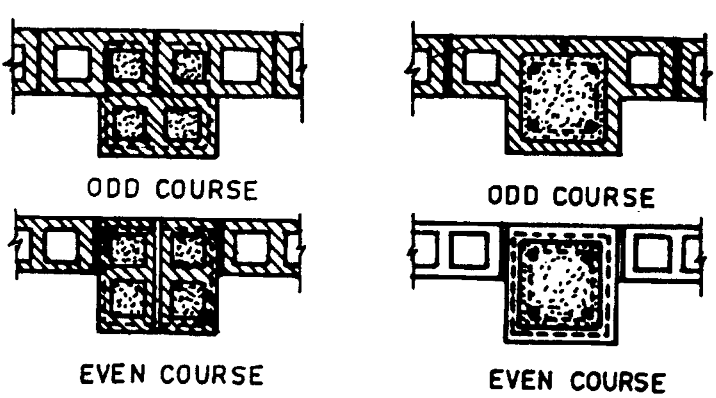


FIG. 9 CONSTRUCTION OF CONCRETE BLOCK MASONRY

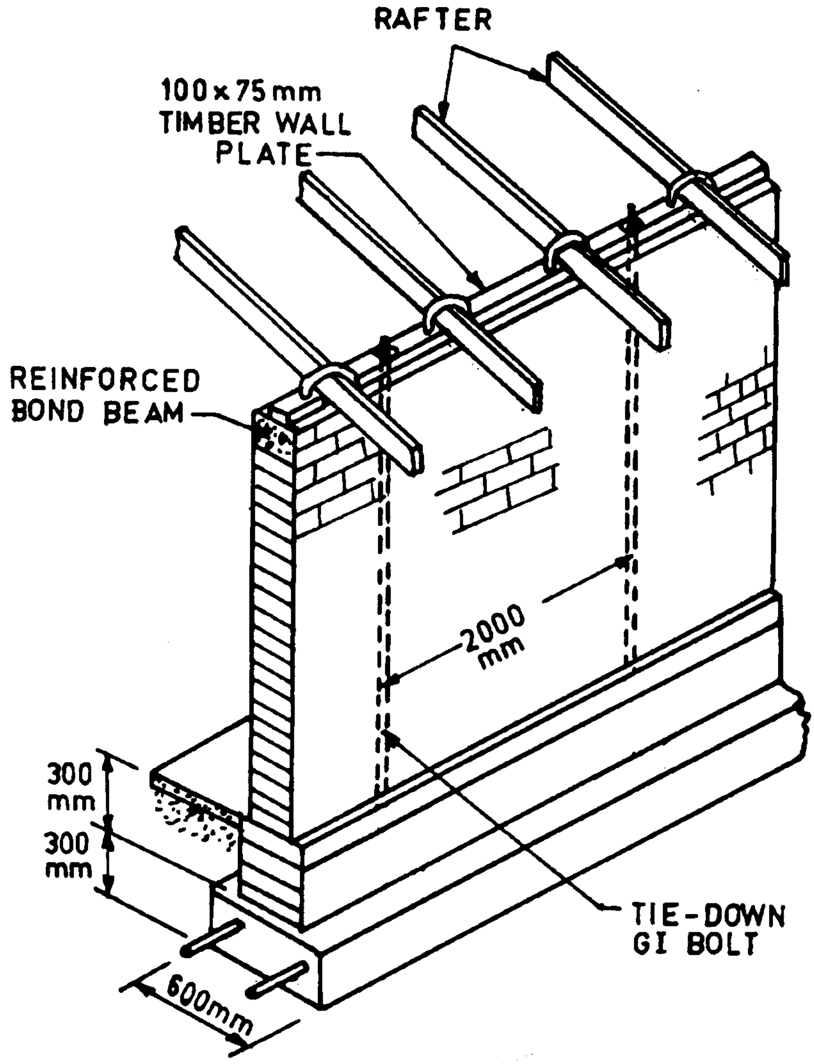


FIG. 10 FIXING OF WALLS TO THE FOUNDATION USING TIE-DOWN BOLT

d) For evaluating the roof pressures on interior buildings, a shielding factor of 0.80 can be considered for gabled roofs.
e) In all buildings where wind loading is the dominant loading no increase in allowable stresses in steel over and above that specified in IS 800 is permitted.
f) In all buildings where load bearing masonry is used a parapet of minimum height 600 mm may be provided. Also the roof slab may be anchored to the continuous lintel through adequate ties.
g) In multi-hazard prone areas with earthquake zones III and above, even if the design forces are governed by wind loading, ductile detailing provisions as given in IS 13920 shall be followed. The design forces would however be computed based on wind loading in such cases.
h) In flood prone areas all public buildings including cyclone shelters shall be constructed on raised ground with appropriate peripheral retaining walls.
j) If buildings are constructed with openings at the ground level/stilted buildings, adequate symmetric shear walls shall be provided in both the principal directions of buildings. This is absolutely essential in multi-hazard prone areas for earthquake regions with zone-III and above.
k) Wherever feasible, without compromising functionality, the corners of the buildings shall be rounded off with suitable radius of curvature so as to reduce the drag forces.

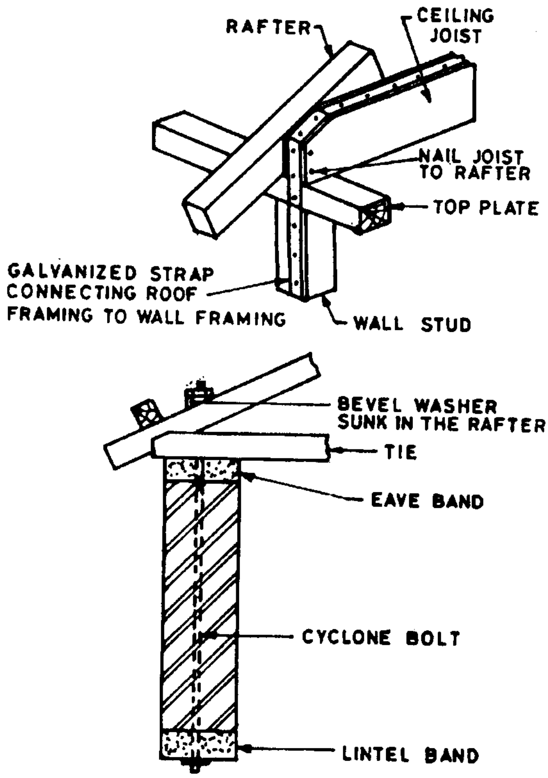


FIG. 11 CONNECTION OF ROOF FRAME TO WALL FRAME

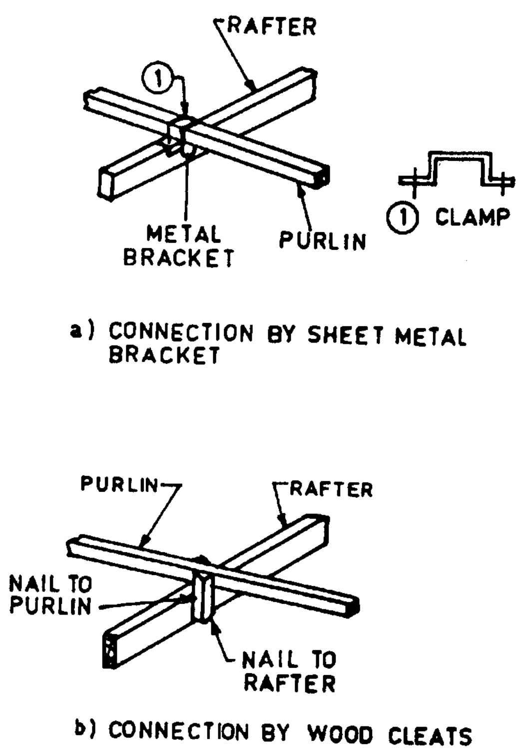


FIG. 12 CONNECTION DETAILS BETWEEN PURLIN AND RAFTER

m) In industrial buildings with gable roof plan bracing shall invariably be provided at the bottom chord level of trusses to avoid bottom chord buckling due to uplift force as well as to distribute the horizontal loading from gable ends (*see* Fig. 13). Upper chord bracing is also desirable at least near gable end walls.

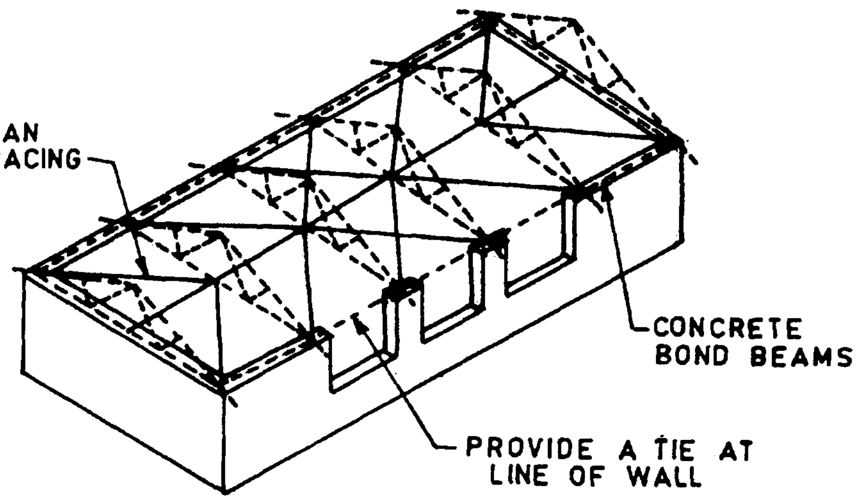


FIG. 13 WIND BRACING FOR ROOF TRUSSES

ANNEX A

(*Clause* 2)

LIST OF REFERRED INDIAN STANDARDS

IS No.	*Title*
800 : 1984	Code of practice for general construction in steel (*second revision*)
875 (Part 3) : 1987	Code of practice for design loads (other than earthquake) for buildings and structures: Part 3 Wind loads (*second revision*)
13920 : 1993	Ductile detailing of reinforced concrete structures subjected to seismic forces — Code of practice

ANNEX B

(Foreword)

COMMITTEE COMPOSITION

Cyclone Resistant Structures Sectional Committee, CED 57

Organization	*Representative(s)*
In personal capacity *(61, Civil Lines, Roorkee - 247667)*	DR PREM KRISHNA (***Chairman***)
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Andaman Public Works Department, Port Blair	SHRI S. P. LALLA SHRI B. N. NAGARAJA (*Alternate*)
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Engineer-in-Chief's Branch, New Delhi	LT-COL S. K. SHARMA SHRI R. DAMODARAN (*Alternate*)
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Structural Engineering Research Centre, Chennai	DR N. LAKSHMANAN SHRI S. GOMATHINAYAGAM (*Alternate*)
Structwell Designers & Consultants Pvt Ltd, Mumbai	SHRI R. N. RAIKAR
In personal capacity *(B XI /8091 Vasant Kunj, New Delhi-110070)*	SHRI O. P. GOEL
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Member Secretary
SHRI ALOK KESARI
Deputy Director (CED), BIS

Bureau of Indian Standards

BIS is a statutory institution established under the *Bureau of Indian Standards Act*, 1986 to promote harmonious development of the activities of standardization, marking and quality certification of goods and attending to connected matters in the country.

Review of Indian Standards

Amendments are issued to standards as the need arises on the basis of comments. Standards are also reviewed periodically; a standard along with amendments is reaffirmed when such review indicates that no changes are needed; if the review indicates that changes are needed, it is taken up for revision. Users of Indian Standards should ascertain that they are in possession of the latest amendments or edition by referring to the latest issue of 'BIS Catalogue' and 'Standards: Monthly Additions'.

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Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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