Design, Analysis and Feasibility Study of Cyclone Shelter Using BIM and ETABS Software

S. S. Khatu[1], P. D. Mahadik[1], S. J. Chikhale[1], Y. R. Kulkarni[1]*

Abstract

India is having long coastline of 7516 km of which 10% hit by the tropical cyclones several times. The east coast of India is particularly prone to the cyclonic situation. Besides this, the storm surges and rarely occurring but devastating natural hazards like Tsunamis are also creating coastal population vulnerable and at risk for these natural events. To mitigate these types of hazards, cyclone shelters are the most important structural mitigation measures. Therefore, we attempted to prepare the Cyclone Shelter model in REVIT software and ETABS software. We studied and prepared a plan as per the government specified norms and Regulations. This plan is used in REVIT for structural design and then subjected to structural analysis to test various loads. We modified the specified design as per the space utility, usage of modern material and convenience of people in distress during disaster event. The structure designed is successfully tested in ETABS for dead load, live load, Earthquake and wind load. We suggest the use of advanced civil software for design, analysis and feasibility check in such structural mitigation measures as a rapid tool.

Keywords: *Cyclone shelter, Disaster, BIM, ETABS*

1. Introduction

Cyclone and storm surges are among the most destructive of all-natural disasters. The region of the world which are vulnerable to such disasters include the island in the South-West Pacific, South-East Asia (e.g., the Philippines, Viet Nam), Countries adjoining the

[1] **S. S. Khatu, P. D. Mahadik, S. J. Chikhale, Y. R. Kulkarni,** Department of Civil Engineering, Gharda Institute of Technology, Ratnagiri, India 415708

* Corresponding Author Email: yrkulkarni@git-india.edu.in

Bay of Bengal (e.g. India, Bangladesh and Myanmar), South-East Africa, the Caribbean and parts of the USA and Latin America around the Gulf of Mexico and Atlantic Ocean. India has a long and tragic history with cyclones. The Indian subcontinent is one of the worst affected regions of the world when it comes to tropical storms. On an average 10% of the coastal area of India is hit over by the tropical cyclone on an year (NDMA report, India). Particularly the East coast of India faces this natural hazard every year. On the other hand, West coast of India, which was considered relatively safe for cyclonic events, is facing increasing numbers of cyclones postulated as result of Climate Change. Cyclone shelters are the first line of defence against calamities such as cyclones surges (Choudhury et al., 1994), (Hoqueet al., 1994). They are the Buildings constructed on elevated ground to withstand wind speed, moderate earthquake and storm surges. These are the mitigation measure for the threats caused by the Cyclone, Floods, Inundation, and Earthquakes etc (Akm Saiful et al., 2011), (Bosuniaet al., 2011). These are the structures proposed worldwide by the specifications given by Disaster Management Authorities for their respective countries. There are different types of design of cyclone shelters designed in different countries (Figure 1). In case of India, Government of India specified the norms for the construction of Cyclone shelters (GOI-UNDP DRMP Report, 2006)

Figure 1: Design of Cyclone Shelter in various Countries

2. Review of Work on Cyclone Shelters

Majority of studies on cyclone shelters are carried out in Bangladesh and Myanmar as they are the most affected countries due to large tropical cyclones. (Mahmood et al.,2014) studied the state of multipurpose shelter in Bangladesh. They have explained overview of cyclones and cyclone shelter management in Bangladesh. Community needs, requirements in designing and finalization of proposed shelter locations are important. (Faruk et al., 2018) carried out analysis of inclusiveness and accessibility of Cyclone Shelters in Bangladesh, they have described widely accepted inclusive design principles and design standards that can make shelters more user friendly, accessible and inclusive. (Okazaki et al., 2018)carried out a case study on use of cyclone shelter in Bangladesh, They have described that these shelters have saved many lives; they could not accommodate all the residents of the cyclone high-risk areas located on islands in coastal deltas.

(Bihari and Mukherjee, 2015) in their work studied the architectural design strategies for Primary School cum Cyclone Shelter in coastal areas, they have explained that primary schools can be converted into cyclone shelters to greatly reduce the devastation caused by cyclones in India and proved that cyclone shelters are an economical and affective way to save many lives. (Danilo and Ray, 2017) in their work studied a shelter for the victims of the typhoon Haiyan in the Philippines the design, they have said the shelter mostly used locally sourced materials, manpower and understanding the needs and requirements of the users (Belinda et al., 2015) study the post-disaster shelter design and CPoDS. They have explained that there are numerous temporary sheltering projects but there is no perfect shelter which is economic and can be mass-produced and implemented rapidly and respond all the needs of a shelter, and the needs of the survivor. (Arunachalam et al., 12) reviewed the cyclone disaster mitigation in Indian scenario and challenges for future. They have explained reliable forecasting, quality construction, effective decision support systems and policy implementations are some of the future challenges for combating the fury of natural disasters. (Coulbourne et al., 2002) in their research paper, reviewed design guidelines for community shelters for extreme wind events. They have explained about minimum loads, design and construction standards for shelters are needed as communities are presently designing and constructing such structures.

3. Methodology

To design the cyclone shelter we have followed the following process (Figure 2):

1. Initially, we started checking the feasibility of various shapes such as Hexagon, circle and other traditional shapes. Hexagon and circle are perfectly aerodynamic but there was no roominess so we skipped these shapes resulting in more empty space outside the rooms also.
2. Therefore, we decided to go with the Sqircle shape as both the aerodynamics and roominess was maintained.
3. We have decided to take average population for the villages located on coast of Ratnagiri district, Maharashtra to decide the area of structure. This is because the frequency of cyclonic events is increasing in recent years and Ratnagiri is one of the mostly affected regions along west coast of Maharashtra.
4. Further, we designed the basic plan in AutoCAD in order to facilitate it in REVIT
5. The actual architectural model is developed in REVITREVIT software (V20). The norms are used as per government specified (GOI-UNDP DRMP Report, 2006).
6. The architectural model along with structural elements then used in ETABS for the various loads like Dead load, Live load, Earthquake and Wind load.

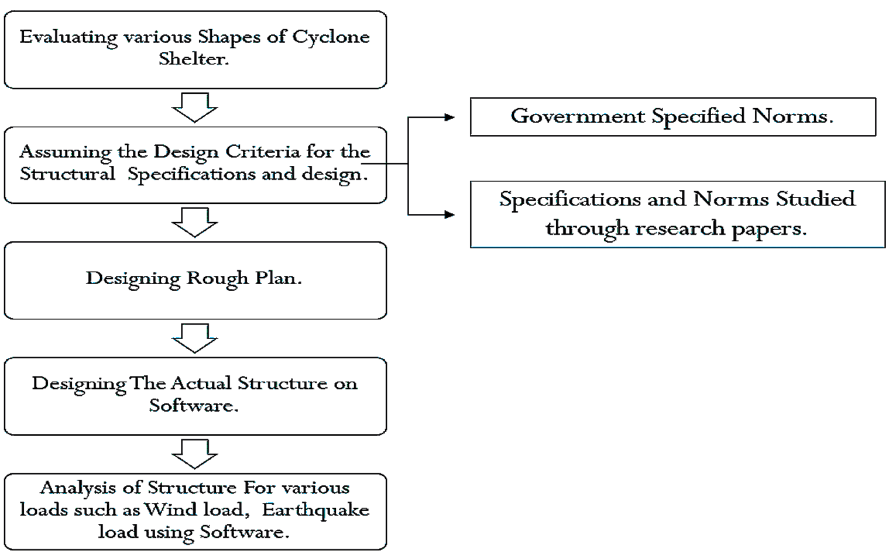

Figure 2: Methodology Adopted for the Present Study

4. Results and Discussion

4.1 Architectural work using REVIT: For the making of structural plan Autodesk AutoCAD is used and For Designing of structure Autodesk REVIT is used.

Step 1: For structural plan in AutoCAD we consider lot of designs like circle, hexagon, rectangle, etc. but those are not economical or aerodynamics. Hence, we finalized design called Squircle which is combination of Square and circle (Figure 3a). Due to its unique shape this plan works as aerodynamic structure. Rounded corners provided in plan are very helpful for diverting high wind flow during cyclone. After finalizing plan we imported same plan in REVIT and created centerline plan version in REVIT (Figure 3b).

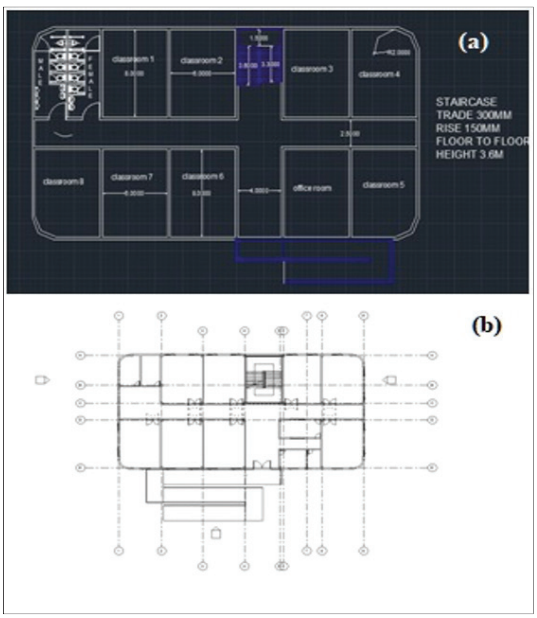

Figure 3: (a) Architectural Plan (b) Centreline Plan

Step 2: After creating centerline plan we are ready to work on building structure. We designed Pile foundation, Plinth, Column, Beam, Slab, Stairs, Ramp, etc (Figure 4). The specifications are used as follow: Foundation size: 2.5x2.5x0.5m, Pile: dia-0.5m, ht-6m, Column size: 300x450mm, Beam size: 300x600mm.

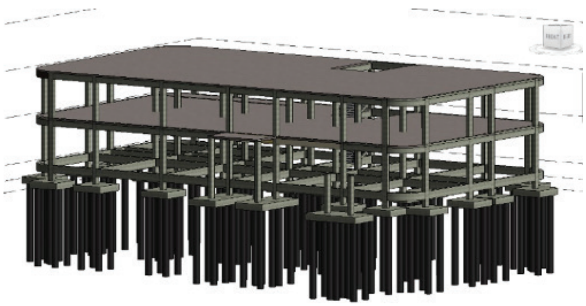

Figure 4: Structural Components

Step 3: After finishing with Structural component, we have to work on Architectural Components such as Walls, Doors, Windows, Floor, etc. (Figure 5). We keep the wall material of AAC Block, door material of Wood and window material as Fiber Reinforced Plastic (FRP) material. FRP has higher resistance than steel and low thickness to withstand the heavy wind forces during the cyclone events.

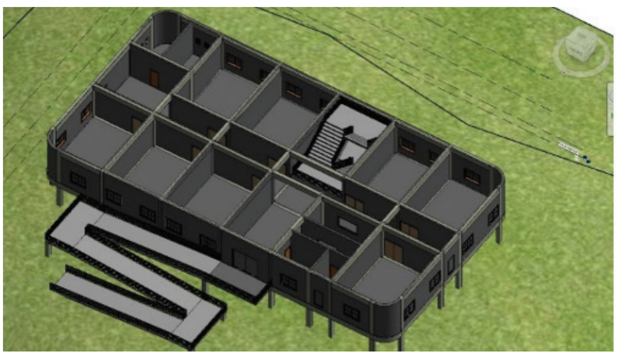

Figure 5: Architectural Components

During designing of architectural components, we took care of economy as well as stability. Also we studied cyclone shelter guidelines and make some changes considering that the structure is different than regular building. The changes made are enlisted follow:

- Provision of Wide Ramp for main entrance.
- Provision of Stairs at back as an emergency exit.

- Provision of Outward opening Doors.
- Provision of windows with FRP
- Provision of separate space in washroom for handicap people.
- While making of this structure we also consider guidelines of school so that we can use this structure as primary school also while there is no cyclone condition.

Step 4: After finishing with architectural components, we started work on Plastering walls, Washroom-component, furniture, Ceiling, Lighting, Paint etc. (Figure 6a). For making model complete outer look is also important. So, after completion of finishing work we started work on outer design, exterior lighting, topography, nature components such as trees, etc. (Figure 6b).

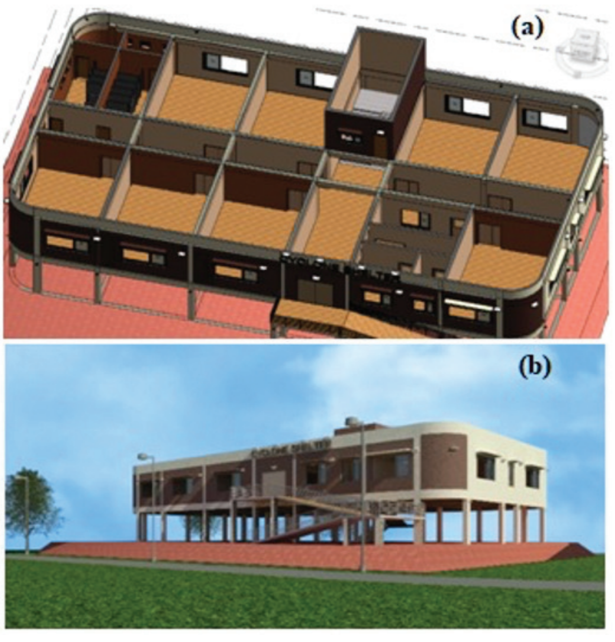

Figure 6: (a) Finishing Work (b) Rendered Model

Step 5: (Providing school components for regular use of structure). After completing cyclone structure, we fill those rooms with school furniture so that we can use this structure as Primary School for regular days (Figure 7) and while cyclone condition this building can work as a Cyclone Shelter.

Figure 7: School Furniture

4.2. Design and analysis work using ETABS: After Completing this work in REVIT our model became ready for analysis study in Etab. Center line diagram is prepared and imported to ETABS model and the following steps by steps procedure are followed.

Step 1: (Defining of property): Select define menu > material properties. Add new material in the defining material property the concrete of M30 and steel of grade FE 500. For our work the size of structural components (beam, columns and slabs) are taken as per the requirement.

Table 1: Beam, Column and Slab Details

Beam No.	Size	Column No.	Size	Slab	
Beam 1	300*400	Column 1	300*450	Material	Concrete
Beam 2	300*450	Column 2	300*500	Type	Membrane
Beam 3	300*500			Thickness	150 mm

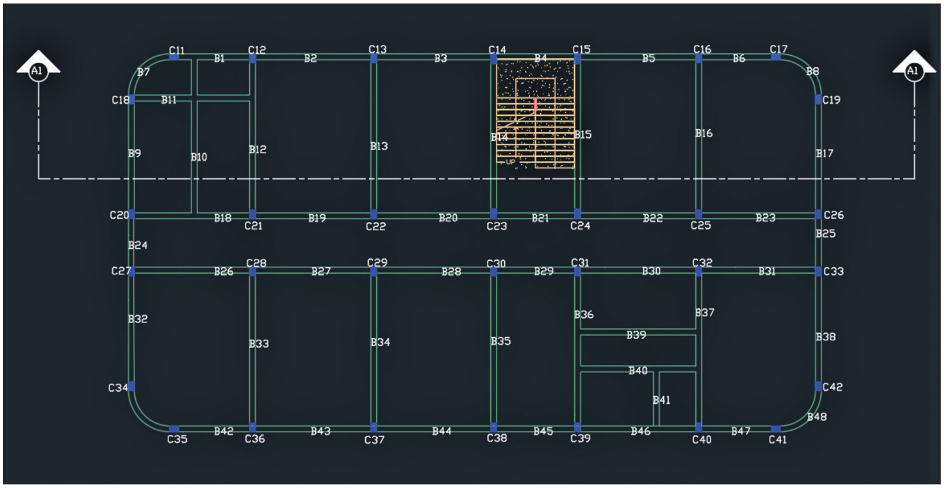

Figure 8: Structural Layout of the Plan

Step 2: (Assigning of property and support): After defining the property we have to draw the structural component and using command menu>draw line for beam and draw column in region for column (Figure 9). By keeping the plan at the base of the structure and selecting all column supports are assigning by Assign menu>joint/frame>restraints, (supports)>fixed.

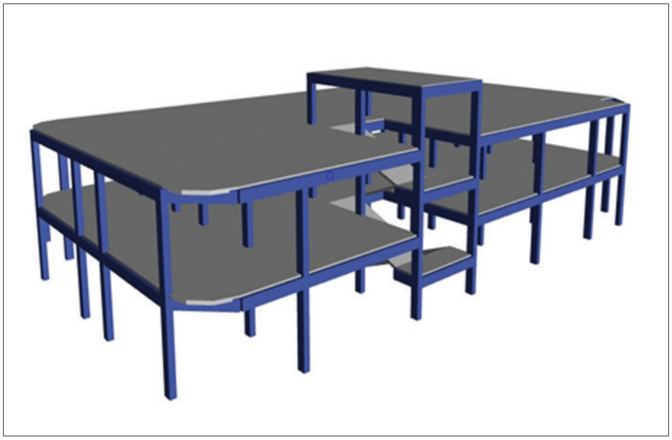

Figure 9: ETABS 3D View Model

Step 3: (Defining of load): The loads in ETABS are defined as using static load cases command in define menu (Figure10).

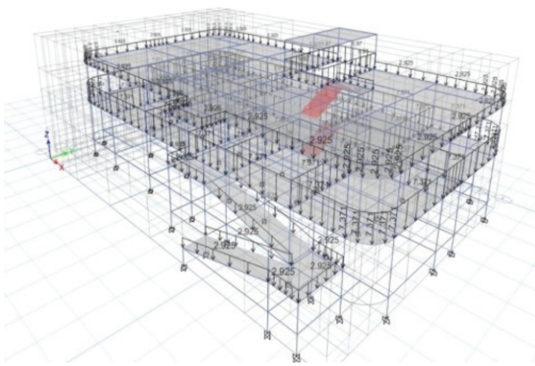

Figure 10: Wall Load Assign

Dead Load: (IS 875 part 1): The dead loads are permanent loads which result from the weight of the structure itself or from other permanent attachment, In dead load case self-weight of structure is automatically taken by ETABS just we have to take self-weight multiplier as 1.

Live Load: (As per IS 875:1987 (part 2)): Live loads are temporary loads; they are applied to the structure on and off over the life of the structure. The imposed loads, specified herein, are minimum loads which should be taken into consideration for the purpose of structural safety of buildings.

Classroom & lecture room = 3 Kilo Newton per square meter (KN/m^2)

corridors and passages = 4 KN/m^2

Toilet and washroom = 2 KN/m^2

On roof -if accessible = 1.50 KN/m^2

-if not accessible = 0.75 KN/m^2

Super Imposed Load: (IS 875 (part 1) This load is mainly caused on structure by the nonstructural elements of building such as tiles stones, partitions, filling material and plastering.

Wind Load: (As per IS 875 (part 3)): Buildings are subject to horizontal loads due to wind pressure acting on the buildings. The wind loads acting on exposed surfaces of a given storey are idealized to be supported by upper and lower floors. Here in software are

(ETABS) we are not defining load pattern as per directly IS 875 (part 3): 2015 because by inputting CPi and CPe values we don't get to know what is wind load before analysis so here we are calculating wind load as per IS 875 (part 3): 2015 and apply the load as per storey height with respect to different condition and parameters.

Earthquake Load: (As per IS 1893:2000): Seismic loading which means application of an earthquake-generated agitation to a structure. It happens at contact surfaces of a structure either with the ground, or with adjacent structures, or with gravity waves from tsunami. These are some important factors are considering while designing the earthquake load in ETABS.

For X direction and Y direction

– Response reduction R = 5

– System = SMRF (Special Moment Resisting Frame)

– Seismic zone factor Z = 0.16

– Silt type = II for Medium Soil as per Table 4 of IS 1893 (Part 1): 2016

– Importance factor = 1.5 as per Cl.7.2.3 and Table 8 of IS 1893 (Part 1): 2016

– Percentage of Imposed Load to be Considered in Seismic Weight = 25% for LL is up to 3 kN/m^2

as per Cl.7.3.1 and Table 10 of IS 1893 (Part 1): 2016

Step 4 (Analysis): After the completion of all the above steps analysis was performed and checked for errors (Figure 11). We used (A11:1.2(DL+SIDL+LL+WLX)) [kN-m] load combination as a sample for deformation.

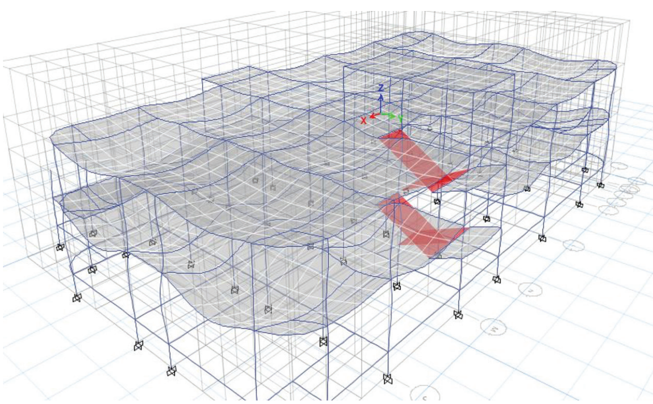

Figure 11: Deformation Views After Analysis

Shear and bending moment diagram are analytical tools used in conjunction with structural analysis to help perform structural design by determining the value of shear forced and bending moment at a given point a structural element such as beam. We have analyses and created shear and bending moment in our model and the results show stability throughout the structure (Figure 12).

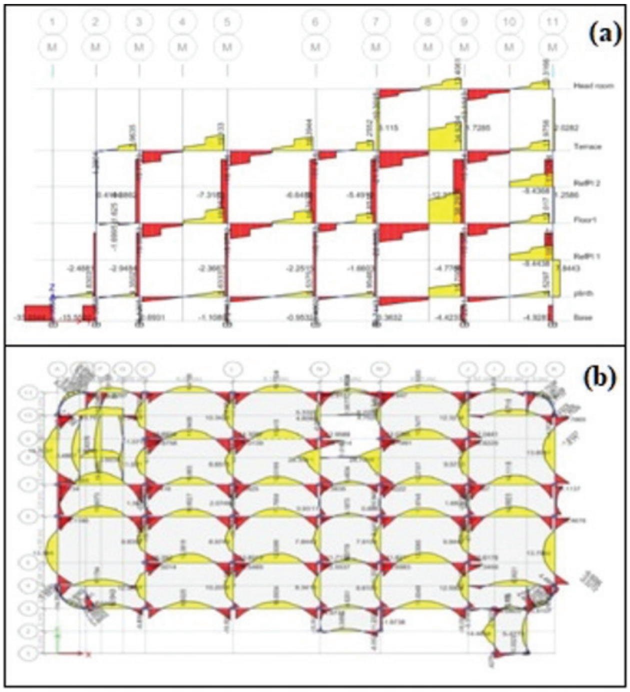

Figure 12: (a) Shear Force Distribution (b) Bending Moment Distribution

Step 5 (Design): After the analysis is over design of the structure elements was done as per IS 456:2000 guidelines. For this go to design menu>concrete design>select design combo after this again go to design menu>concrete frame design>start design/check of structure then ETABS performs the design for every structural element (Figure 13).

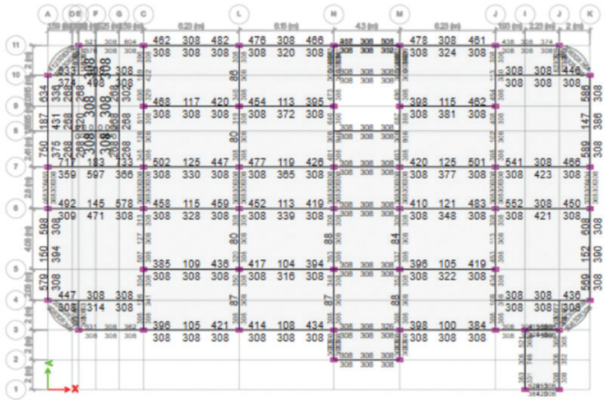

Figure 13: Longitudinal Reinforcement Design

5. Conclusion

Recent trend of increasing cyclonic events along west coast of India suggesting for more disaster resilient infrastructure to be created for this natural hazard. The Nisarg Cyclone in 2020 gave us an example for the need of disaster mitigation structure, particularly in rural population along coast line. The use of software in overall process of the development of disaster resilient structures is necessary for expeditious and accurate development. In this study we attempted to design the Cyclone shelter in REVIT and ETABS with government specified norms and additional changes were made for better stability of structure and ease of movement for distressed people during cyclone event. We made modification to material for the better strength. Structural component like beam, slab, column and footing are designed manually and the results obtained from ETABS software are compared with manual method. The structural analysis by using ETABS software show the structure is withstand to all types of load. Calculation by both manual as well as software analysis gives almost same results. We suggest that use of software for design and feasibility study for structural mitigation measures will be helpful for rapid progress in work and efficiency in the structure for disaster prone regions. This study further demand the use prototype and model based approach with the simulation for further analysis.

Acknowledgment

We thank to our Principal and Head of Department of Civil Engineering, Gharda Institute of Technology (GIT) for the necessary support. We are also thankful to all the faculty of the department of Civil, GIT for their significant inputs time to time during the project evaluation process. We are also thankful for the reviewers for their significant inputs in improvement of manuscript.

References

1. Choudhury, Jamilur R, (1994) "Cyclone shelter and its multipurpose use." Proceedings of the IDNDR Aichi/Nagoya International Conference..
2. Hoque, Abdul, and Abu Mohammad (1994) "Cyclone shelter planning for disaster management and community development in Bangladesh: a case study of Khurushkul union of cox's bazar district.".
3. Islam, Akm Saiful, et al. (2011) "Performance of coastal structures during Cyclone Sidr." Natural Hazards Review 12.3: 111-116.
4. Bosunia, M. Shamim Z., and P. Eng. (2010) "Design Criteria for Shelters in Coastal Areas of Bangladesh Under Multipurpose Cyclone Shelter Program." Wind Storm and Storm Surge Mitigation 4: 94.
5. Guidelines for Design and Construction of Cyclone/Tsunami shelters, GOI-UNDP DRMP Report, 2006
6. Mahmood, Muhammad Nateque, Subas Prasad Dhakal, and Robyn Keast. (2014) "The state of multi-purpose cyclone shelters in Bangladesh." Facilities .
7. Faruk, Mohammad, SyedaAtia Ashraf, and Muhammad Ferdaus. (2018) "An analysis of inclusiveness and accessibility of Cyclone Shelters, Bangladesh." Procedia engineering 212: 1099-1106.
8. Miyaji, Mari, Kenji Okazaki, and ChihoOchiai. (2020) "A study on the use of cyclone shelters in Bangladesh." Japan Architectural Review 3.4: 590-600.
9. Bihari, D. A. and Mukharji Shreya (2015) Architectural Design Strategies for Primary School cum Cyclone Shelter in Coastal India.
10. Ravina, Danilo, and Rowell Ray Shih. (2017) "A shelter for the victims of the Typhoon Haiyan in the Philippines: The design and methodology of construction." Pollack Periodica 12.2: 129-139.
11. Torus, Belinda, and Sinan MertŞener. (2015): "Post-disaster shelter design and CPoDS." A| Z ITU Journal of the Faculty of Architecture 12.1 269-282.
12. Arunachalam, S., SelviRajan, and Prem Krishna. (2015) "Cyclone Disaster Mitigation-Indian Scenario and Challenges for Future." Wind Engineers, JAWE 40.3: 283-289.
13. Coulbourne, William L., E. Scott Tezak, and Therese P. McAllister. (2002) "Design guidelines for community shelters for extreme wind events." Journal of Architectural engineering 8.2: 69-77.