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DESIGN AND ANALYSIS OF THE STRUCTURE OF A DRILL RIG

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ABSTRACT: World energy demands are increasing with every passing day. A major portion to meet world's energy demand depends upon the Fossil fuels extraction especially Petroleum. In Pakistan like many other countries in the world, a major portion of the electricity is produced from petroleum products. The extraction of these petroleum products from several feet beneath the earth surface requires certain techniques like drilling the well using a drill rig. In this paper, an effort is made to design a drill rig. First, a 3D model is designed using CAD software. Three different types of structures are modelled by varying the cross section of the structures. Then these structures are analyzed using CAE software. A comparison is presented of all these structures and an optimum structure with minimum deformation is suggested.

Key words: Drill rig oil, Mast structure, Simulation, CAE

INTRODUCTION

Drilling the well is one of the basic operation in extraction of oil from beneath the earth in both on and off shore (Geekiyanage *et al.*, 2018) (Craig and Islam, 2012) operations. Drill rigs are designed and developed for drilling holes within the surface of the earth (Sajjad and Jung, 2019). Drill rig is a huge system used to drill a well of water, well of oil, or natural gas wells(Pape *et al*., 2017). They can be small to extent that these can be taken by a person auger (Beebe *et al.*, 2018). Drill rigs can be used to sample mineral resources, take a look at rock, soil and groundwater characteristics, and additionally may be used to put in sub-surface fabrications, along with facilities, special equipment's, tunnels or wells (Tudor *et al.*, 2018). A drill rig is a cell system mounted on the top of vehicles, tracks or trailers, or land. Oil and natural gas drill rigs are not only handiest to discover earth's resources but additionally to drill holes that permit the oil or natural fuel to be extracted from the reservoirs(Li, 2019). Broadly speaking in onshore oil fields, a well is drilled and then drill rig is moved off the place. A smaller rig is constructed for convenience(Srivastava and Teodoriu, 2019). Small drill is moved directly to the well and set properly on line (Austefjord *et al*., 2018). This frees up the previous drill rig to drill hole at other place and operation is streamlined bearing in mind specialization of sure offerings, i.e., completions vs. drilling (Soe *et al.*, 2018).

Figure 1: Land rig

MATERIALS AND METHODS

Drilling rig is split into the subsequent most important systems. Following are the major systems of drill rig oil.

Hoisting system: Hoisting System consists of pulley system, used for lowering and rising of the travelling block via large pulley and wires system. It is used for elevating and lowering of the drill pipes. It consists of the components shown in Figure 2. Draw works is huge gyratory drum with metal wire wrapped around it.

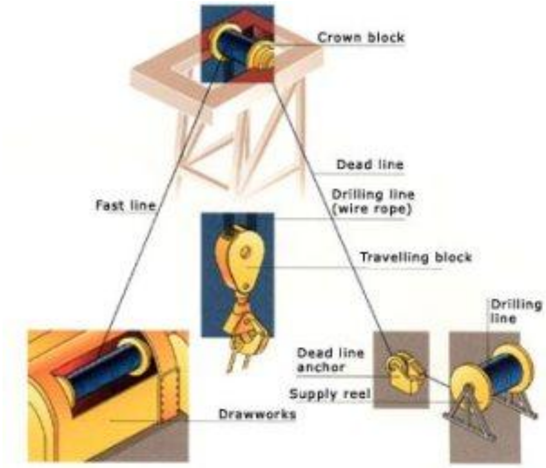

Figure 2: Hoisting System.

The drum is further connected to the motor and gearing system. The movement of the drill hook and travelling block in or out of the well is controlled by draw works drum. The metal wire or drill line received over a pair of sheaves at the top of the tower of drill rig, commonly known as crown block and similarly wrapped over sheaves at the bottom known as travelling block with a suspending drill hook.

The elevator which is connected to the travelling block is used to pull out the drill string or casing from the hole. However, the drill line is received over the sheaves at top and bottom, it is connected with the reverse drum through dead line anchor so it can`t move. The other end attached with draw works drum of the drill line, known as fast line.

Rotary system: The drill rig rotary system is used to revolve the drill string and also drill bit at the bottom. It is used to provide rotary electricity to drill bit for cutting. The equipments included in this system are shown in Figure 3, which is mainly rotary house, swivel, Kelly, rotary drives, drill string and drill table (Tetsuo *et al*., 2002).

Figure 3: Rotating System (Petroprophet, 2019)

Swivel is connected with the kelly house and hook, which makes a robust joint, because it offers the pressure seals and endure the overall weight of the drill string.

The Kelly is hexagonal in cross-section, provides rotational motion to the drill string. It is made of treated steel to prevent from unnecessary wear caused by braking connections.

Circulating System: The Circulating equipment consists of the following components; flow lines, nozzles, mud pumps, tanks and mud pits. The mud is impelled by the mud pump with the help of sand pipe and rotary hose into drill string. The mud travels down through the drill string to drill bit, where it is sprayed by nozzles at the lowermost of hole.

Drill rig oil includes the following sub components.

Centrifuge: It is a system used to separate fine slits and soil from the drill mud.

Solids Control: It is a system that is used to prepare drill mud for the process of drilling.

Chain tongs: It is wrench with a segment of chain that is wrapped around anything that is to be tightened or loosened.

Desander/Desilter: It incorporates hydro cyclones that remove sand and silt from the drill mud.

Degasser: It is a tool that is used to remove air and gas from the drill mud.

Draw works: It is the segment consists of the spool, which has a primary feature to move in and out of the drill line to elevate or move down the travelling block.

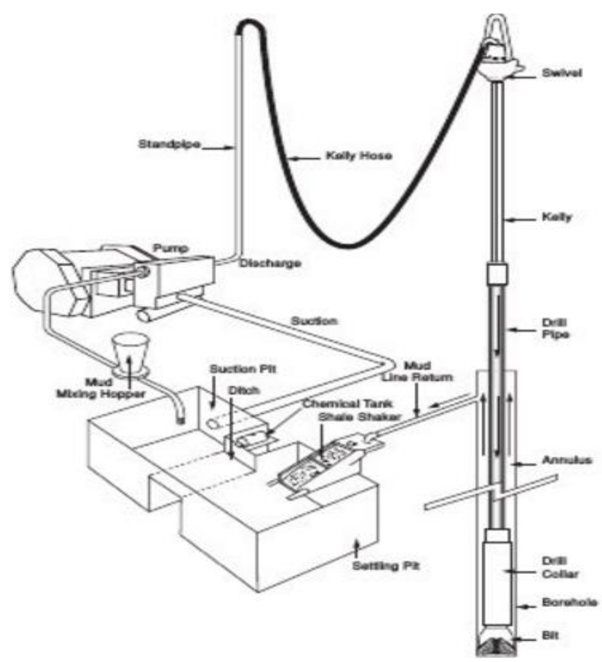

Figure 4: Circulating System.

Pakistan Journal of Science, 71 (4 Suppl.): 2019, Page 119-125
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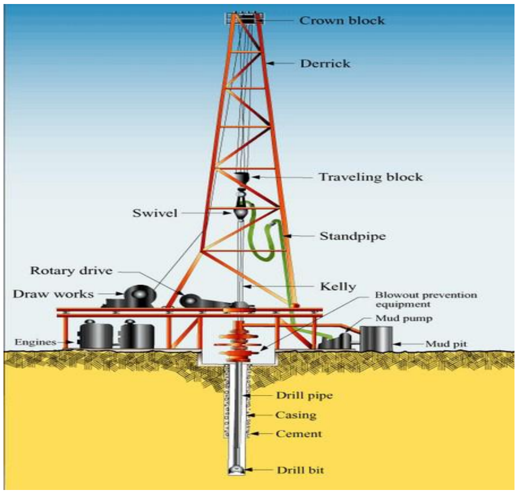

Figure 5: Drilling system overview(Bu and Dykstra, 2014)

Drill Bit: It is a tool at the end of the drill string, which tears apart the rock that is to be drilled. It incorporates highly pressurized fluid at its exits.

Elevators: It is a tool that grips the drill pipe and moves it in or out of the drilled hole.

Mud motor: It is a hydraulically powered tool located simply at the top of the drill bit that spins the drill bit.

Dust pump: It is a reciprocal kind of pump that is used to drill mud into the system.

Mud tanks: It is frequently known as mud pits, which are used to store the drill mud.

Rotary desk: These are used to rotate the drill string which is connected to gears and bit at side.

Shale shaker: It is used to filter the slits from mud after cutting before pumping it back to the hole being drilled.

Figure 6: Drilling system (Energy, 2019)

Working: Drilling a hole with drill rig oil includes following techniques.

Drilling a well: The group set the rig and the process of drilling is started. Hole is drilled down to a determined depth that is near to the oil lure (Hasle *et al.*, 2009; Aadnøy and Andersen, 2001). Following are the fundamental steps in drilling:

1. Locate the drill bit, drill pipe and collar within the hole.
2. Connect turntable and Kelly, and start operating.
3. During drilling, drill mud moved in and out of the hole with rocks that are cut.
4. As the hole gets deeper and deeper more drill pipes are entered and fitted in it.

Cement the hole: When they attain the targeted depth, casing- region has to be cemented. In order to save the hole from collapsing casing-pipe sections are fitted inside the hole. The spacers are provided with the casing pipe to hold it still inside the hole. The casing pipe is fitted in the hole and the grout is then pumped in the hole to cement it. It is then allowed to be hardened.

Testing for oil: Drilling process progresses and the team drill the hole; then put in casings and cemented it and drills again. When the oil appears with the rock cuttings, it means the drilled hole has reached the oil reservoirs.

At this point, group participants remove the drilling equipment from the hole and carry out numerous checks to verify this finding:

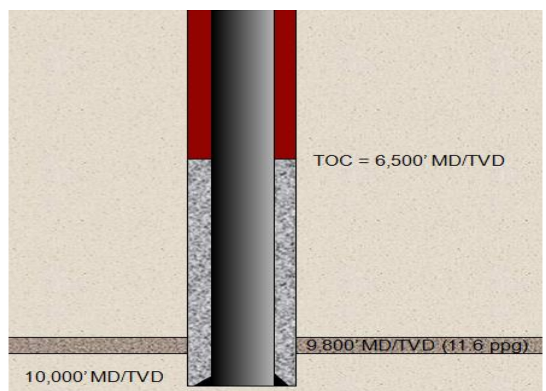

Figure 7: Cementing the hole (Formulas, 2019)

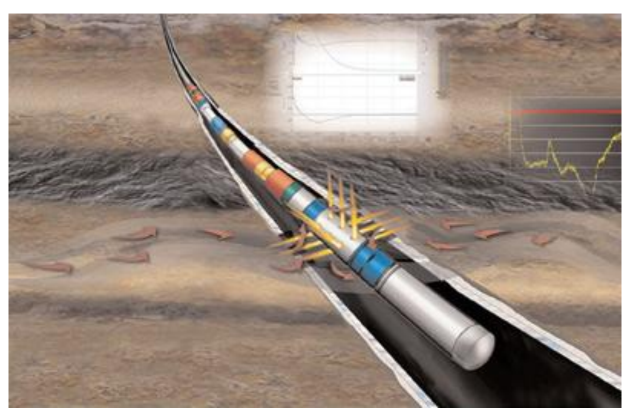

Figure 8: Drilling perforation.

- Properly logging – a sensor is lowered down into the hole to test the rock formation.
- Drill-stem checking out – a device is lowered into the hole to check the pressure.
- Centre samples - samples of rock are taken to search for traits of resource rock.

Oil well: After the final depth is reached, the perforating gun is lowered down into the hole. It contains explosives that are used to create a small hole in the casing to allow the flow of oil or gas up the hole after the casing is perforated and the tube is fitted in the hole with packers to seal it from outside. Ultimately, they set up a Christmas tree that regulates the flow of the oil or gas out of the well.

Oil Extraction: After the drilling is finished, a pump is placed at the well head. Inside the pump system, motor drives an equipment field that is acting as a lever. A bladed rod is pushed up and down by this lever. A sucker rod connected with pump is attached to the bladed rod. This device creates a pressure that causes the oil or gases to flow upward.

Figure 9: Oil extraction.

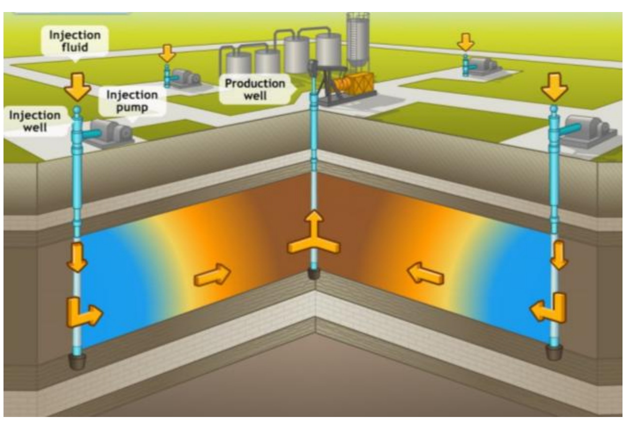

Figure 10: Enhanced oil recovery (Guilhem, 2019)

Enhanced oil recovery: In few instances, when the oil is too heavy to drift, drilling of another hole is carried out into the reservoir. This new hole is used to inject the high pressure steam into the reservoir. The steam heat then causes the oil to get thin and high pressure of steam pushes it out of the well. This is known as enhanced oil recovery process.

Design: Three structure variants are designed having different cross sectional area. CAD models are developed for all variants. The geometrical details of these structures are as follows:

Cross-section's dimensions: The cross section used in all three structures is of I beam cross section of different dimensions.

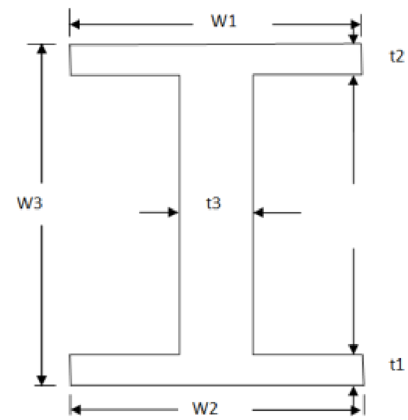

Figure 11: Cross Section of the structure

Cross section dimensions such as width and thickness of flanks are enlisted in Table I.

Table I – Width and thickness of flanks

Model No.	W1 (m)	W2 (m)	W3 (m)	T1 (m)	T2 (m)	T3 (m)
1	0.3	0.3	0.6	0.03	0.03	0.03
2	0.1	0.1	0.2	0.01	0.01	0.01
3	0.15	0.15	0.3	0.015	0.015	0.015

Mast model dimensions:

Height = 44.8 m
Width across shoes = 7.6 m
Length from front to rear shoe = 6.6 m
Top crown width = 3.3 m

Mast Model: ANSYS is used for pre-processing the structures. The coordinates of the nodes of the structure are calculated from the CAD file and compiled. These are then imported in ANSYS Design Modular to create the nodes points. The mast structure is created by joining these node points through line. Then cross section is assigned to complete the design as shown in figure 12.

Mast Analysis: In this section steps about the analysis procedure carried out on the structure model are discussed.

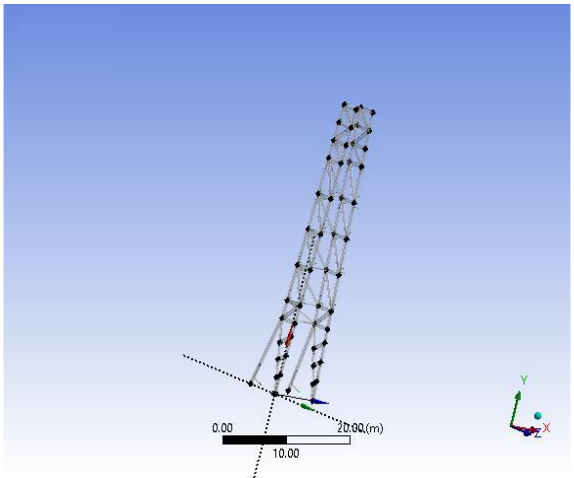

Figure 12: Points of structure

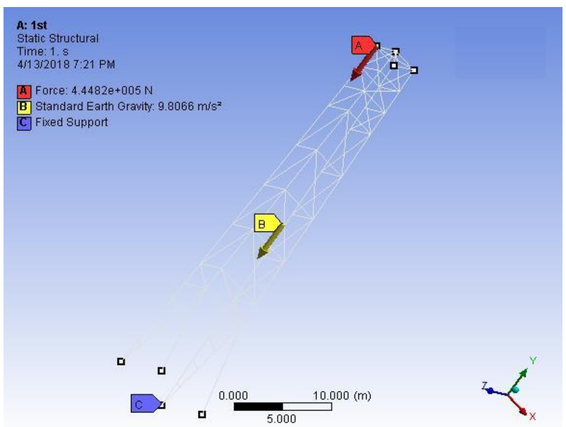

Figure 13: Boundary conditions

1) Meshing:

First step involves the meshing of the structure.

2) Boundary condition

The boundary conditions applied are as follows:

a) Fixed support

Structure is fixed at the base as shown in the figure 13.

b) Standard Earth gravity

Earth's gravity on the structure is applied in downward direction to incorporate structure weight as it is shown in the figure 13.

c) Hook load

A hook load of 444820 N is applied at the top in –y direction as shown in the figure 13.

RESULTS AND DISCUSSION

The analysis results which include the total deformation, axial forces, total shear force and total bending moment are included in the Table II. The analysis results of total deformation and total bending moment are shown as below,

Total Deformation: Total deformation is plotted for all three structures as shown for the structure 1 in figure 14, for the structure 2 in figure 15 and for the structure 3 in figure 16.

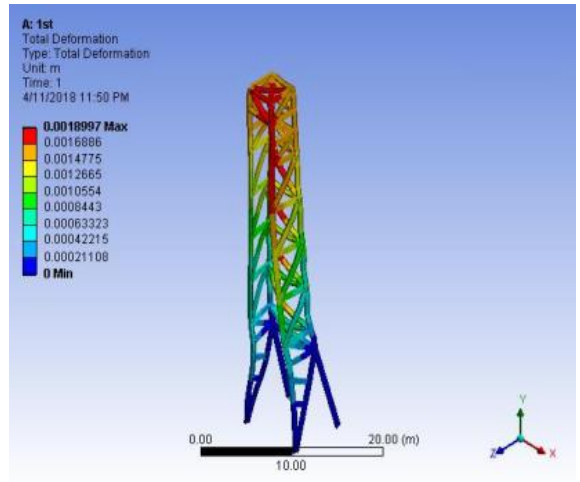

Figure 14: Structure1, Total deformation

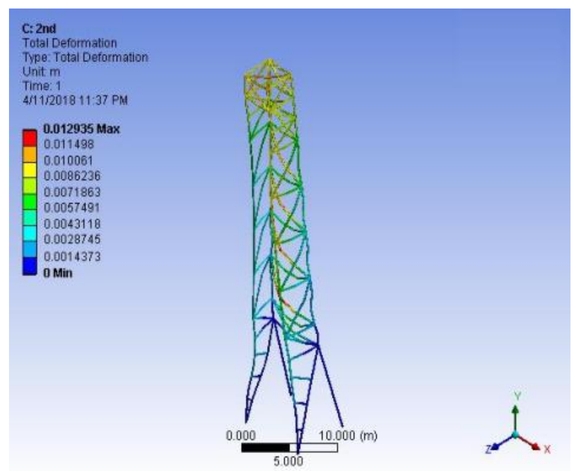

Figure 15: Structure 2, Total deformation

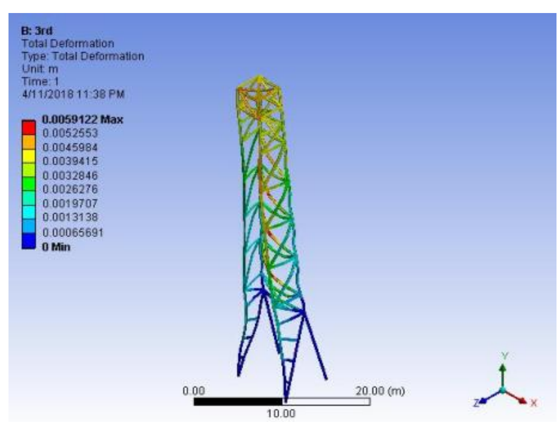

Figure 16: Structure3, Total deformation

Total Bending moment: The total bending moment results of all three structures are plotted as shown in figure 17 for the structure 1, figure 18 for the structure 2 and figure 19 for the structure 3.

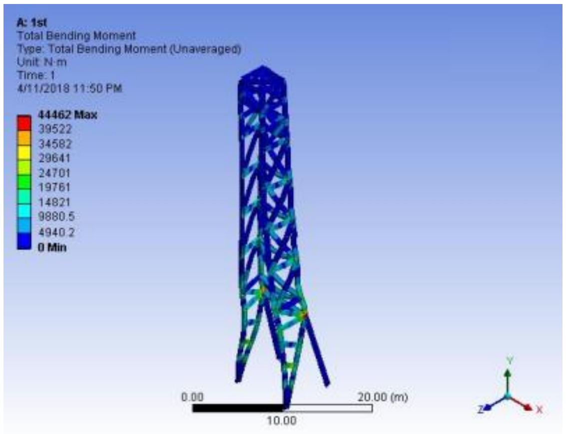

Figure 17: Structure1, Total Bending Moment

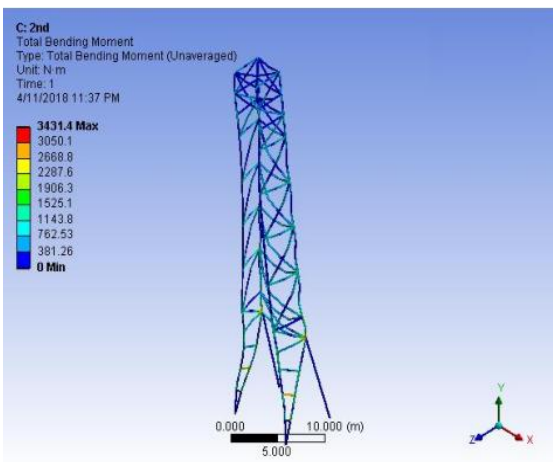

Figure 18: Structure2, Total bending moment

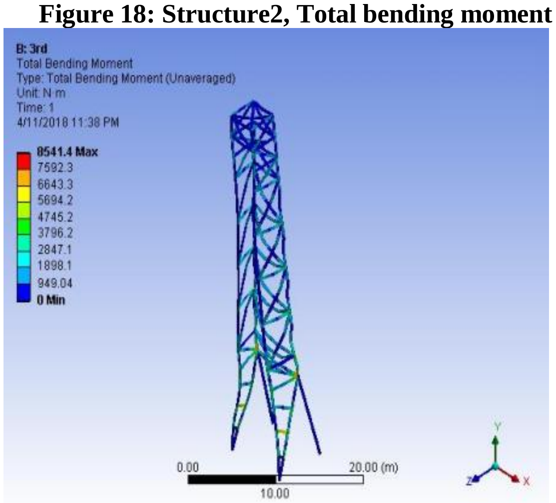

Figure 19: Structure3, Total Bending Moment

Table II. Result Summary Of All Structures.

No.	Hook Load (N)	Total Deformation (m)	Axial Force (N)	Total Shear Force (N)	Total Bending Moment (Nm)
1	444820	0.0018997	31854	28519	44462
2	444820	0.012935	3186.4	2970	3431.4
3	444820	0.0059122	7398.8	6929	8541.4

Comparison charts: The comparison charts of total deformation and bending moment are plotted as follows;

A. Total Deformation

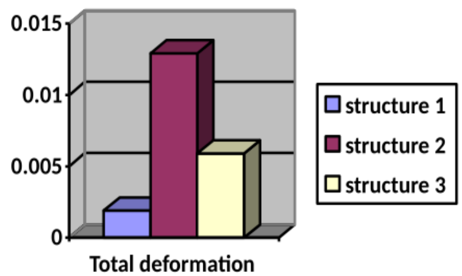

Figure 20: Comparison chart for total deformation

B. Total Bending Moment

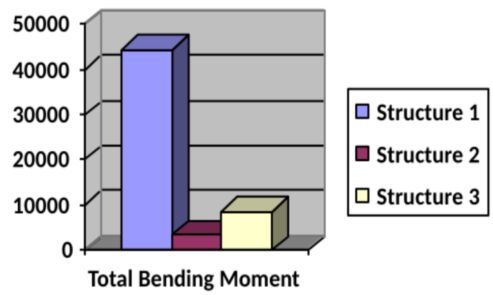

Figure 21: Comparison chart for total bending moment

Conclusions: It can be observed from above mentioned results that Structure 1 shows minimum deformation and best suited for our application. The max defection is observed at the side of the structure, so it is recommending that cross links should be used to reduce the deformation.

Maximum bending moment is observed at the base of the tower. Reinforcement can be added to minimize the maximum bending moment.

It is also evident that by increasing the elements, deflection is increased as weight is increased. It is thus important to use optimum number of elements.

So, it is concluded that structure 1 is best suited for our loading application as it meets all the design criteria and safety requirement of the design. This design will be used for future development and prototype testing.

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