ANALYSIS AND DESIGN OF CYCLONE SHELTER ALONG EAST COAST OF TAMIL NADU, SOUTH INDIA

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Abstract

India has a coastline around 7500 km long, surrounded by the Bay of Bengal on the Eastern side and the Arabian Sea on the western side. Coastal hazards caused by human activities and natural calamities like storm surges, coastal flooding, sea level rise and cyclones are frequently happening due to climate change. Tropical cyclones are very common and expose vulnerability cause severe damages to the coastal community such as property loss and live to lose. To reduce these impacts by disaster management activities. Cyclone shelters are one of the engineering constructions for management plan along the suitable locations to protect the people, prevent property loss and are a typical phenomenon that involves social, psychological, economic, environmental, geological, political, global issues of concern. Various cyclone structural models were adopted in Indian states like Andhra Pradesh, Odisha, West Bengal and Tamil Nadu. They could not withstand long duration due to structural design and it needs a better solution with a scientific and technological based approach. This study focusses the structural design for cyclone shelter as the designed circular shape with lateral stiffness is provided by Shear wall to the structure and its behaviour is very different from the normal frame structure and analysis carried for the performance of comparison of cyclone pressure wind load of buildings between with & without a shear wall. This analysis is done by using STAAD-Pro. The dead load, live loads, wind loads (during cyclone) are to be applied for beams, columns and slabs; wind load calculations were done as per IS 875 Part-3. Indian Meteorological Department (IMD), Chennai has categorized for the high wind speed of Super cyclone is 220 Km/hr and applied the same wind speed to the Circular cyclone shelter and the shelter was withstood for high intensity of cyclone impact. Planning of the Circular Cyclone Shelter from the old needs proper an analysis and design of structural members to resist during super cyclones and storm surges. Existing rectangular cyclone shelters are not safe for high intensity Cyclones in Odisha, West Bengal and Myanmar. This study suggests the Circular Cyclone Shelters is suitable for any environmental condition compared to other types of existing rectangular cyclone shelters for protection measures. The circular Cyclone shelters will be used as migration centers and livestock storage throughout cyclones and protect against storm surges. Circular Cyclone Shelters will be very useful in remote Coastal Communities.

Keywords: Natural Calamities; Hazard Management; Cyclone Shelter; Shear wall; Frame structure;

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1. Introduction

Various development activities due to the swelling population in the past few decades cause sprawl, land exhausting and Artificial calamities. Along the coastal areas are enormous sources for improving social structures and establishment all over the coastal countries attracting the people trend to move coastal areas (Nagalakshmi et al., 2021). More than 50% world population live along the shoreline has stated by the UN in 1992 (Ashbindu Singh et al., 2006). Coastal populations always face so many natural calamities like cyclones, storm surges, coastal inundation and giant waves are exposed to direct vulnerability. The cyclone is a low depression area coiled by closed isobars to migrate towards a coastal region with increasing intensity and stimulate a high impact on the coastal properties and communities. During tropical cyclones the weather condition triggered high wind speed exceeds above sixty-seven kilometers per hour defined by World Meteorological Organization (WMO, 1976). They are called 'Typhoon' in China, 'Taifu' in Japan, 'Willy' in Australia, 'Cyclone' in the Indian Ocean, 'Baguio' in the Philippines, and 'Hurricane' in USA. The impact of cyclone varies place to place depending the environmental factors such as latitude, altitude, wind speed, direction, wind motion, Coriolis force, coastline morphological and contributing with El-Nino phenomenon etc. Also, loss of the property, community, social impact, economy and becoming recovery also varies among the coastal region based on intensity and magnitude of the cyclone sever (Priya et al., 2015).

India has coastal line of 7500 km comprised of east and west coast (Ranadhir Mukhopadhyay, 2014) extremely vulnerable to natural hazards particularly earthquakes, floods, drought, cyclones and landslides and cyclones to climate change, is showing to around ten percentage of the globes Humid low pressure, which causes severe damage to the environment. The mitigation measures focusing on appropriate precautions through cyclone alert warning and shifting people and properties from coastal areas to elevated land can reduce life loss and properties (Priya et al., 2015). It is a very high cost to locate a safe place for evacuation, complicated and embarrassing situations for them (Kennedy et al., 2012 & Biswanath Dash, 2016). Overcome an issue, needs to undertake appropriate shelters constructions in suitable locations will establish to decrease the impact with social benefits along the coastal region. (Henceforth, NCRMP). Cyclone disaster management can be done with the cyclone shelter designed to evacuating people in short- duration during inundation (Paul et al., 2002, Naonori KUSAKABE, 2011 and Mari Miyaji et al., 2017). In 1977 Andhra Pradesh was worst affected by cyclone, insist that the shelters withstand the environmental suitability and regular maintenance (Choudhury, 1994) and focus on minimizing the impact and precaution measures such as cyclone tracking system or surge forecast advancement (Seo, 2017).

The paper focuses on the design parameters of cyclone shelter and analysis that the comparative study of various loads acting on the existing rectangular Cyclone Shelter and proposed Circular Cyclone Shelter along the east coast of Tamil Nadu. The main view for research is Site Suitability and Environmental aspects for an Analysis and Design of Circular Cyclone Shelter and to identify the Environmental suitability of the Cyclone Shelter situated. Needs to determine the structural behavior of the Cyclone Shelters with and without shear walls and to perform the analysis and design of the structural element as per IS code of practice and the Cyclone Shelter will be analyzed using STAAD-Pro software.

2. Materials & Methods

The study's main objective includes a surveying and technical assessment of the previous shelters in relation with safety, management options; identify gaps, inputs for improvement of future construction of shelter. Tamil Nadu has 13 coastal district facing high impacts due to natural calamities such as Cyclone, storm surge, Tsunami and etc., among them Cyclone cause severe damage frequently due to climate change it needs proper planned and analyzed coastal structure to prevent and protect coastal communities from the impact of Cyclone. In this study mainly focuses on planning, analysis and design of Circular Cyclone Shelter for this the analysis has been made for Live load, Dead load and Wind force using STAAD-Pro. Software.

During analysis consider the environmental conditions such as maximum wind speed, storm surge and maximum wave height has refereed from adopted Guidelines 2006 for Design and Construction of Cyclone Shelters. From this for design calculation maximum wind speed has considered 50 m/s (180 km/hr) and maximum storm surge has considered 10 meters. The circular cyclone shelter design also included a qualitative comparison of existing rectangular cyclone shelters, which is discussed in detail in the end result.

Analytical Investigation

Comparing the rectangle Cyclone Shelter and circular Cyclone shelter with various parameters like dead load, live load and Wind load by using STAAD.pro (Structural Analysis and Design computer program). During the analysis has considered the probability of cyclonic wind speeds are often exceeding the regional basic wind speeds in the coastal area, revised IS 875 Part-3: 2015. To presented the K_4 factor that is Cyclonic importance factor, for augmenting the design wind speed (V_z) with numerical values 1.15 and 1.30 for Industrial structure and post-cyclone significance structures correspondingly (Baswa et al, 2017).

Therefore, factor k_4 has been introduced with a maximum value of 1.30. However, the maximum value may be used only for structures of post-cyclone significance such as Cyclone Shelters, Hospitals, School, Colleges and community buildings, communication towers, Power-plants and water tanks, while a minimum value of 1.15 may be used for industrial structures, damage to which can cause severe economic losses. The reasons of economy; other structures might be designed for a k4 value of unity that is without considering the cause of the probable higher wind speeds in cyclone. Input values from the wind speed, wind pressure and wind load calculation to analyze the both shelters by STAAD-Pro. Design wind speed $V_z=V_b\ k_1\ k_2\ k_3\ k_4$ (Where, V_b = basic wind speed 61 m/s (220 Km/hr) as per IMD, Chennai for Super Cyclone, k_1= Probability factor 1.07, k_2= terrain height, structure size factor as shown in table 1, k_3= Topography factor Data 1.0, k_4= Cyclonic importance factor 1.30) therefore V_z= 84.85 k_2^2 m/s. and Design wind pressure $p_d= k_d\ k_a\ k_c\ p_z$ (Where K_d= Wind directionality factor 1.0, Ka= Area averaging factor is 0.90, k_c= Combination factor 0.90) Wind pressure calculated according to the height of the shelter 20 m, therefore Design wind pressure pd=3.56 kN/m^2 as shown in table 1.

Table 1: Design wind pressure (pd)

Height in Meter	**K_2**	**pd = 3499.2 K_2^2**	**kN/m^2**
10	0.91	2897.6	2.89

15	0.97	3292.3	3.29
20	1.01	3569.5	3.56

Design wind load acting on the shelter is F= Cf Ae pd (Where, Cf= Force coefficient 0.6, Ae= Effective frontal area 6, Pd =Design wind pressure pd = 3499.2 K_2^2) so the Design wind load F= 3.6 pd and F is calculated as per Table 2,

Table 2: Design Wind Load

Height in meter	**Design Load F=7.32 pd N/m**	**F kN/m**
10	3.6 x 2897.6 = 10431.36	10.43
15	3.6 x 3292.3 = 11852.28	11.85
20	3.6 x 3569.5 = 12850.20	12.85

To change the uniform load into point load and the loading at the top of the shelter and bottom of each area in change of nodes must be determined & assumed as uniform above the area. The loads at the middle of these areas are calculated from design wind load by interpolation method. The point loads performing at nodes are calculated as shown in Table 3,

Table 3: Calculation of Nodal point loads

Node	**Loading level (m)**	**Load kN/m**	**Nodal point load kN**
6 – 6 (17.75m)	+16.25 to 19.25	12.85	12.85x3= 38.55
5 – 5 (14.75m)	+13.25 to 16.25	11.99	11.99x3=35.97
4 – 4 (11.75m)	+10.25 to 13.25	11.23	11.23x3= 33.69
3- 3 (8.75m)	+7.25 to 10.25	10.47	10.47x3= 31.41
2 – 2 (5.75m)	+4.25 to 7.25	10.43	10.43x3=31.29
1 – 1 (2.75m)	+1.375 to 4.25	10.43	10.43x2.875= 29.98
G – G (-0.25m)	+0 to 1.375	10.43	10.43x1.375= 14.06

Applying the nodal point loads for the both Circular Cyclone Shelter as well as the existing Cyclone Shelter and also considered the dead load and live load for the given wind load, using STAAD.Pro software Results under loading condition shown in Figure 1 and Rendering view of Circular Cyclone shelter shown in Figure 2.

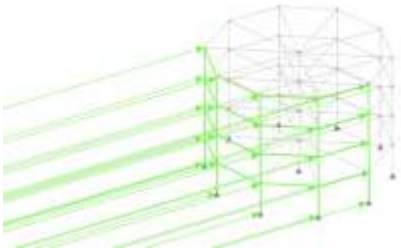

Figure 1: Circular Cyclone shelter under loading condition

Figure 2: Rendering view of Circular Cyclone shelter

The rectangular Cyclone Shelter was analyzed for the dead load, live load and wind load using STAAD.Pro software. Its results of under loading failed condition shown in Figure 3 and Rendering view of Circular Cyclone shelter shown in Figure 4.

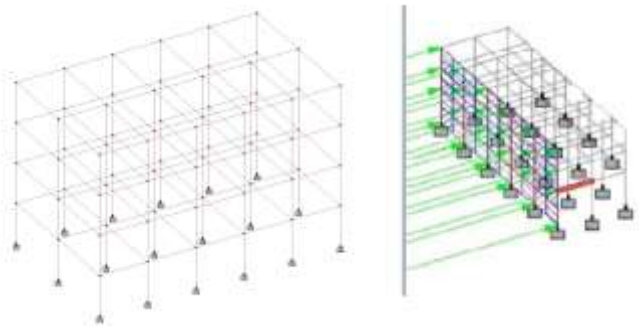

Figure 3: Rectangular cyclone shelter under loading failed condition

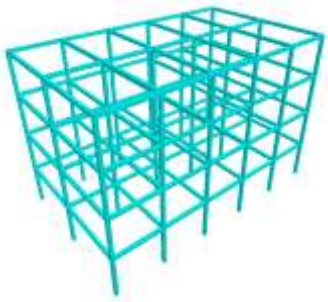

Figure 4: Rendering view of rectangular cyclone shelter

The proposed cyclone shelter design is circular in shape to withstanding the high intensity of cyclone impact with the shear wall. Shear wall provide great strength and rigidity in the direction of orientation and significantly decrease the lateral sway. It's easy to construct and implement and efficient in terms of construction rate and minimizing cyclone damage. Structural elements based on 2006 Guidelines for Design and Construction of Cyclone Shelters, and shear wall design as per IS 13920:1993 (Reaffirmed, 2003). The circular cyclone shelter 4 meter elevated from the ground to avoid flooding during and post cyclone. The shelter's roof has a helipad to transport patients to the hospital in the event of a medical emergency where the ground routes are obstructed by the flood.

Storm Surge varies based on coastal morphology, bathymetry, and nonlinearity. During analysis and design of shelter to consider the environmental conditions of that coast have to collect data (GDCCTS, 2006). This circular cyclone shelter can withstand any environmental force and resist strong winds but other time of shelter like rectangular structures could not withstand because the longer section of the rectangular structure built parallel to the coast shown in Figure 5.

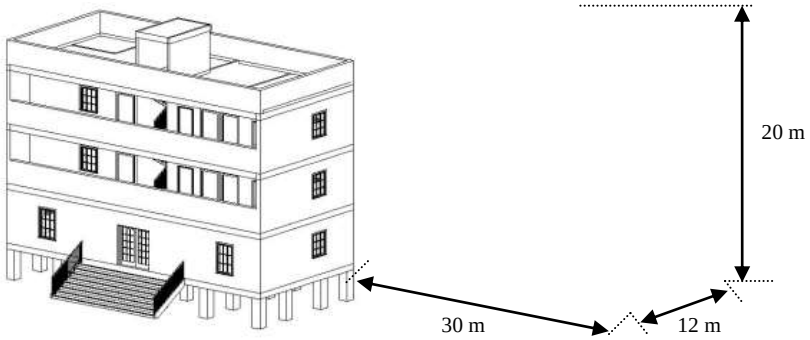

Figure 5: Elevation view of rectangular cyclone shelter

High rise buildings can be susceptible to risky motion during wind events that can cause occupant discomfort and decrease the overall appeal of the structure (Kareem, 2005 and Bitsuamlak, 2009). Shape of the building, wind extremes environmental condition and cost of the construction also should be considered while construction. (Peter A et al. (2008). The proposed Circular Cyclone Shelter should act as the perfect aerodynamics structure during Super Cyclones and withstand as shown in Figure 6.

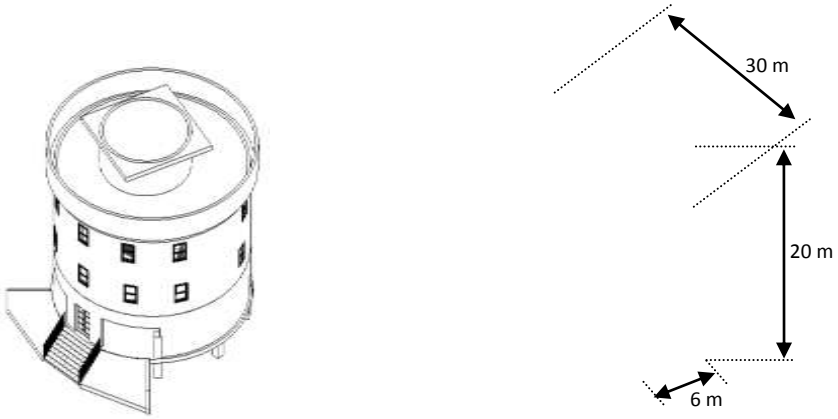

Figure 6: Elevation view of Proposed Circular Cyclone Shelter

3. Results and Discussions

Already exiting rectangular shelters are not safe during Sever Cyclone activity based on the various Load analyses by the STAAD-Pro. The rectangular shelter was not withstanding while giving lateral force equal to Super Cyclone wind speed 220 kN/hr but the circular shelter withstands extreme wind load as shown in figure 7, during disaster also winds and high waves travel naturally around a circular shelter rather than getting caught on corners. A circular roof also avoids 'air-planning' where strong winds can lift the roof structure off the building (Claire L Cardwell, 2018).

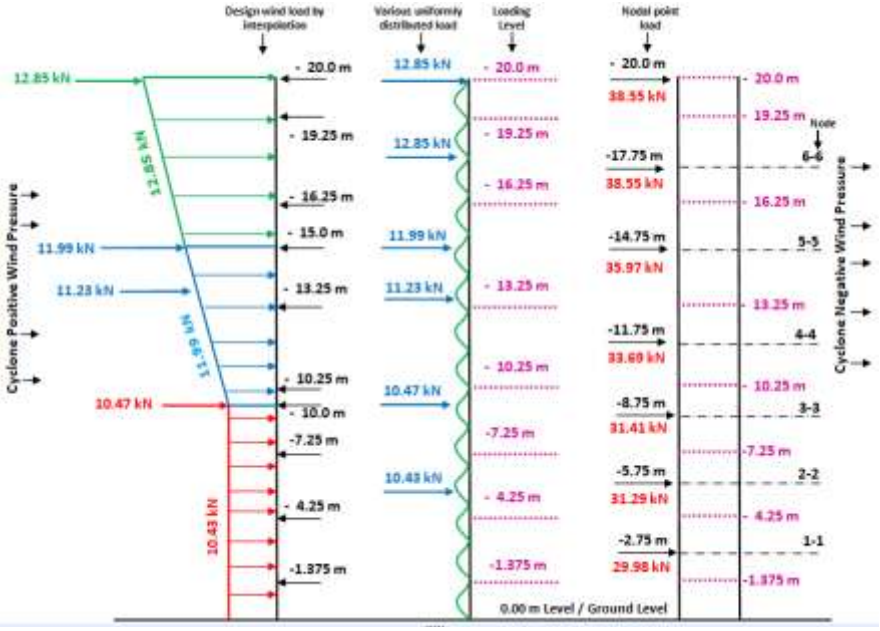

Figure 7: Cyclone wind pressure and wind load acting at nodal point

The common finding from this study analysis recommends the circular shelter is suitable for any environmental condition compare to other existing shelters for protection measures (Biswanath Dash, 2016). The circular Cyclone shelters will be used as evacuation centers and livestock storage during cyclones and protect against storm surges. Cyclone shelters will be very useful in remote coastal people. The development of the circular cyclone shelter from the old requires suitable structural analysis and design to withstand super cyclones and storm surges. Old Cyclone Shelters are not safe for high intensity Cyclones in Odisha, West Bengal and Myanmar (UN-HABITAT, 2012).

4. Conclusion

The study has analyzed existing shelters and circular shelters in STAD-Pro. using different kinds of loads and assessed existing cyclone shelter both quantitatively and qualitatively on different structural and non- structural aspects and use of cyclone shelters. This analysis concludes the circular shelters suitable for establishment in specific locations along east coast of Tamil Nadu, South India for evacuation and saving properties during worst situations caused by cyclones.

Author Contribution

Anburaja Durai – Conceptualization, methodology, writing, original draft preparation.

Nagalakshmi Radhakrishnan – Resulting, Reviewing and discussion.

Data Availability

All the data generated or analyzed during this study are included in this published article.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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