Rapidly Deployable Disaster Relief Shelter

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Abstract— Disaster relief shelters play a vital role in large-scale disasters and are an important part of disaster response and recovery. Shelters are used to provide private and secure places for people to live who have left or lost their usual accommodations as a result of some form of disaster. This paper presents two different configuration which are easily deployable (i.e., capable of being packaged in a small volume to enable transportation by air, rail, ship, or truck) for two different type of material i.e. Polypropylene sheet and HDPE sheet. Shelter is analyzed under self-weight and load combination of self-weight and wind load according to (IS: 875 Part-3). Cost of two shelter are compared in this paper. Results of deflection and stresses as well as cost of both shelters are compared and most considerable configuration has been decided.

Key words: Disaster Relief, Rapidly Deployable, Shelter

I. Introduction

Disaster relief shelters play a vital role in large-scale disasters and are an important part of disaster response and recovery. Disaster relief shelters are used to provide private and secure places for people to live who have left or lost their usual accommodations as a result of some form of disaster. Disaster relief shelters not only provide immediate and short-term shelter for the victims of a disaster, but they also help them to recover from the trauma of a disaster as well as provide a base to start the process of rehabilitation.

II. Objective

The aim of study is to develop light weight rapidly deployable configuration of relief shelter and develop the shelter which is easy to assemble and deploy to reduce time and manpower as well as Functional and reliable way of transportation and packing.

III. Scope of work

Two different type of deployable configurations are developed. Two different materials (i.e. Polypropylene and high density polyethylene) are selected for both configuration. ABAQUS 6.13 Finite element software is used for modelling and analysis of both shelter. Shelters are analysed under the self-weight and load combination of self-weight and wind load. Wind load is calculated as per IS: 875 (Part-3) 1987, code of practice for design loads (other than earthquake) for buildings and structures Part 3 wind load. Cost comparison is carried between both shelters.

IV. Methodology

First of all two different configurations are prepared then finite element analysis is being carried out for both type of shelter configuration. At last cost comparison is carried out for both type of shelter.

A. Design Configuration

Two different deployable configurations are developed. Minimum floor area is decided according to UNHCR standards. According to these standards minimum requirement of floor area is 3.5 m^2/person. If we consider minimum four person in single family than total minimum floor are requirement is 14 m^2. Two different plan shapes are considered i.e. Rectangular and hexagonal. According to plan dimension size of individual sheets is being determined. Dimension of both shelters are as followed.

1) Shelter Type-1

- Floor area: 14 m^2
- Dimension of shelter: 3.5m (W) X 4.0m (L) X 2.5m (H).
- Dimension of single panel: 2.0m (W) X 2.6m (H).
- Thickness of panels: 60mm.

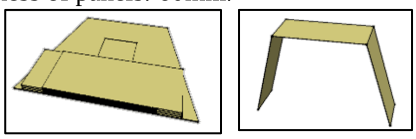

Fig. 1: Deployment stage-1 and 2 for shelter type-1

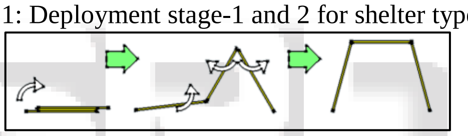

Fig. 2: Detail deployment of individual side panel in stage-2 for shelter type-1

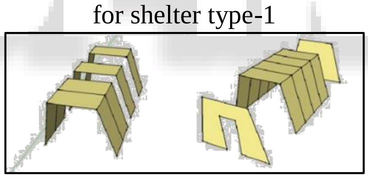

Fig. 3: Deployment stage-3 and 4 for shelter type-1

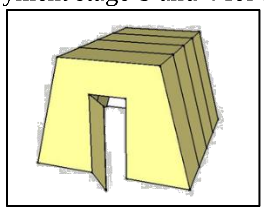

Fig. 4: Final fully deployed form of shelter type-1

Side panels are divided in four parts. Each part consists three panels. Two side panels and one roof panel. These panels are folded like accordion doors (folding doors). After deployment of these panels, front panel and back panel is connected with the help of clamps to side panels. Rubber gasket is provided between wall panels and roof for air and water tightness. All the wall panels are connected with the help of aluminium hinges that allow the panels to fold. At the end all door and windows are fitted to the openings.

2) Shelter type-2

- Floor area: 15m2.
- Shape of shelter: hexagonal (radius: 2.4m).
- Dimension of single wall panel: 2.4m (W) X 2.5m (H).
- Thickness of panel: 60mm.

Wall panels are divided in two parts. Each part consists three panels. These panels are folded like accordion doors (folding doors). After deployment of these wall panels, roof is connected with the help of clamps. Rubber gasket is provided between wall panels and roof for air and water tightness. All the wall panels are connected with the help of aluminium hinges that allow the panels to fold. At the end all door and windows are fitted to the openings.

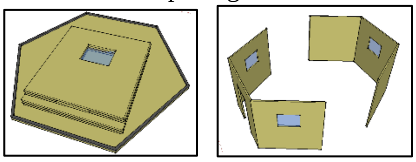

Fig. 5: Deployment stage-1 and 2 for shelter type-2

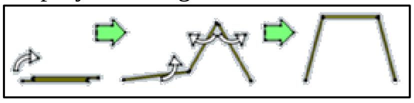

Fig. 6: Detail deployment of individual wall panel in stage-2 for shelter type-2

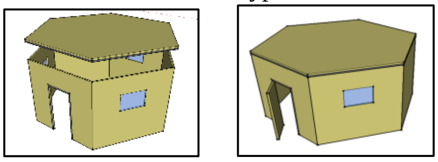

Fig. 7: Deployment stage-3 and final fully deployed form of shelter type-2

B. *Finite element modelling and analysis of both shelters*

This chapter describe the modelling and analysis of three different shelter configuration. ABAQUS 6.13 is used for modelling and analysis of shelter. S4R shell element is used for modelling of shelter panels. Connections between wall panel to wall panel and wall panel to roof panel are defined as beam (rigid) connection. Boundary condition at base of shelter is provided as fixed boundary condition. Size of mesh is 50mm x 50mm.

Material	Modulus of elasticity N/mm^2	poison's ration	yield strength N/mm^2	Density g/cc
Polypropylene	1300	0.42	30	0.908
HDPE	1000	0.46	26	0.965

Table 1: Material Properties

Both shelter types are analyzed for two different materials e.g. polypropylene and HDPE under DL (self-weight) and DL+WL. Wind load is considered for wind angle 0^0 and 90^0. Using above material properties in table-1 model of shelter has been analyzed. Properties of material are taken from the distributor of plastics sheet. Above table-1 shows the data of material properties which are already tested before. After defining the material properties in ABAQUS parts of model are prepared using planer shell method. All these parts are assembled in assembly module. Gravity and general loading steps are defined in step module. Loading and boundary conditions are defined in load module. Interaction module is used to define the connection properties between wall to wall panel and roof to wall panel. Meshing is done in mesh module using mesh size 50mm x 50mm and S4R shell element. After defining job in job module it is submitted and after completion of job results are available in visualization module. Results of deflection and von mises stress are presented for all three type of shelters in this chapter.

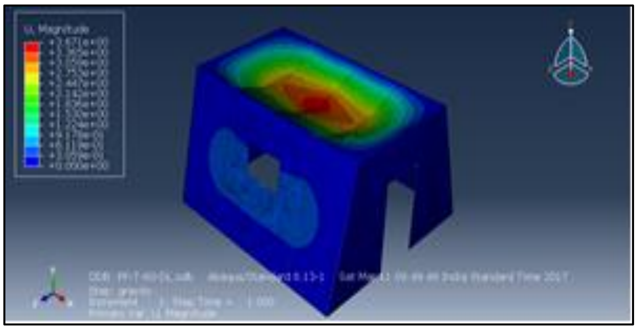

Fig. 8: Deflection of shelter type-1 under Self-weight

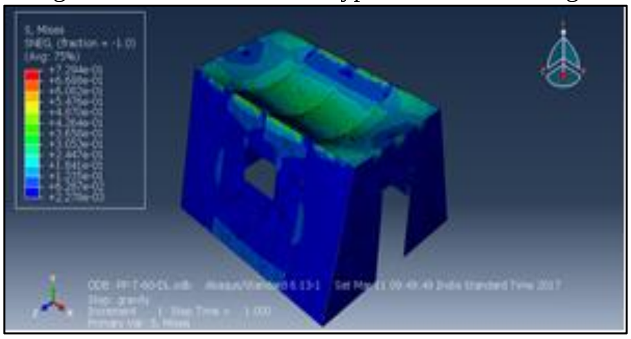

Fig. 9: Stresses of shelter type-1 under Self-weight

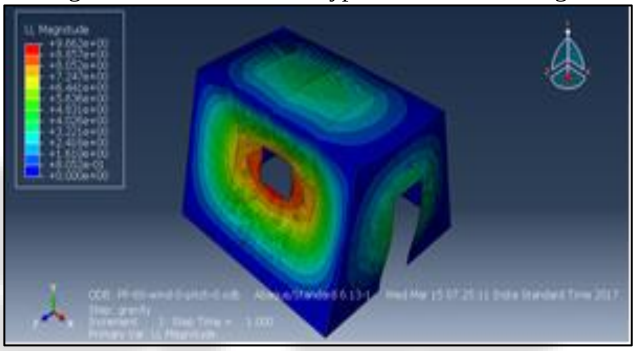

Fig. 10: Deflection of shelter type-1 under self-weight and wind load (wind angle-0 and roof angle-0)

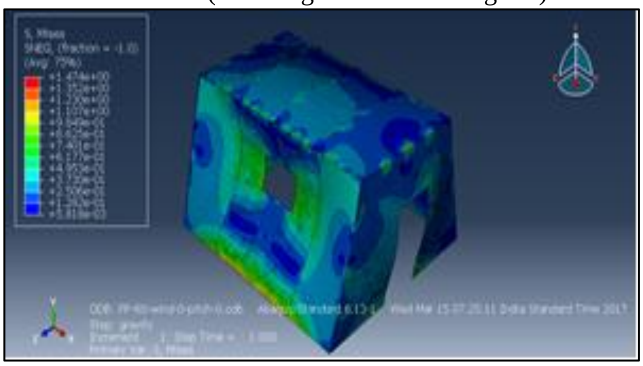

Fig. 11: Stresses of shelter type-1 under self-weight and wind load (wind angle-0 and roof angle-0)

Above fig. 8 to 11 shows the typical deformed shape of shelter and stress distribution under for shelter type-1, material polypropylene, roof angle-0 and wind angle-0. Similarly models are prepared and analyzed for two materials PP and HDPE for roof angle 0, 5 and 10 respectively under the self-weight as well as self-weight and wind load (i.e. Wind angle 0 and 90). Stresses are maximum at the connection between roof to roof panel, wall to wall panel and roof to wall panel. Wind load assigned to roof and wall panel is calculated as per the IS: 875 (Part-3) 1987, code of practice for design loads (other than earthquake) for buildings and structures Part 3 wind load.

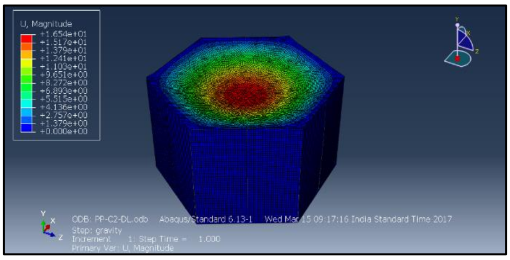

Fig. 12: Deflection of shelter type-2 under Self-weight

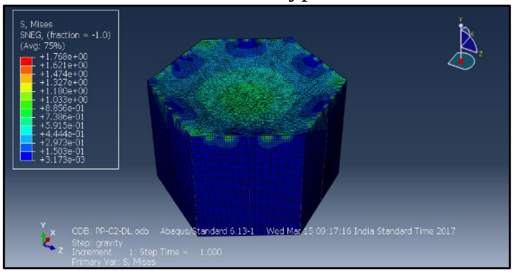

Fig. 13: Stresses of shelter type-2 under Self-weight

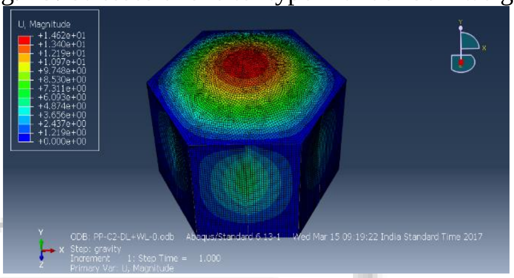

Fig. 14: Deflection of shelter type-2 under self-weight and wind load (wind angle-0 and roof angle-0)

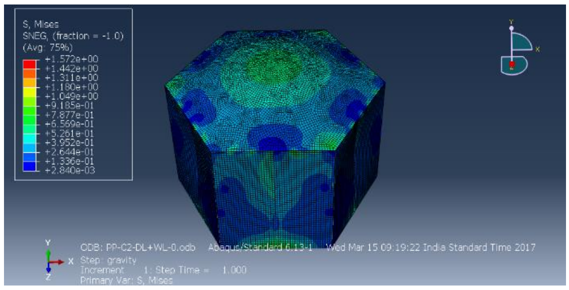

Fig. 15: Stresses of shelter type-2 under self-weight and wind load (wind angle-0 and roof angle-0)

Above fig. 12 to 15 shows the typical deformed shape of shelter and stress distribution under for shelter type-2, material polypropylene, roof angle-0 and wind angle-0. Similarly models are prepared and analysed for two materials PP and HDPE for roof angle 0 only under the self-weight as well as self-weight and wind load (i.e. Wind angle 0 and 90). Stresses are maximum at the connection between roof to roof panel, wall to wall panel and roof to wall panel. Wind load assigned to roof and wall panel is calculated as per the IS: 875 (Part-3) 1987, code of practice for design loads (other than earthquake) for buildings and structures Part 3 wind load.

C. Cost self-weight comparison

Cost of shelter is calculated by available market price of material and self-weight of shelter is calculated by multiplying total area of sheet and thickness of sheet with density of material.

shelter type	self-wt.	self-wt.	floor area	sheet area	cost of PP	cost of HDPE
	(PP)kg	(HDPE)kg	m^2	m^2	135₹ /mm/m^2	150₹ /mm/m^2
type-1	2376	2525	14	43.6	353160	391500
type-2	1796	1909	15	32.9	266976	296640

Table 2: Cost comparison and weight comparison

V. RESULTS

Load Combination	Wind Angle	Roof Angle	Material Type	Max. Deflection mm	Allowable Deflection mm	Max. Von-mises Stress N/mm²	Allowable Stress N/mm²
DL	-			3.67	17.95	0.729	
DL+WL	0	0	PP	9.66	11.96	1.474	30
DL+WL	90			5.39		1.401	
DL	-			5.31	17.95	1.078	
DL+WL	0	5	PP	10.0	11.96	1.588	30
DL+WL	90			5.79		1.376	
DL	-			3.68	17.95	0.751	
DL+WL	0	10	PP	10.2	11.96	1.778	30
DL+WL	90			6.1		1.095	
DL	-			5.06	17.95	0.773	
DL+WL	0	0	HDPE	12.55	11.96	1.443	25
DL+WL	90			6.93		1.356	
DL	-			7.41	17.95	1.168	
DL+WL	0	5	HDPE	13.03	11.96	1.545	25
DL+WL	90			7.51		1.327	
DL	-			5.12	17.95	0.812	
DL+WL	0	10	HDPE	13.25	11.96	1.732	25
DL+WL	90			7.91		1.071	

Table 3: Results of deflections and stresses for shelter type-1

Load Combination	Wind Angle	Roof Angle	Material Type	Max. Deflection mm	Allowable Deflection Mm	Max. Von-Mises Stress N/Mm^2	Allowable Stress N/Mm^2
DL	-	0	PP	16.54	40	1.79	30
DL+ WL	0			14.62	26.67	1.57	
DL+ WL	90			14.55		1.53	
DL	-	0	HDPE	22	40	1.81	26
DL+ WL	0			16.99	26.67	1.41	
DL+ WL	90			16.9		1.36	

Table 4: Results of deflections and stresses for shelter type-2

Results of analysis are tabulated for both shelter types. Maximum deflection and stresses of shelter should be within permissible limits of deflection and stresses. Panel are required to meet the deflection limits under service load as prescribed by IBC: 2012. Maximum von mises stress should be less than yield strength of material. Allowable deflection for dead load is span/120 and for dead load and wind load is span/180 as per IBC. Allowable stress for polypropylene is 30 N/mm^2 and 26N/mm^2. Table 3 and 4 shows the results of deflection and stresses for shelter type-1 and 2.

VI. Conclusion

Deflection and stresses due to self-weight is minimum for shelter type-1 and material polypropylene between two types of shelters. Deflection and stresses due to self-weight and wind load is minimum for shelter type-1 and material polypropylene between two types of shelters. From the results of cost comparison and self-weight comparison the cost of shelter type-2 is minimum and self-weight of shelter type-2 is minimum. Deflection and stresses for shelter type-2 and material polypropylene are higher than shelter type-1 but they are within permissible limits of deflection and stresses as shown in table 3 and 4.

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