

# **Guidelines for Design and Construction of Cyclone/Tsunami Shelters**

**GoI-UNDP Disaster Risk Management  
Programme**



**Ministry of Home Affairs  
Government of India**

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# Preface

Cyclones are destructive because of their associated long duration high rotatory winds, very heavy rainfall and storm surge. It is more so when they strike coasts of countries/states bordering the North Bay of Bengal. In the past, 21 out of 24 cyclones with large loss of lives (human deaths 10000 or more associated with cyclone disasters) in the globe took place in these areas. This was due to very serious storm surge problem of the region. In the past, some of the record storm tides (combined effect of surge and astronomical tides) of the world, upto 13 m have been observed in this region. Shallow bay, low flat zigzag terrain, high astronomical tides, high density of population, socio economic conditions, lack of awareness, inadequate preparedness and absence of hedging mechanisms add to the problem. The only prescribed measures to save vulnerable population from the onslaught of storm surges are to temporarily evacuate the population on receipt of warnings and look after them for 2-3 days by arranging shelters, food and health care facilities. Therefore, construction of shelters along vulnerable coastal areas is one of the important cyclone mitigation measures.

Most parts of coastal India are susceptible to high wind speed exceeding 50 m/s (180 km/h) and probable maximum storm surge height varying from 12.8 m near Contai in West Bengal to about 2.5 m near Vishakhapatnam in Andhra Pradesh along the East coast and 5 to 6 m in the Gulf of Cambay region and about 2.1 m near Tiruvanthapuram in Kerala on the west coast. Surge varies from place to place and variation is not linear. At some places, variation of surges between two points close to each other are large due to bathymetry and terrain conditions. These facts have to be taken into consideration while designing the cyclone shelters.

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**New Delhi**

**A.S.Arya**

**National Seismic Advisor**

**GoI-UNDP DRM Programme**

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# **Design Recommendations for Construction of Shelters**

## **1. Problem Statement**

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India is highly vulnerable to a variety of natural and manmade disasters. Among natural hazards, the most notable ones are earthquakes, cyclones, floods, droughts and landslides. Tsunami is an additional concern of safety after the super tsunami of 26<sup>th</sup> December, 2004. These natural hazards are a huge developmental problem. India's vulnerability to tropical cyclones is well known.

India has a long coastal line from the Kutch in Gujarat to West Bengal and the various Island groups that are exposed to tropical cyclones at different times (Fig 1). This area accounts for almost 6% of the total geographical area. Cyclones in India have often been devastating, and the most recent one being the Orissa Super Cyclone of 1999 which killed 8913 people and caused huge damage to the infrastructure of the state. It required national and international humanitarian efforts to bring the normalcy in the state.

The long coast line of India is also vulnerable to various other kinds of natural hazards. Figures 2 and 3 shows the seismic zones and the flood prone areas respectively. The flood hazard map in figure 3 also shows the probable maximum storm surge height above the concurrent astronomical tide at various points of the east as well as the west coast of India. It can be noted that the majority of the coastal areas fall under the moderate Seismic Zones III with some parts of Gujarat and the entire Andaman & Nicobar Islands coming under the most severe Seismic Zone V. Hence, it is important that any mitigation and preparedness measures taken up in these coastal areas should also consider the multi-hazard nature of these areas. It is also important to note that the entire coast line is not uniform in terms of intensities of various hazards. The hazard intensities of earthquakes, floods and cyclonic storms in the west coast and the east coast are presented in Tables 1 & 2 respectively for ready reference. For exact details of a site, reference may be made to the original sources.

Worldwide, construction of cyclone shelters has been a proven means of preparedness as the vulnerable populations can be evacuated to these structures immediately after receiving the cyclone warning. India too has a 40-year history of construction and maintenance of cyclone shelters, notably from states such as Andhra Pradesh, Orissa and Tamil Nadu. Cyclone shelters constructed in these states proved effective and have become a source of local motivation for preparedness.

## **2. Main Issues in Cyclone Shelter Design**

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Largely, the following issues can be identified as most important while designing cyclone shelters.

### **2.1 Normal use and emergency uses of cyclone shelters**

Cyclone shelters will often be used for a short period of time during the events of natural hazards such as cyclone, tsunami or flood. The sustainability of cyclone shelters depends on the use and maintenance of cyclone shelters during rest of the year when there are no natural hazards happening. As huge investments are made to erect cyclone shelters, it is prudent that these structures are put to various other uses that will take care of maintenance of the shelter as well.

Table 1. Various natural hazards on the west coast of India and their intensities

Name of coastal State	Eq. Hazard Zone <sup>1</sup>	Design Cyclonic Wind <sup>2</sup> (m/s)	Storm Surge <sup>3</sup> (m)	Astronomical High Tide <sup>4</sup> (m)*	Flood Proneness <sup>3</sup>	Tsunami Prone-ness <sup>5</sup> (m)
Gujarat	V, IV, III	50 & 47	2.5 – 5.0	1.1 – 4.1	In 5 coast districts	10 – 12 1945 Eq.
Dadra & Nagar Haveli	III	44	5.0	1.9	-	*
Daman & Diu	III	50 & 44	5.0	1.1	-	*
Maharashtra	IV & III	44 & 39	2.9 – 4.2	1.9	-	*
Goa	III & II	39	3.4	1.0	-	*
Karnataka	III & II	39	3.4 – 3.7	0.8	-	*
Kerala	III	39	2.3 – 3.5	0.8	In 9 coast Districts	3 – 5
Lakshadweep	III	39	*	0.5	-	*

Table 2. Various natural hazards on the east coast of India and their intensities

Name of coastal State	Eq. Hazard <sup>1</sup>	Design Cyclonic Wind <sup>2</sup> (m/s)	Storm Surge <sup>3</sup> (m)	Astronomical High Tide <sup>4</sup> (m)*	Flood Proneness <sup>3</sup>	Tsunami Prone-ness <sup>5</sup> (m)
Tamil Nadu	III & II	50,47,39 PMWS-64	2.7 – 7.0 except 11.0 near tonidi	0.5	-	7 – 10
Pondicherry	III	50,47,39 PMWS-64-78	3.0 – 4.5	0.5	In 1 coast districts	10 in 1 district
Andhra Pradesh	III & II	50 PMWS - 78	3 – 6	0.68	In 8 coast districts	5
Orissa	III & II	50 & 44 PMWS – 78	2.7 – 9.8	0.90 -1.40	In 3 coast districts	*
West Bengal	IV & III	50 PMWS- 78	12.0 -12.5	2.6	In 3 coast districts	*
Andaman & Nicobar	V	44	*	1.0	-	3 – 6

\* Data not available

PMWS- Probable Maximum Wind Speed

<sup>1</sup> IS:1893-2002 Part I Seismic Zoning Map.

<sup>2</sup> IS:875-1987 Part 3.

<sup>3</sup> BMTPC. Vulnerability Atlas of India. 1997. BMTPC, GoI., New Delhi.

<sup>4</sup> Taken from SOI Indian Tide Table Part I, 1998.

<sup>5</sup> UNDP Situation Reports (Private Circulation).

There is a difference of opinion among experts on what kind of normal use to which these shelters be put to. The consensus seems to be on such uses that will not hinder the primary use (as cyclone shelter) of the structure. Consideration of the local ethos and values in the design of cyclone shelter would likely improve its use. For example, use of the building as community centre and for school will permit the use of the building as emergency shelter without any difficulty. Providing separate toilets for both men and women would improve the 'usability' of the shelter by the communities.

## **2.2 Number and location of cyclone shelters**

The existing number of cyclone shelters in India is not sufficient to accommodate the vulnerable populations in coastal areas. Hence, action is needed in the State to bridge the existing gaps. The number of cyclone shelters to be built largely depends on the number of vulnerable populations to be sheltered during emergencies. The effectiveness of a cyclone shelter, thus, depends on the assessment for the number of likely users and considerations in design and structural aspects of the shelter.

## **2.3 Multi-hazard resistance of cyclone shelters**

It is necessary that the cyclone shelters are multi-hazard resistant for the reason that the coastal areas are multi-hazard prone. This will significantly increase the life of the structure, its utility, and hence the economic efficiency of the investment made.

## **2.4 Maintenance of cyclone shelters**

Even strongly built structure can deteriorate in the absence of proper maintenance. Proper maintenance is possible through involvement of communities in planning and design of the shelter as such a design would include the features necessary for the sustainable use of the shelter. The experience from elsewhere reveals that the communities have actively used these shelters when their opinions were considered in its location and design parameters. Such a participatory approach not only brings the sense of ownership but also the pride of possession. For example, it is logical that a shelter can be used for running a school when features necessary for school are also made available in the shelter.

Cyclone shelters should not be looked only as a means of mitigation but also as a means of development as these shelters provide facilities for a wide variety of sustainable uses such as education and health care and promote the local development. Efforts are made to make sure that these guidelines are broad enough to promote local imagination and innovation without leaving any doubts/gaps that would create confusion on important issues.

# **3. The Design Recommendations**

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Based on the experiences of various states in construction and maintenance of cyclone shelters a common strategy has been evolved for sustainable use of the shelters. It is to be noted that the states should have maximum leverage in deciding the appropriateness of each element discussed here below. The larger experience suggests that the construction and maintenance of cyclone shelters would be sustainable only when the local communities are involved at all stages which enable the communities to identify the aesthetically appealing and functionally efficient cyclone shelters as their own and put to use throughout the year. Hence, it is suggested that the states may allow the local bodies such as Panchayat Raj Institutions and Urban Local Bodies in selection process of its location and use.

The recommendations for construction of cyclone shelters deal with the following design and construction aspects of cyclone shelters:

- Sustainable Use
- Building
- Accommodation Capacity
- Location
- Height of the Cyclone Shelter
- Inner Design
- Structural Specifications
- Staircases
- Material Selection
- Water Supply
- Toilets and Sewerage
- Construction of Earthen Mounds (*Killas*)
- Other Considerations
- Provision for Helipads

#### **4. Sustainable Use**

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The more a shelter is used in normal time, the better it is maintained, the more successfully it serves in emergencies. Regular use also provides economic justification for the investment. Among a number of alternatives suggested, primary schools have been found most suitable and compatible for normal time use of shelters. These could also be used temporarily for community gatherings, health camps, election booths, etc. The following guidelines would help in sustainable use of the shelters.

1. It should be noted that the primary use of the cyclone shelter is for protecting people from the vagaries of nature such as flood, cyclone and tsunami act as relief camp during other disasters.
2. The shelter should always be made and protected keeping all concerns pertinent to its primary use.
3. The features pertinent to other uses should then be overlapped with those of the primary use of the shelter with no compromise on its primary use.
4. Broadly, the States will have maximum say on the kind of sustainable use the shelters be put to. States are advised to encourage local innovations based on local needs and necessities identified by the village communities to be fitted in.
5. The use of cyclone shelters for housing the offices which are of the permanent occupation nature (e.g. Panchayat offices, hospitals etc) has to be discouraged, since these offices cannot be relocated during the periods of occurrence of natural disasters, which occur without prior notice, and hence hinders the usability of the shelter for the primary purpose for which it is meant.
6. The cyclone shelter should ultimately become a “Community asset/resource” such that it will have a broader impact on the livelihood of the villages. Hence, it is appropriate to locate the cyclone shelters inside or near the villages. Ultimately, the idea is to assure their regular use during the normal period as well.
7. Using the shelter as primary school on regular basis will not come in the way of sheltering since most rural primary schools use mats for seating the children and where low height desks/benches may be used, they could be stored in a small space or used for people sitting or standing on them.

8. Other temporary uses may be for village gatherings, camps, marriages, and other community activities.
9. Such a sustainable use should also generate required finances to supplement proper maintenance of the structure.

## 5. Accommodation Capacity

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1. Capacity should be decided based on the local assessment of vulnerable populations and availability of any multi-storied buildings and buildings located on elevated grounds which can accommodate some of the vulnerable people during the times of cyclone, tsunami and flood.
2. Experience on capacity assessment of cyclone shelter indicates that, on an average, about 50-60% of total population of vulnerable locations may be using the cyclone shelter during emergencies.
3. Importance should also be given to the sustainable utility aspect of the shelter. For example, a 4-room [6 m x 5.4 m + verandah (1.8 m)] school will have a clear floor area of about 1850 sft and a similar floor area on the terrace. Such a school will accommodate about 200 students and will provide around 7 sq.ft. per student. From the past experience, in our country as well as in other Asian countries, it is observed that an area of 2 sq ft/person has generally been provided for sheltering purposes. Such a density may lead to suffocation and inhuman environment. The area of the four room school could accommodate about 600 persons counting the area on the floor at a rate of 3 sq.ft. per person. Counting the available open area on the terrace another 600 persons can be accommodated. Hence, *a four room school could be assumed to accommodate easily upto 1000 persons.*

## 6. Location

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1. Emphasis should be given such that the cyclone shelters are located on the available high elevated land. Guidance on the levels can be taken from large scale maps or from survey of India. Exact location within the broad contour is left to the decision making mechanism adopted locally involving communities & local authorities.
2. In absence of available elevated area, the structure may be elevated through construction of a mound or shelter be built on stilt.
3. States are advised to carry out a survey within 10 km band width from the coast and identify all villages therein and submit the list to the Survey of India which should provide the information on astronomical high-tide levels and ground levels within a level range of  $\pm 0.5$  m.

*Note:- High tide line on the coast may be found from the people/fisherman living in the village.*

4. Regenerating mangroves and raising shelter belt plantations will help reducing the fury of the storm surge. Suitable isolation distance must be provided between the shelter belt and the cyclone shelter to avoid damage to the foundation of the building by the roots of the shelter belt.



## 7. Building

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1. RCC or brick masonry two storied building with or without stilt depending on the storm tide levels is considered suitable. Height depends on the storm tide levels. In view of general soft top soil in coastal areas, pile foundations may be preferable. However, suitable type of foundations should be considered based on local conditions and soil strata.
2. Shape: Any shape (circular, hexagonal, octagonal) is suitable. However, square or rectangular may be used provided the peripheral corners are rounded for improving the aerodynamics of the structure.
3. Doors: Should be opened outwards into a box having four heavy duty stainless steel hinges fixed firmly to the holding medium.
4. Windows: Louver type of window is suggested with non-breakable and non-brittle items made of Fiber Reinforced Plastics (FRP).
5. Parapet:
6. For RCC buildings: The height of the RCC parapet over the first floor roof will depend upon design storm surge height and may be taken from 0.8m to 1.35 m having holding-pipes on top or inside of the parapet (Table 3; Fig 4) depending on the design surge levels.
7. For masonry buildings: The parapet may be made of brick masonry up to a height of 0.8 m with pipe railing at top.

## 8. Height of the Cyclone Shelter

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The total height of the shelter above high tide line should meet the requirement of the design height of the storm surge. The height of the structure may be worked out as follows:

1. A minimum of 1 m should be ensured between the ground level and the high-tide level.
2. Raise the plinth about 1.2- 1.5 m above the ground level.
3. Where needed, add 2.2-4.5 m high stilt depending on surge height.
4. Add one livable storey of 3.5 m height to the above level so arrived. This will be sufficient for most surge heights (Table 1 & 2, Fig 5).
5. Design the roof to act as shelter space with parapet all around in case of larger storm surge in the area (Table 1 & 2).

## 9. Inner Design

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1. Provide bunkers with resting facility for small children, elderly/sick persons (Fig 6).
2. Provide storage shelf facilities in every room and verandah for accommodating the personal belongings of the occupants (Fig 6).

## 10. Structural Specifications

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1. Imposed Load for design of floor slab and beams:  $500 \text{ kg/m}^2$ .
2. Wind velocity for East Coast of India and Gujarat coast: Basic wind speed 65 m/sec with modification factors  $K_1=1.08$ ,  $K_2=1.05$ , and  $K_3=1.0$  as per IS 875 - standards with specified normal load factors.
3. Wind velocity for West Coast (excepting Gujarat) and Andaman & Nicobar Islands: Basic wind speed 50 m/sec with modification factors  $K_1= 1.08$ ,  $K_2= 1.05$ ,  $K_3 = 1.0$  as per IS 875.
4. Roof Terrace: Design for same imposed load as that of the first floor in case of larger than 7 m storm surge height; for lower surges design for  $250 \text{ kgm}^{-2}$ .
5. Earthquake load will not be considered simultaneously with that of wind loading. EQ Importance Factor is to be taken as 1.8 for the shelter design. Rest of the norms should be followed from the relevant IS codes. The floor live load will be taken as for secondary uses (say school, community gathering etc) as per IS:875 Part II.
6. Vents: Provide as per the norms for adequate ventilation. Louvered vents to be used in shelter in various walls just above floor level to drain water flowing in and out in case of higher than first floor surge height.
7. Shelves: Provided at door-window level in line with seismic band at that level.

## 11. Staircases

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1. Need to be located up to first floor level clearly and spacious enough for the movement of the people. The staircases should have a width of 1.5 to 2 m depending on shelter capacity with multi-entry possibilities.
2. Alternatively a ramp with a slope of 1:8 to 1:10 may be considered upto the first floor for carrying physically disabled and elderly people.
3. A staircase of minimum 1.2 m width may be provided from the first floor to the terrace level.

### 11.1. Material Selection

1. Load bearing brick masonry structure may be adopted where no requirement of stilt. All stilted shelters should be raised on RCC frame and upper portion (first floor and above) could be constructed with load bearing brick masonry structure as an alternative to continuing the RCC framed structure.
2. Light weight pre-cast concrete blocks (aerated flyash mixed concrete or hollow concrete) can be considered as an alternative for non-load bearing filler and partition walls so as to reduce weight on foundations. When using solid bricks, rat-trap bond may be adopted to save about 25% of bricks as well as weight.
3. Corrosion resistant steel must be used as there would be considerable improvement in the service life of the structure (say TMT-HCR 500 of SAIL or TATA).
4. Good concrete with proper cover to corrosion resistant steel results in a durable structure. The use of blended cements is to be encouraged as it enhances the

durability of the structure. All the materials should conform to the relevant IS Codes.

## **12. Water Supply**

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1. Number of tanks: Minimum two tanks should be provided to cater for drinking as well as for the toilets.
2. Capacity for water requirements: According to the National Building Code of India, for schools a water supply of 45 lts per day per person is required. Assuming a storage capacity of 50% of the water supply requirement the two tanks should have an overall capacity of 4500 lts. Therefore, each tank should have a minimum capacity of 2000 lts (For each additional 500 persons or additional 100 students, the capacity of the each water tank should be increased by 1000 lts.)
3. Provision shall be made for rainwater harvesting from roof to the tanks.
4. Sedimentation-based water filters should be adapted for rainwater harvesting structures for purifying the water for drinking purposes.
5. Provide a hand-pump at the first floor level in stilt structures and at the ground floor for non-stilt structures for drawing ground water during normal use as well as emergencies.
6. Arrange cleaning of the terrace at least during the rainy and cyclonic season (April-May and Oct-Dec) such that the harvested water from roof is clean. Clean the water harvesting system (including the tank) once in a month in all seasons and adopt water purification system as found necessary.

## **13. Toilets and Sewerage**

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1. Criteria for toilets: To serve the requirements of school with 200 students, minimum 2 toilets for boys and 2 toilets for girls need to be provided in addition 6 urinals may be provided for boys. These will also serve the needs of the shelter in emergencies. (For each additional 500 persons or additional 100 students, one additional toilet each for men and women should be provided.)
2. Size of each toilet should be minimum 9 sq ft/toilet, preferably 12 sq ft.
3. Septic tanks should be provided. Tanks should be properly sealed and roof sufficiently elevated so as to prevent inundation during flooding.

## **14. Construction of Earthen Mounds (Killas)**

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*Killas* are necessary in places where there are no available high elevated areas. The shape of *killa* depends on the shape of the main structure with sufficient clearance from the edge of the *killa*. The clearance from the edge should be minimum 6 m (See Annexure II).

## **15. Other Considerations**

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1. Elevated approach road may be laid up to the shelter with gravel/cement.
2. Provision for appropriate power back-up facilities such as generator/solar power cells may be made. These should be located above the design surge level.

3. Communication facilities such as wireless radios/walkie-talkies may be provided.
4. Community participated Maintenance and Management Committees may be formed for the regular maintenance of the shelter.

## **16.Provision for Helipads**

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Heavy cyclones often inundate large areas and situation may arise that helicopters may have to be used to access the affected areas. The terraces of cyclone shelters may be used to provide space to land helicopters as they are high rising and sturdy structures. The design parameters have to be ascertained and the cost implications are worked out for taking the dynamic forces generated during landing/takeoff of the helicopter on the structural design of the shelter. Hence, this option has been kept open for the consideration of the States with following points as guideposts:

Identify critical areas where cyclone shelters need to accommodate helipads. These areas include:

- Large stretch of low-lying areas which are difficult to reach quickly with the available means of water based transport.
- Areas with higher density of vulnerable populations with high frequency of cyclones.
- Areas with critical/strategic installations that could prove fatal when a secondary disaster is triggered due to floods and cyclones.

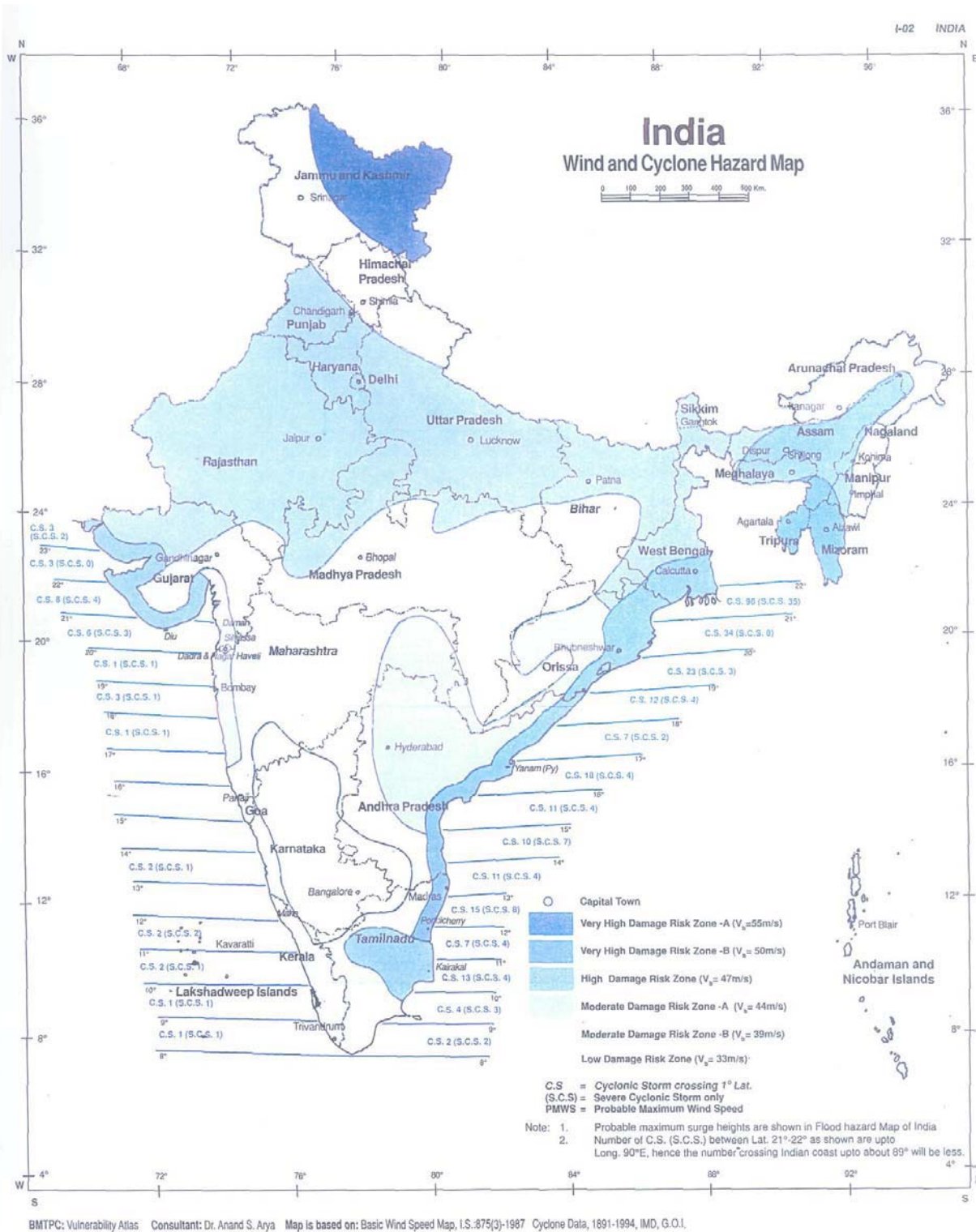
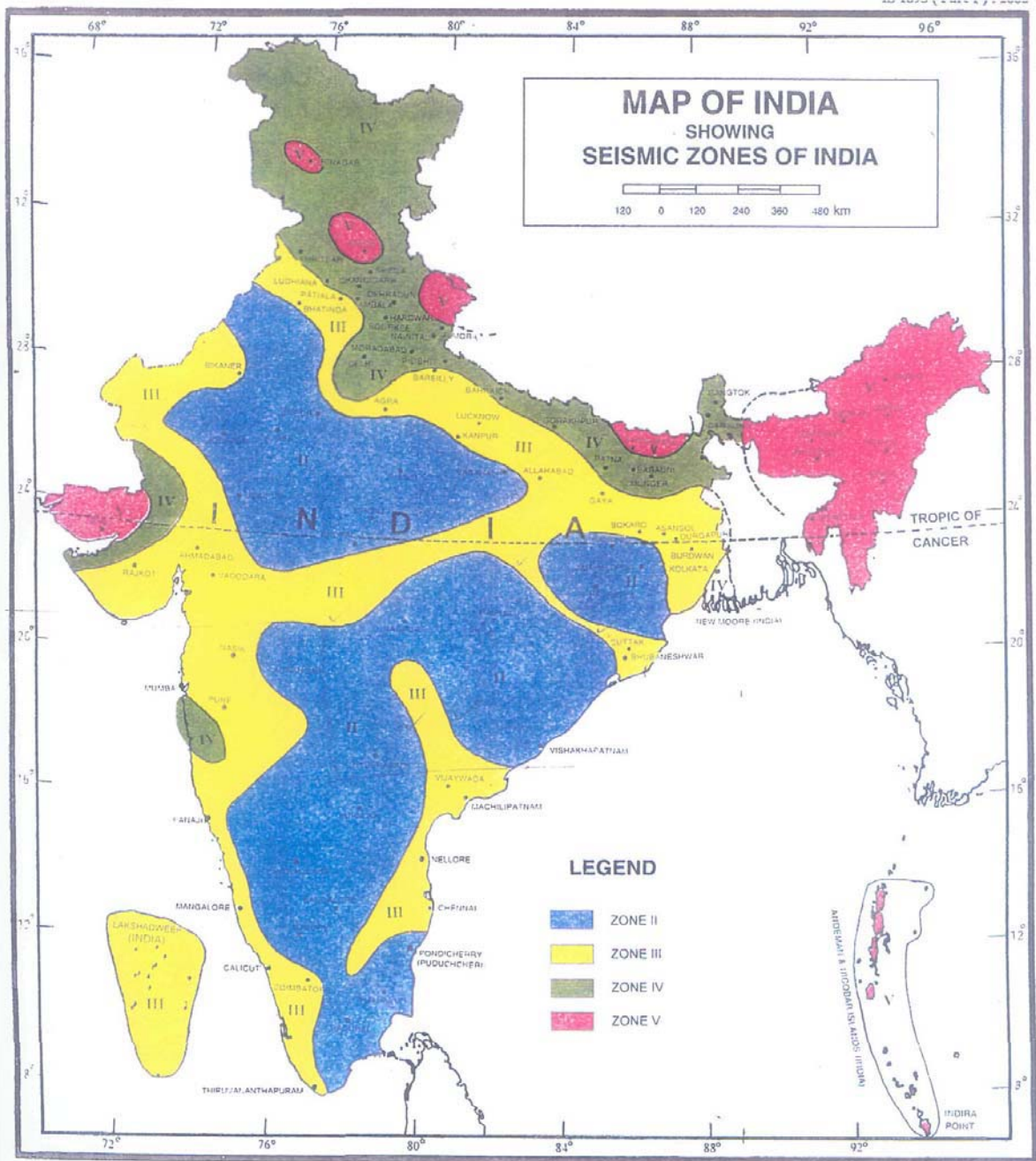


Fig. 1. Wind and Cyclone Hazard Map of India

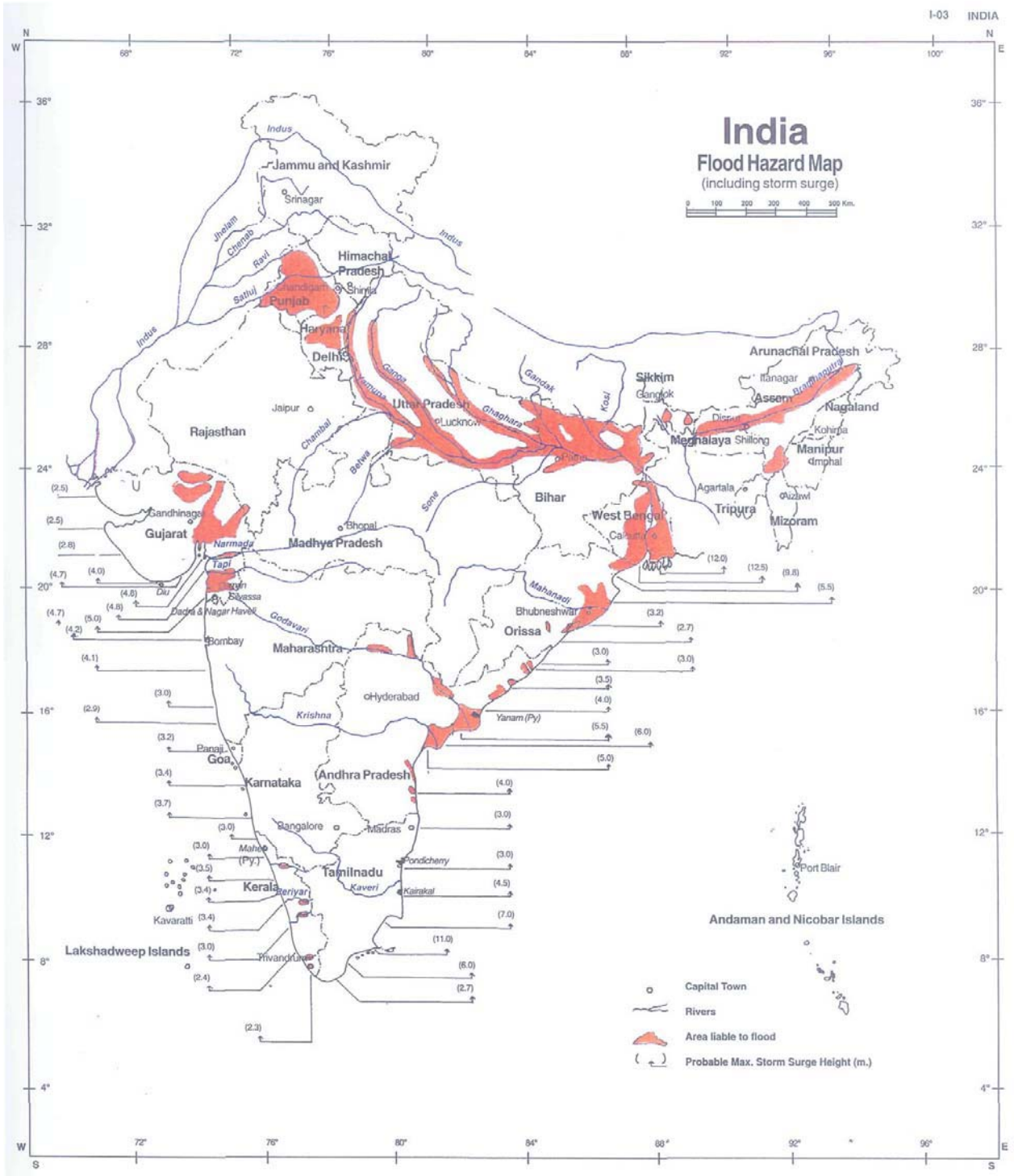


NOTE : Towns falling at the boundary of zones demarcation line between two zones shall be considered in High Zone.

© Government of India, Copyright Year 2001.

- Based upon Survey of India map with the permission of the Surveyor General of India.
- The responsibility for the correctness of internal details rests with the publisher.
- The territorial waters of India extend into the sea to distance of twelve nautical miles measured from the appropriate base line.
- The administrative headquarters of Chandigarh, Haryana and Punjab are at Chandigarh.
- The interstate boundaries between Arunachal Pradesh, Assam and Meghalaya shown on this map are as interpreted from the North-Eastern Areas (Reorganization) Act, 1971, but have yet to be verified.
- The external boundaries and coastlines of India agree with the Record/Master Copy certified by Survey of India.

**Fig. 2. Seismic Zones of India**



BMTPC : Vulnerability Atlas Consultant : Dr. Anand S. Arya Map is based on: Flood Atlas, 1987, C.W.C., G.O.I. Cyclone and PMP Data, 1891-1994, IMD, G.O.I.

Fig. 3. Flood Hazard Map of India

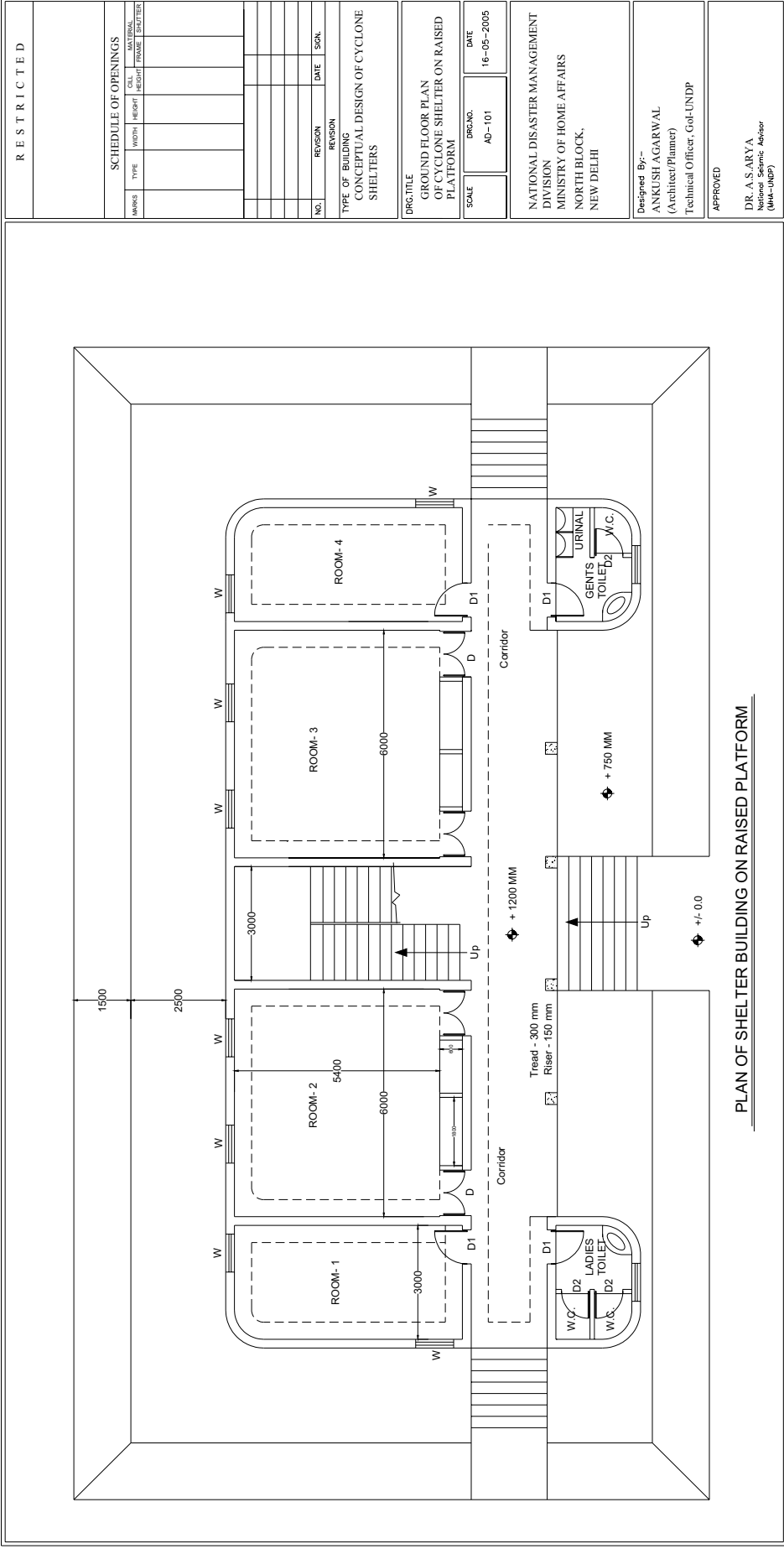
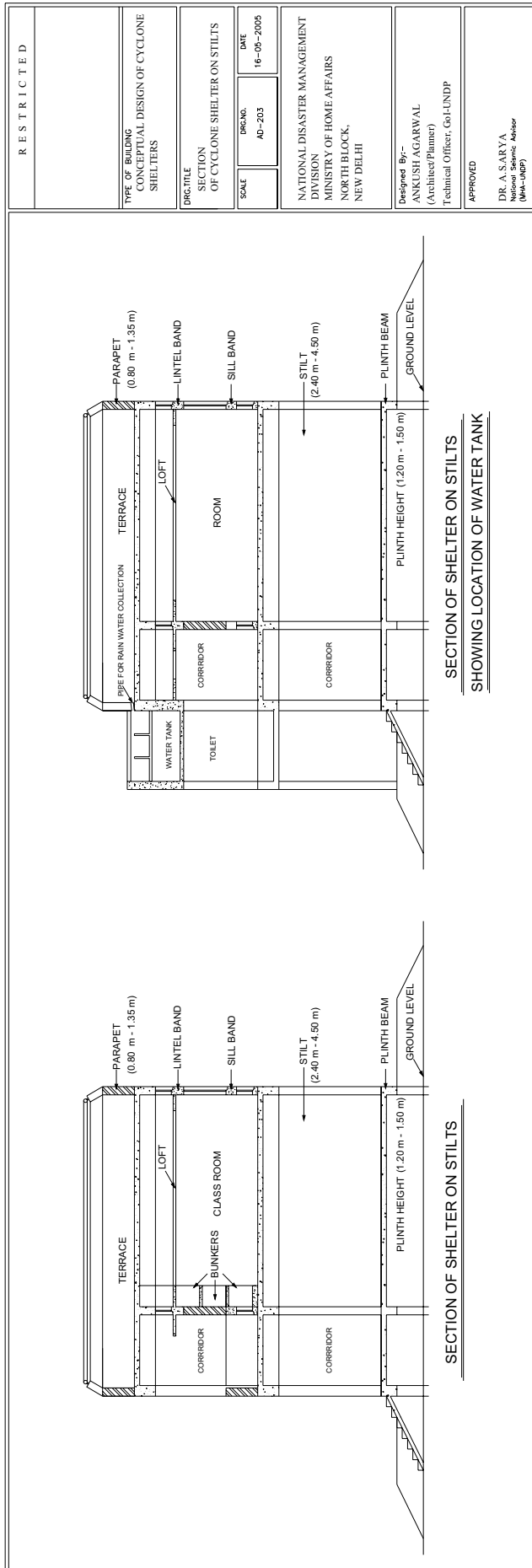
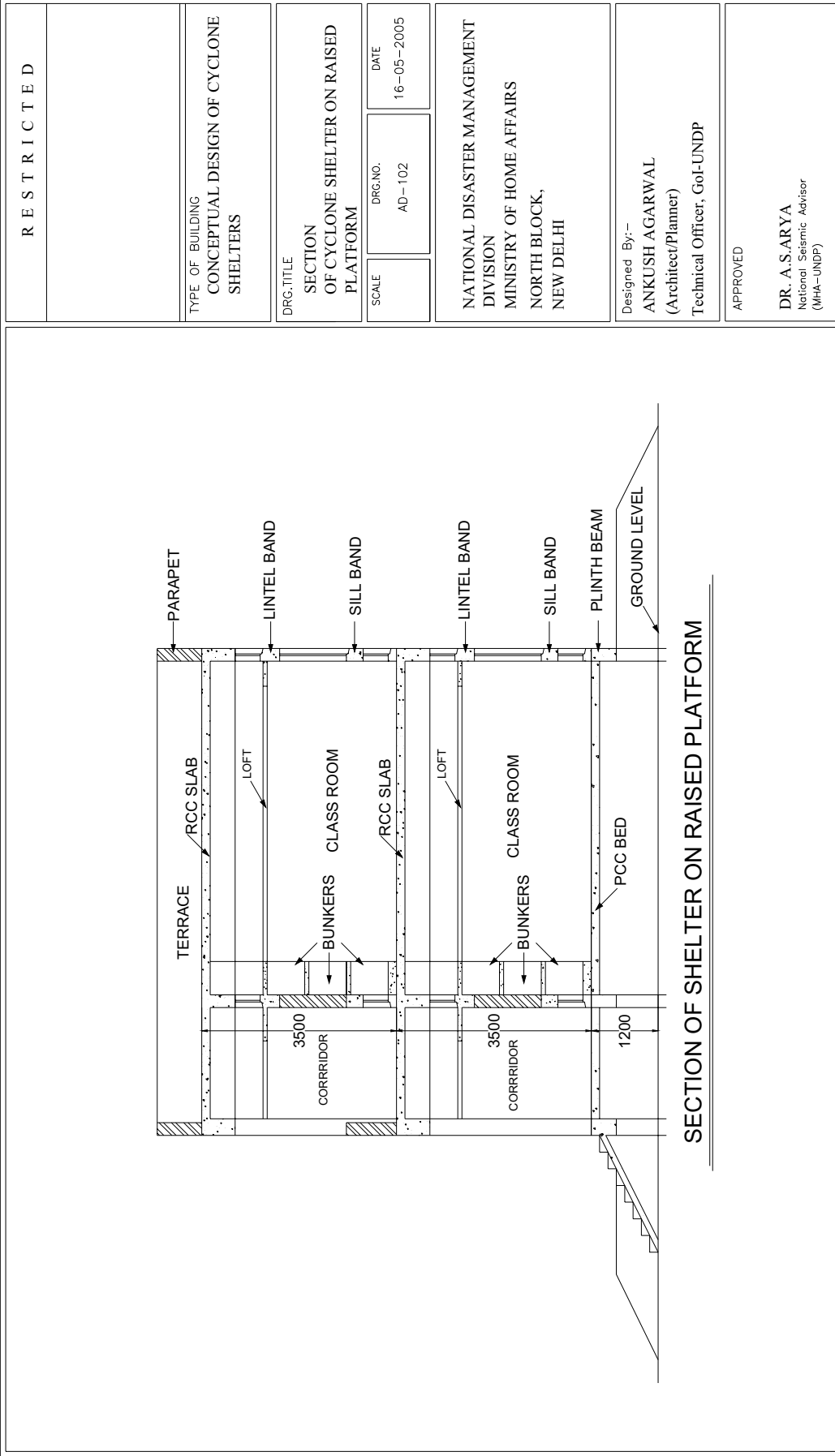


Fig. 4. Plan of shelter building on raised platform.

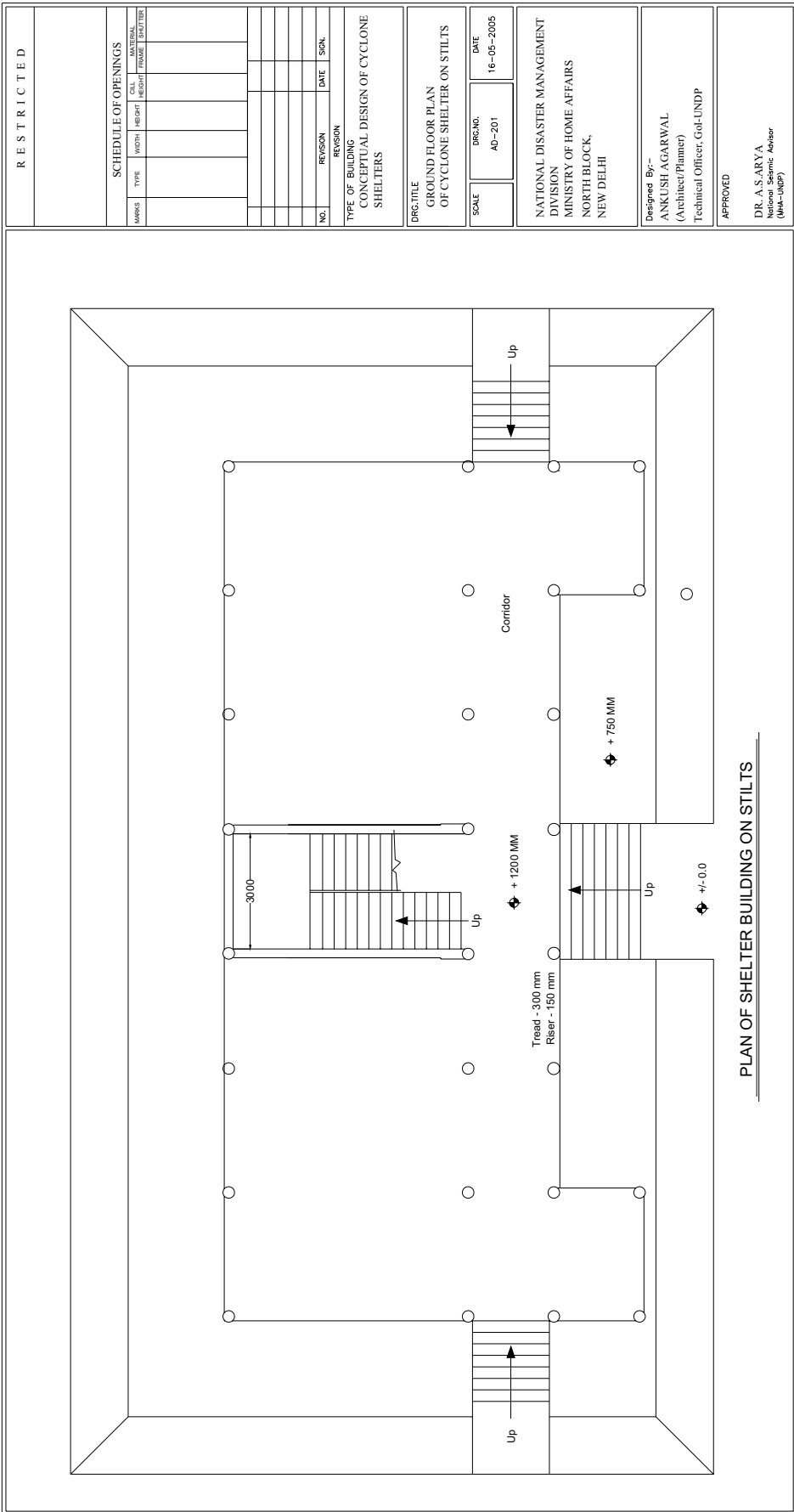




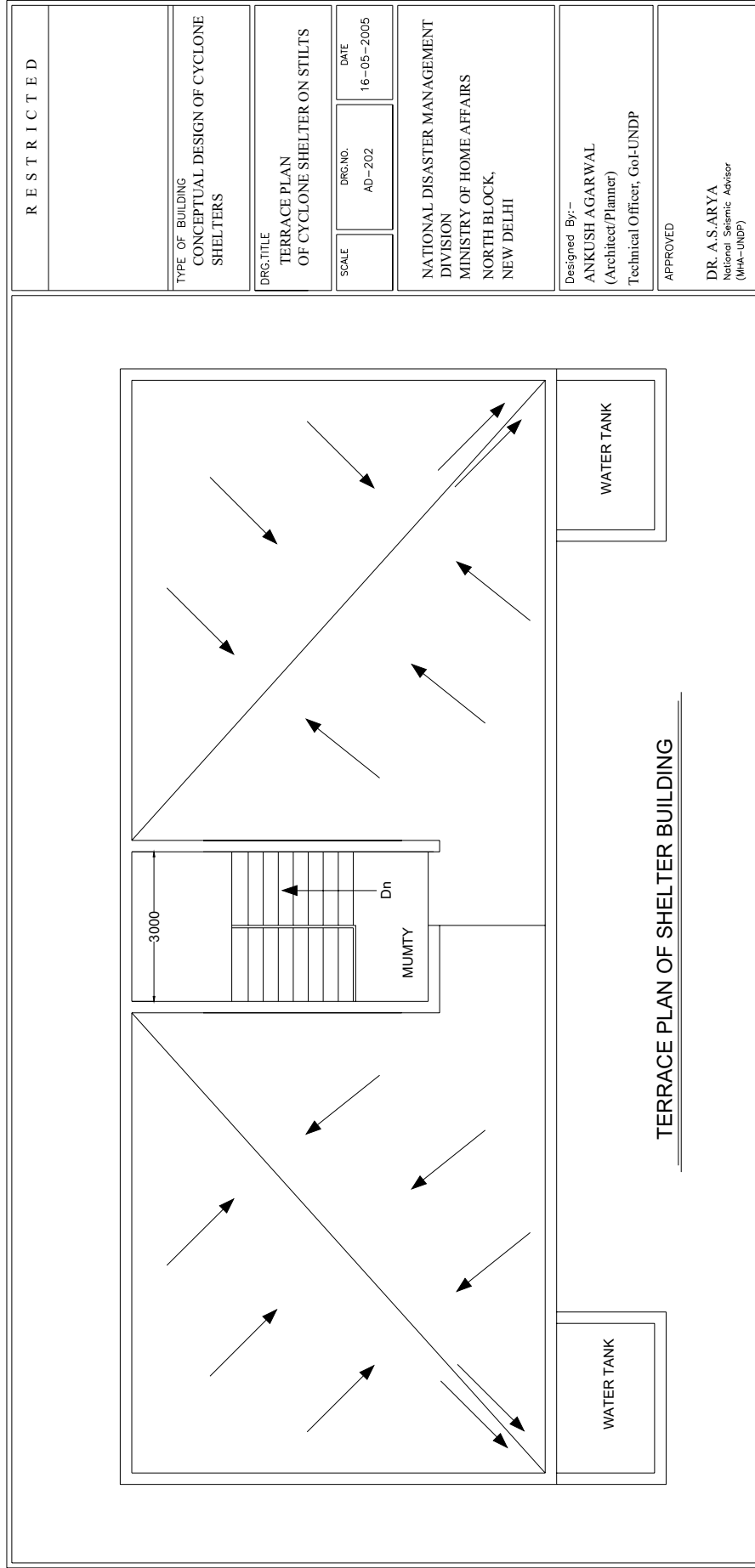
**Fig. 5. Section of Shelter on Stilts showing location of water tanks**



**Fig. 6. Section of Shelter on raised platform**



**Fig. 7. Plan of shelter building on stilts**



**Fig. 8. Terrace plan of shelter building**

## **17.Proceedings of the Workshop**

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### *17.1. Multi-Purpose Cyclone Shelters: Orissa Experience (N Sanyal, Managing Director, OSDMA)*

The thickly populated Orissa coast has a coastal belt of 480 km, 6 coastal districts, 28 coastal blocks, 7 blocks adjoining Chilika Lake. Orissa coast has a cyclone frequency of 5 cyclones in a year and is situated in Earthquake Zone III, highly flood prone, with some areas even vulnerable to drought conditions and chemical and industrial hazards.

Orissa had a bad experience of 1999 cyclone where 8913 people and 444500 cattle died, 14 districts got affected, more than 2 million houses damaged and 18,43,047 ha of cropped area heavily damaged. Many villages are still to be connected through proper roads in Orissa. For Orissa, The most problematic months in terms of cyclones are October and November.

The concept of multi-purpose cyclone shelters (MPCS) has been evolved over the time in the state. Before 1999 cyclone, the state had 23 cyclone shelters. Now, there are 97 MPCS taken up by the state through various funding mechanisms of which 92 are complete and 89 were already handed over to the Cyclone Shelter Maintenance and Management Committees (CSMMC) for their maintenance.

Funds for maintenance are a problem in Orissa, as the case in any other state. It has been estimated that around 2 crores is required to renovate various cyclone shelters and approaching CRF was not fruitful as the norms do not allow construction/maintenance of permanent establishments. There is a need to at least relax such norms to consider expenditure requirements of this kind in future. Orissa constructed some cyclone shelters from the Chief Minister's fund. These shelters are smaller (2000-2500 m<sup>2</sup>) when compared to the other shelters built using World Bank funds.

Recent estimates by IIT-Kharagpur suggest that the state needs 286 shelters each accommodating 3000-5000 people along the coast line to bridge the existing gaps within 10 km distance from the coast line. Among the coastal districts, Jagatsigpur has gaps identified after the 1999 cyclone, Puri has gaps between lagoons and coastal areas, and Ganjam has less probability of damage due to terrain conditions. Chilka Lake has to be covered under NCRM which are not covered under any other program till date. These areas could be inundated if there is a storm surge of more than 2.5 m.

Some key features of the shelters built so far are provision of separate toilets for men and women; construction on mounds of 1.2 – 1.5 m; 2 storied, pile foundation, designed for a wind velocity of up to 300 kmph, loads as per the IS standards, provision for drinking water through rainwater harvesting, generators/solar panels for power supply, ramps for disabled persons, and barbed wire fencing. The MPCS were selected based on the guidelines provided by IIT and PRIs/community members were involved in forming the CSMMCs. In the present DRM, the members of CSMMCs are being trained in various search and rescue techniques, supplied with walki-talkies and radio sets, introduced awards for better maintained MPCS as an incentive. The state has identified vulnerable areas and a total of 286 cyclone shelters including 26 for the Chilka lake area need to be built.

### *17.2. Experiences from Andhra Pradesh (Chief Engineer, Panchayat Raj)*

Andhra Pradesh has a coast line of 1000 km, 9 coastal districts, and 1 interior but vulnerable district. During 1977 cyclone, more than 10000 lives were lost due to unpreparedness after which nearly 1112 cyclone shelters were built in equal number of inhabitations. Maintenance of these shelters has been a problem. Out of 1112 shelters, 597 are in good condition, 412 need major repairs, 103 require replacement and 1170 new ones are needed. Around 22-25% of the population in these areas needs cyclone shelters which totals to 1170 cyclone shelters. Financial requirements are Rs 6.14 crores for drinking water facilities, Rs 3.68 crores for sanitation facilities and Rs 60.08 for construction of roads for proper connection of cyclone shelters with the villages. This amounts to Rs 444.08 crores for the entire project.

The existing shelters are not constructed for tsunami resistance. The other problem with the existing structures is that these were constructed away from the inhabited areas and hence are not maintained properly. The maintenance of these structures requires higher allocation rates than the existing norms and initial total reconstruction/repair costs for the existing structures require 4 crores with annual maintenance costs of Rs 60 lakhs thereafter. The existing designs consider 250 kmph as wind velocity.

The future designs would consider locating the sanitation blocks away from the main block as they have become a problem for sanitation due to poor maintenance during the calamities. There is also a need to strengthen them with proper communication facilities, drinking water facilities, and generator for power.

### *17.3. Design Criteria for Cyclone Shelters (Kirti Shah, Architect, Gujarat)*

It is important to consider the fact that the cyclone shelters are to be used only for few days in a year and their use during non-emergency situations should also be considered for getting maximum out of such a capital investment. To achieve this, the backward planning from its secondary use to the primary use looks like a logical approach. The community aspect should get higher importance apart from the technical aspects of it and the design should consider the behavior of people during stress conditions for deciding the size and other details.

See that the staircase is as much wider as possible and provide multiple entry points to the building to avoid stampede. Central hall can have multiple accesses as the building is put to multiple uses. The multi-purpose uses that a shelter can provide include school, hospital or as a community asset for conducting various programs. The terrace would accommodate people as soon as the stress conditions abate and hence the load bearing capacity of the terrace should also be designed accordingly. The height of parapet also becomes an important element.

There could be shelves for storing the valuables of communities, three tier cabins/bunks would be useful for elderly people and children who needs to take rest. Sufficient water should be provided through water harvesting facilities. The hand pump should be provided on the first floor such that he people can use it in the wake of floods. Awareness generation about the better maintenance of the shelter can be done with the help of useful handouts telling do's and don'ts of using shelters etc. Finally, the cyclone structure should become a symbol of collective pride and encourage belongingness among all.

#### *17.4. Design Criteria for Cyclone Shelters (Prof Arya A.S., National Seismic Advisor, MHA)*

Cyclone shelters should not only be looked at as a means of mitigation but also as a means of development as these shelters provide facilities for wide variety of uses such as education, health care, community function facilities etc which promote development of a village.

It is a fact that the coastal areas are prone to multiple hazards such as cyclones, floods, earthquakes, fire, storm surge etc. The available cyclone and wind zone maps help us in delineating the boundaries for the cyclone hazard into different zones along with the possible tide levels. The West Coast of India is relatively less vulnerable to cyclones compared to the East Coast. Similarly, the combination of hazards observed on the west coast is different from that of the East Coast, including the intensity of these hazards, and hence any design criteria used should take this into consideration.

The shelter design should consider the wind velocity, wind pressure, height of storm surge, possible tsunami effects, hydrostatic water pressures, earthquake effects, fire safety, flood inundation, shape and size of the building, and use of building roof to act as shelter etc. Choice of material, durability and thermal comfort are also important considerations. Use importance of the building should be first considered before considering the construction and architectural aspects. For important buildings such as schools/hospital uses, the wind velocity considered should be higher when compared to normal uses such as housing. Hence, shelters need to be designed for higher wind velocities. The architectural considerations include functional, climatic, layout, shape, behavioral and typological considerations.

When a cyclone shelter is expected to be a multi-purpose shelter, then the structure should be located near/within the inhabited areas. There should be ventilators at the floor and just below the roofing for proper ventilation and draining of flood waters on inundation.

## 18. Killas for Cyclone Shelters

*Killas* or earth mounds have become an essential part of the cyclone hazard minimization to protect livestock from the cyclone surge. Hence, *killas* could be made use of to protect the cyclone shelters from storm surge. The following guidelines govern the use of *killas* along with cyclone shelters.

- The side slope shall be 1:2 (vertical : horizontal).
- The borrow pits from where soil will be excavated for constructing the *killas* shall be located not closer than 8 m from the toe of the proposed *killas*. These borrow pits shall preferably be located on one side but not more than on two sides of the *killa* due to land problem.
- The slope of soil excavation in borrow pits shall also be 1:2. The plans and sections of the *killas* with the proposed borrow pit location and dimensions are shown in Fig A.1, A.2 respectively.
- The depth of the excavation in borrow pits shall not exceed 2.5 m. Table A.1 shows all the dimensions of *killas* together with those of borrow pits for all the types.

**Table A.1. *Killa* and borrow pit dimensions**

Killa type	Height (h) above ground level	Dimensions of Killas		Dimensions of borrow pit	
		Width	Length	Width	Length
K-1 (Shelter on top)	3.0	43	55	59	49
K-2 (Shelter on top)	4.5	43	61	75	65
K-3 (Shelter on top)	6.0	43	71	93	83

- The shelters proposed to be constructed on *killas* may have reinforced concrete beam and floor system on brick masonry walls.
- Structural analysis has shown adequacy for the proposed structural system in extreme loading conditions. However, the construction of these buildings on newly filled *killas* or on the existing *killas* will require special attention. This includes the proper compaction of soil in the *killas*.
- To minimize the effects of differential settlements reinforced concrete strip foundation below the walls have to be considered. This type of foundation will also allow uniform settlement of the structure, if there is any, due to the settlement of the soil.
- The slope of the *killa* should be lined with stone pitching or grassed for protecting it from erosion. Care should be taken to provide cement lined channels along the slope to drain the water from the top of the *killa*.
- The borrow pits could be used for growing fish which would provide earnings for maintenance of the structure.



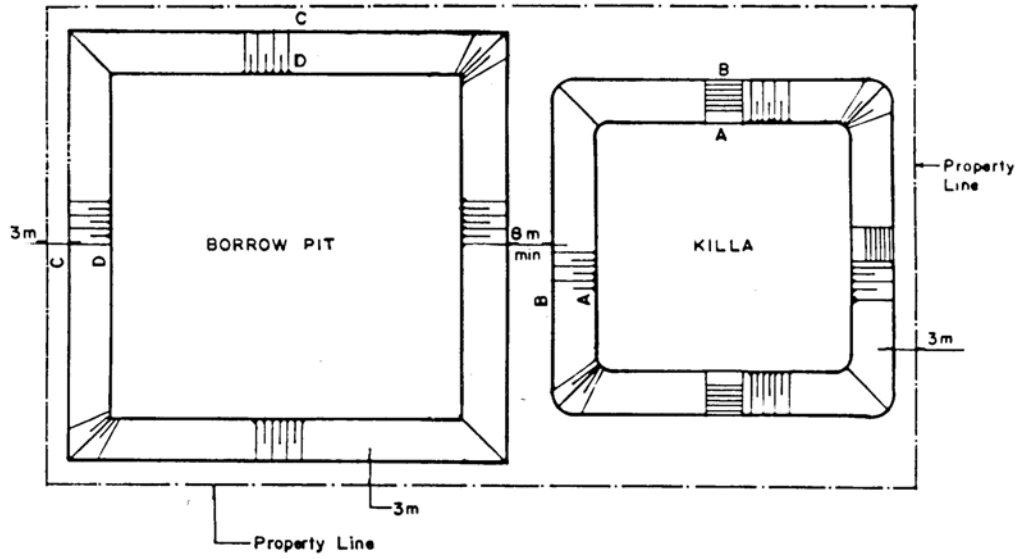


Fig. A.1. Plan of killa and borrow pit

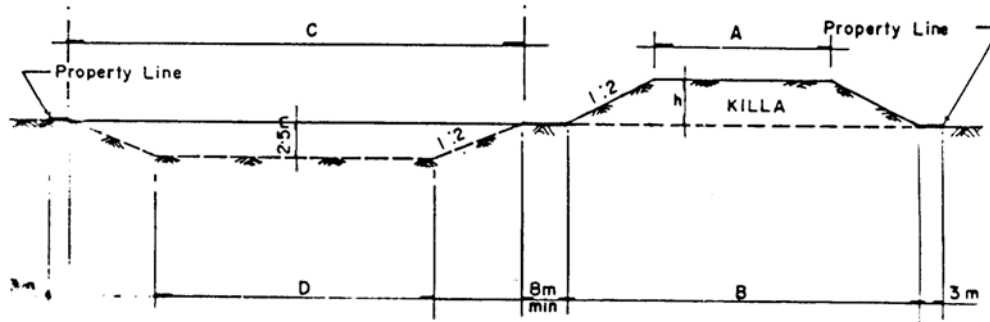


Fig. A.2. Section of killa and borrow pit

Source:- Multipurpose Cyclone Shelter Programme, Part-I, Volume-I, Main Report published under UNDP/World Bank/Government of Bangladesh Project BGD/91/025.

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Prepared by:

***Professor Anand S. Arya and Ankush Agarwal***

*under the GoI-UNDP Disaster Risk Management Programme*

Email: [anand.s.arya@undp.org](mailto:anand.s.arya@undp.org), [ankush.agarwal@undp.org](mailto:ankush.agarwal@undp.org)

**NATIONAL DISASTER MANAGEMENT DIVISION**

Ministry of Home Affairs, North Block, New Delhi

Tel: 91-11-23093178; Tele/fax: 23094019, Email: [ndmindia@nic.in](mailto:ndmindia@nic.in); Website:

[www.ndmindia.nic.in](http://www.ndmindia.nic.in)