Feasibility Study of Dodecahedron Shaped Deployable structure as Distress Relief Shelters

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Abstract: India is prone to substantial amount of disaster by natural calamities, manmade disaster and nuclear hazards. Disaster risk can be further augmented by assailability of changing demographics, indigent socio economic conditions, and unplanned population migrations. Disaster relief shelters play an indispensable role in disaster response and recovery system. Disaster relief shelters provide privacy and security for people. Deployable structures have the competency to transform and adopt multiple predetermined configurations in an anticipated way. The deployment is done through known paths in safe and controlled manner. Ease of transportation, erection, overall sustainability by high material efficiency, maximum use of natural resources are the key characteristics that enhance the usage of deployable structures as distress relief structures. Abiding by National Disaster Management Authority of India's 'National Guidelines on temporary shelters for disaster affected families; the dodecahedron shaped disaster relief shelters will serve its purpose. Distress relief shelters not only serves as housing for natural calamity affected population but also for the refugees migrating. This paper will present the 2D and 3D design of deployable structure using Building Information modeling for the use of disaster relief shelters. Apart from it, usage of distress relief shelter is discussed and detailed literature review is provided.

Keywords — BIM, Deployable structure, Distress relief shelters, Dodecahedron, Low cost housing, Umbrella mechanism.

I. INTRODUCTION

A. Deployable structure

The deployable structures in the field of construction was first introduced in 20th century. The allowance of structure to be packaged into a small configuration for ease of transportation and to be expanded when needed made this deployable construction technology a novel and unique type of construction. Retaining the workability, operability, serviceability, of the traditional structures, the deployable structures are able to undergo large variations in configuration in a controlled and free manner. Deployable structure can transform and adopt multiple predetermined configurations. The deployment is always done through a safe and controlled way. Deployable structures have many potential applications ranging from emergency shelters and other temporary or permanent facilities. Small volume they occupy during storage and insulation, and their fast and easy erection procedure serves as their main advantage. A new concept of self-stabilizing deployable structures featuring stable, stress-free states in both deployed and collapsed configuration shows even higher promise. Nowadays deployable structures have their members connected in the factory, to satisfy a set of preassigned geometrical constraints. Interesting forms and design solutions that can satisfy the high aesthetic demands of modern architectural works can be obtained with formation of folded structures. The criteria for the construction and estimate of modern folded structures formed of different materials have led to improvements in systems of spatial structures, all in order to achieve contemporary creative engineering solutions.

B. Building Information Modeling

BIM is a model based intelligent process, which provides insight to help us plan, design, construct, infrastructure and maintenance. BIM goes further than the traditional CAD does by providing configurations to design each components of the building. The BIM allows users to access information of the building right from initial stage to entire project life cycle. BIM helps to connect all the professionals throughout the project life cycle of the building. BIM should not be considered as a software but as the process of creating and using digital models for design, construction and operations of the buildings. BIM models combine 2D and 3D objects to define building designs, along with external factors like geographical locations and local conditions, into virtual building database. This database provides a single, integrated source of all information associated with the project. BIM can be defined as digital representation of physical and functional characteristics of a facility. The

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model is used for analysis to explore design options and to create visualization that helps users to understand how the building will look before the construction. Digitalization is the future of construction industry. BIM is the future of digital design and long-term facility management. Many different disciplines can take advantage of its benefits in the same platform. Thus making the usage of BIM in construction industry is very important. Not only standard buildings can be designed, but also many sophisticated and complex structures can be designed using BIM.

C. Deployable Distress relief shelter

The shape geometry, mechanical properties, material characteristics, deploying pattern with a kinematic behavior and the adaptability to external climatic conditions promotes this deployable structure in distress relief shelter construction. These types of deployable construction are usually practiced in foreign countries. Though India has many new construction technologies blooming, deployable structure construction is still a non-familiar construction technology. Due to its complexity in designing and hesitation in adaptation of new construction technology among population, deployable structure remains a non-familiar technology to Indian population. Though deployable structure construction is practiced in other well-known countries, it is a very high cost consuming type of construction. Modifying the shape configuration, material, transportability, assembly, deploying pattern, we can reduce the overall cost of the structure.

Dodecahedron shaped distress relief shelter is a new of its kind. Due to its deploying pattern of folding and unfolding conditions, it can be easily stored and transported to distress affected locations. The deployable shelters can be transported in folded conditions, creating accessibility to transport more number of shelters to the affected area. The material of which this dodecahedron deployable shelters are locally available. Thus reducing the transportation of material cost at the place of fabrication. These shelters are usually prefabricated and taken to the sites in need of shelters.

From history of past disasters, different states have adopted variety of approaches towards provision of shelters to the disaster-affected population. This history of practice provides us with wide range of experiences, knowledge and possibility to learn the future needs.

The complex use of land, lack of open spaces, stocking of existing shelters and damages incurred to it, different lifestyle patterns, infrastructure, different occupation and the urban settings gives a different context of temporary shelters. In this case deployable construction technology will be the solution most looked on. Sanitation is one of the key technology requirement in disaster relief shelters particularly in flood-affected areas where conventional toilets cannot be functioned. In such conditions, temporary Eco-San toilets can be used. These types of technical options should be included in design of disaster relief shelters. In case of dodecahedron deployable structure, it is designed with sanitation and all emergency basic need facilities, thus fulling the serving purpose.

II. LITERATURE REVIEW

Today's deployable structures have their members connected in the factory, so that they satisfy a set of preassigned geometrical constraints. Some examples of deployable structure application includes temporary shelters or bridges for use after earthquake and other emergencies [1]. Deployable structures are structures that can be easily reduced in size for transportation or storage. The number of everyday structures could be classes as deployable tents and umbrellas are two simple examples [2]. Folded structure have found application in architectural buildings and engineering constructions. Folded structures can be made of wood, metal, glass, plastic, polycarbonate [4]. The provision of shelters is widely accepted as a necessary component of response and recovery during disasters. It is not yet clear which type of shelter is most appropriate given various circumstances that can occur in practice. As a result, inappropriate climate, cultural differences, poorly located settings, camp-related social issues, expenses, overcrowding, poor services, and delays have hindered the provision and performance of shelters in certain cases [5]. Foldable housing units also offer advantage of temporary housing in disaster stricken areas. Such units can be folded, portable or panellised and can be packed in a compact way [8]. Deployable structure is a best solution for emergency housing solution in disaster-suffered area for the provision of medical and dwelling services to the victims. Folded portable structure designed from an assembly, that can be transported by road and airway to the site and erected to the site with mini time with suitable mechanism and make transformation to their area by increasing or reducing it with fold and unfold [10]

III. DODECAHEDRON SHAPED DEPLOYABLE STRUCTURE

A. Dodecahedron

The word dodecahedron is derived from Greek word "dōdeka" which means "12" and "hédra" means "seat".

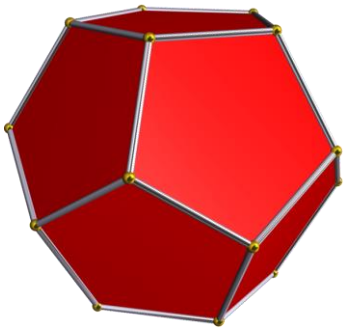

Fig 1: Dodecahedron

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Dodecahedron is a polyhedron, which has 12 faces. A regular dodecahedron is a dodecahedron with 12 regular pentagonal faces. It is one of the platonic solids. Generally, dodecahedron is used to refer to a regular dodecahedron with 12 pentagonal sides. A dodecahedron has 20 vertices or corners, and at each vertex, three edges meet. Dodecahedron has 30 edges. There are two different types of angles in a regular dodecahedron. The angle between sides of the pentagon is 180 degree and the dihedral angle is 116.56 degree. Dihedral angle is the angle between two intersecting planes. In other terms, dihedral angle is defined as union of a line and two half planes that have this line as a common edge. Dodecahedron is a polyhedron because a polyhedron is a solid shape whose faces are all polygons. All the faces of the dodecahedron are pentagons, which is a regular polygon.

B. Material

A fiber reinforced polymer reinforcing system combines light weight, high strength fibers (Glass or carbon) with premium resins to create an externally bonded reinforcing system that is ideal for application to existing structural elements. Fiber reinforced polymer (FRP) also fiber-reinforced plastic is a composite material made of polymer matrix reinforced with fibers. The fibers are usually glass, carbon, although other fibers such as paper or wood or asbestos have been sometimes used. Composites materials are engineered or naturally, occurring materials made from two or more constituents materials with significantly different physical or chemical properties that remain separate and distinct within the finished structure. The usage of FRP composites continues to grow at an impressive rate as these materials are used more in their existing markets and become established in relatively new markets such as biomedical devices and civil structure. FRP composites are light weight, no corrosive, exhibit high specific strengthened specific stiffness are easily constructed and can be tailored to satisfy performance requirements. The usage of FRP composites continues to grow at impressive rate as these materials are used more in their existing markets and become established in relatively new markets such as biomedical devices and civil structures.

It is possible to customize the properties of fiber-reinforced plastics to suit a wide range of requirements. Fiber reinforced polymers typically have impressive electrical and compression properties and display high-grade environmental resistance. One important factor that makes these materials a favorite among different industrial sectors is the manufacturing process, which is quite cost-effective. The rate of productivity is medium to high and a ready bonding is exhibited with dissimilar materials. The other exclusive properties of fiber-reinforced plastics include commendable thermal insulation, structural integrity, and fire hardness along with UV radiation stability and resistance to chemicals and other corrosive materials. The characteristics of fiber-reinforced plastics are dependent upon certain factors like mechanical properties of the matrix and fiber, the relative volume of both these components, and the length of the fiber and orientation within the matrix

Fiber reinforced plastic (FRP) is a type of plastic in which the strength of low strength plastic material is increased by means of high strength of fibers. Fiber reinforced plastics contains to main things one is matrix and another is fiber. The function of matrix is to support and hold the fibers in the correct position. Matrix also prevents fibers from surface damage and environmental conditions. The matrix material should show stability with moisture and temperature. The FRP fibers are the main component, which bears the actual load.

C. Deploying Mechanism

Each side of the pentagon is 6 feet. The total height of the structure is 13.7 feet, formed due to dihedral angle. This is a manually deployable structure. The deployment is carried by the central lever system. The main deploying pattern is designed based on umbrella mechanism. A central stem is provided in the center of the bottom pentagonal plate. This central stem is secured and connected with cross bars in the five direction of the pentagonal edges. The central stem can be unfolded and extended vertically upward. After the extension of the central stem, the levers attached to the central stem is deployed. There are five levers connected to the central stem, in the direction of five edges of the pentagon. These levers are in turn connected to the pentagonal plates forming the dodecahedron. This is the umbrella mechanism. The plates that are connected to the levers are upper plates and lower plates. These plates have central cleft system also known as a division or partition, which allows folding laterally within the levers. The lower plate, which is latched to the top plate, is unlatched and allowed to set in the lower part of the structure. Similarly, all the lower plates will be unlatched from the upper plates. One of the plate from the upper plates will unlatch to form the top most plate of the structure. Step-by-step deployment of the structure is illustrated below.

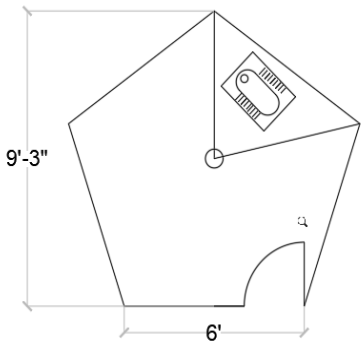

Fig 2: Floor plan

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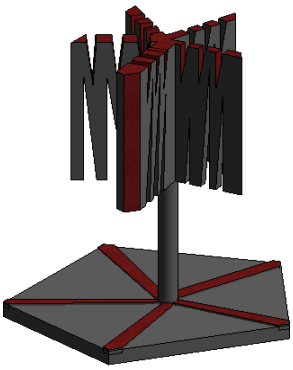

Fig 3: Folded central lever system (shown without the plates)

Fig 4: vertically deployed central stem along with levers deploying (shown without plates)

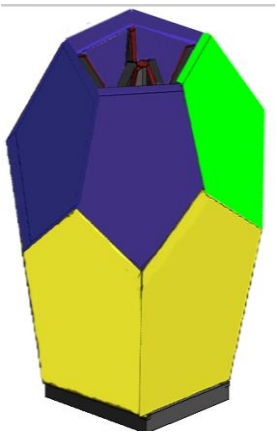

Fig 9: Top most plate provided to only one of the pentagonal side (Green) is latched to

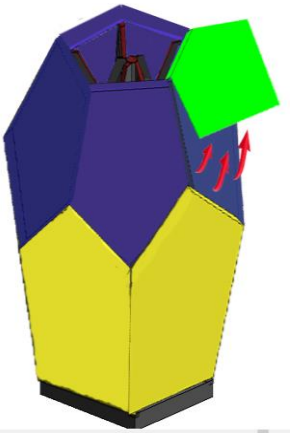

Fig 10: Top most plate (Green) unlatched from the upper plate

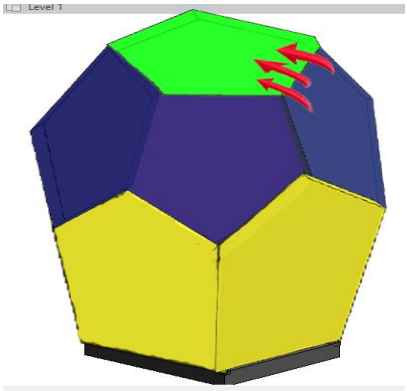

Fig 11: Fully deployed top most plate

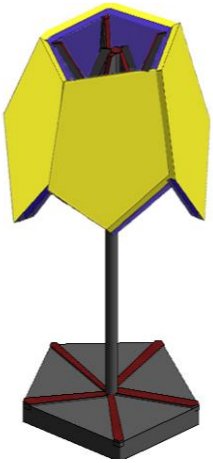

Fig 5: deployed levers with yellow color lower plates and blue color upper plates.

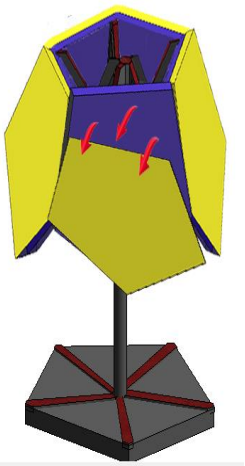

Fig 6: Lower plate (yellow) unlatched from upper plate (blue)

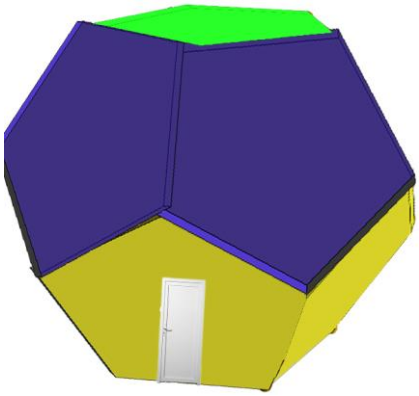

Fig12: Completely deployed dodecahedron structure

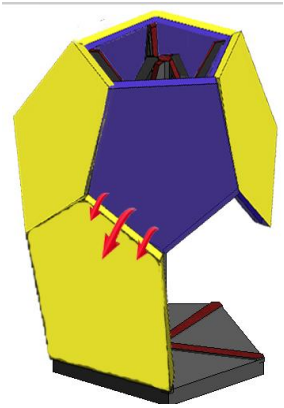

Fig 7: Unlatched plates (yellow) forming lower plates.

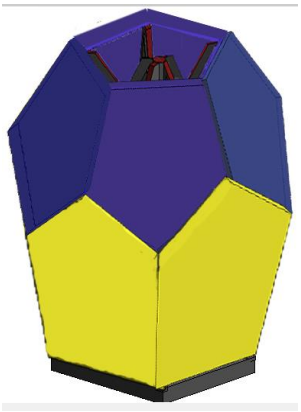

Fig 8: Fully unlatched Lower plates (yellow) from upper plates (blue).

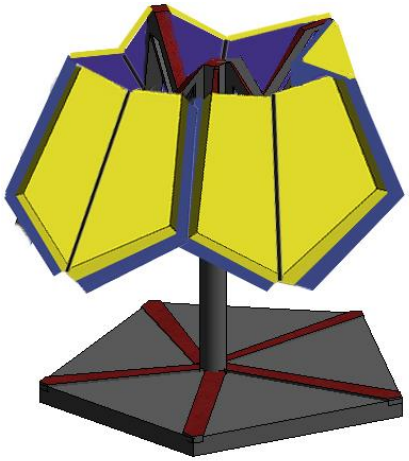

Fig13: Completely folded structure

D. Software used

By using the various platforms of Building information modeling, the dodecahedron shaped distress relief structure is designed. Initially AutoCAD is used for 2D drafting, Revit Architecture is used for 3D modeling, and 3DsMax is used for animation purpose.

E. Sanitation

For sanitation purpose, Eco-San toilets are used. Eco-San toilet is a closed system that does not need water, so it is an alternative to leach pit toilets in places where water is scarce or where water table is high and the risk of groundwater contamination is increased. A considerable amount of land is excavated for the waste collection pit. The dodecahedron structure is placed directly above the excavated hole, aiming to place the eco-san toilet exactly above the excavated pit. Water is not needed necessarily for eco-san toilets. Instead, ash, sand, loose gravel can be used to cover up the waste. This is a very good practice of sanitation, as the water and natural resources are used in a minimal level. Human waste also acts as natural fertilizers, which helps in plants growth and vegetation.

Fig 14: Eco-San Toilet

IV. CONCLUSION

Dodecahedron shaped distress relief shelter is designed using BIM. As this deployable structure is light in weight and eco-san toilet is used, this structure is highly sustainable to environment. Usage of FRP sheets makes the structure lightweight, thus enabling for easy portability. As Deploying pattern is simple, the structure can be easily deployed manually in the required site. This type of distress relief deploying structure provides great privacy and security to the distress affected people or migrating refugees.

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