# COMPARISON OF STRUCTURAL ANALYSIS AND DESIGN OF A RECTANGULAR AND CIRCULAR OVER HEAD WATER TANK USING STAADD PROV8I SOFTWARE AS PER IS CODE.

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**ABSTRACT**

*Indian sub- continent is highly vulnerable to natural disasters like earthquake, draught, floods, cyclones etc. Majority of states or union territories are prone to one or multiple disasters. These natural calamities are causing many casualties and innumerable property loss every year. Earthquakes occupy first place in vulnerability. Hence, it is necessary to learn to live with these events. According to seismic code IS: 1893(Part I): 2000, more than 60% of India is prone to earthquakes. After an earthquake, property loss can be recovered to some extent however, the life loss cannot. The main resign for life loss is collapse of structures. It is said that earthquake itself never kills people, it is badly constructed structures that kill. Hence it is important to analyse the structure properly for earthquake effects.*

*In this project, the modelling of both rectangular and circular water tank is considered for understanding the behaviour during the earthquake. The staging height also varied for different height for a constant capacity of tank of 1 Lakh Liters. Both static and dynamic analysis are carried out and results and tabulated and compared.*

*From the analysis the following conclusions are obtained. The displacement values of elevated tank show that, the displacement values depend on the height of the structure for the same capacity. The Increase in height increases the displacement. For Circular Tank, the increase in staging increases the displacement by 72% and 250% for model Type C2 and C3 when compared with Model Type C. It can be concluded that, the rectangular tanks are better for seismic prone areas and Circular tanks are better for critical wind areas.*

***Keyword*** :- *Over Head Water Tank, Different Shapes, Axial Force, Displacement, Bending Moment and shear Force, Drift, Time Period, Different levels of Staging etc….*

## 1. Introduction

Introduction related your research work In a Country like India, it is a usual situation where natural disasters exists. These may be Earthquake, Floods, Cyclone etc. These natural calamities cause innumerable property losses and many casualties each year. There are many evident that the earthquake is in the first place among other vulnerability. Hence it is better to live with these events in a planned way to avoid the damages caused by this vulnerability. It is also to be understand that the property lost during these events can be somehow restored, but once the life lost is lost. Hence it is very much important to analyse the structure properly for these devastating events.

The water supply is a facility that should serve and remain functional during and after the disaster. Most of the municipalities preferred to supply the water through elevated water tank. Since it is a gravitational flow. The configuration of these structures is especially vulnerable to the seismic, since it has heavier mass at the top with less stiffened column at the bottom. Hence it is at most important to check the service life of the structure even it faces such bad events. In many locations previously, these kinds of structures are collapsed due to its configuration of large mass at the top and unsuitable design of supports. Wrong selection of supporting system is also due to underestimate or over estimate of strength.

For daily life, water is certainly a basic need. In certain area, the sufficient amount of water distribution is necessary. In country like India, the water is mainly stored in elevated water tank. The elevated water tank generally supplies the water with pressure obtained by gravity flow. It rather requires high pressure pumps and naturally distributes water with low cost.

According to study and also as per IS456 provision 60% of the India is subjected to seismic effect. Since, Elevated water tank consists of huge mass on the top of slender staging, it is most likely to subject failures during earthquake events. Since, the elevated tanks are generally used in the seismic prone area as well, hence it is important to investigate the seismic behavior properly. Many of the water tank are collapsed or damaged due to improper geometry selection of staging pattern and also due to lack of knowledge in supporting system selection.

### 1.1. Water Tank

Water tank is mainly used to store water. The following parameters influence the construction of water tanks.

1. Water tank location determines the construction characteristics. It may locate at Indoor, Outdoor or It may be above the ground or underground.

2. Size of the tank will determine the capacity or volume of the water to meet the design requirement.

3. Purpose of water usage. It may be for human consumption, industrial water supply or any other.

4. How water is delivered to the usage point. (Through Gravity, Pumps)

### 1.2. Types of Water Tanks

Water tanks are classified based on the tank located in a building or other structure. Below are the few classifications: Those are:

A. Underground tanks

B. Tank resting on grounds

C. Overhead tanks or Elevated tanks

**Underground water tank**

The Tank which is located below ground is called as an Underground Tank. It is most of the time invisible. The tanks are usually made up of RCC, Steel/ aluminum tank, composite over wrapped metal tank or tanks made with composite materials. The Underground tanks are generally used to store water for drinking water facility, waste water collection, storing for industrial washing etc. There are certain plastic underground tanks, which are alternative to concrete tanks.

**Tanks resting on ground**

Tanks resting on ground are minimal. Only few clear water reservoirs, settling tanks, aeration tanks are constructed on ground. Here tanks are designed only for base pressure. However, the tanks are subjected to water pressure alone. These tanks may be circular or rectangular based on there requirement.

**Overhead tanks or Elevated tanks**

The overhead or elevated tanks have many advantages. It does not require any pumps to pressure the water to flow out. The water will flow by gravity. However, the location of tank should be ideal to equalize water pressure in distribution system. The pressure will not be equal all the time. It depends on the depth of water in the tank. The low water leveled water yields less pressure, However, the full tank may provide too much pressure. The water pressure can be adjusted by providing stand pipes.

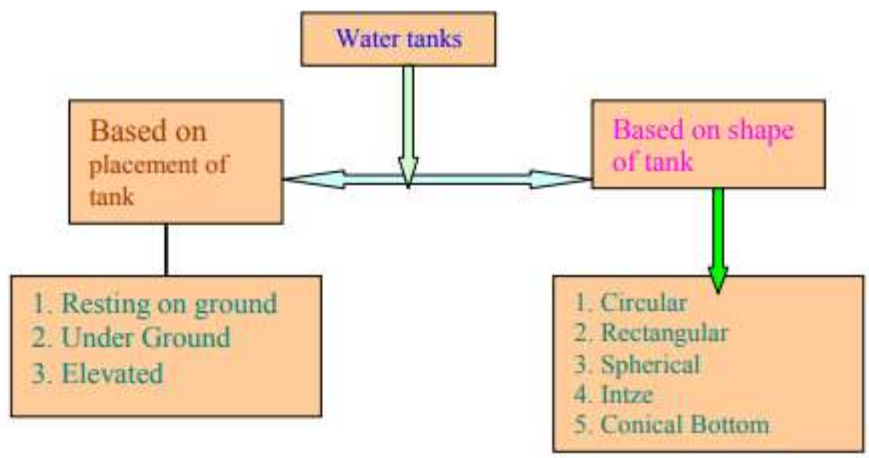


**Figure 0:1 Water Tank Classification.**

**1.3. Types of Elevated Water Tanks Based on Shape**

Types of Water tanks based on shape are as follows

1. Circular tank

2. Rectangular tank

3. Intze tank

### 1.3.1. Circular Tank

Circular water tank is the simplest form of water tank. It requires lesser material for the same amount required for rectangular water tank. Since circular water tanks have no corners, it will be made water tight easily. The walls usually designed for hoop tension and bending moments. For larger storage, generally circular tanks are preferred for their advantageous features. A typical tank diagram is shown in the below image.

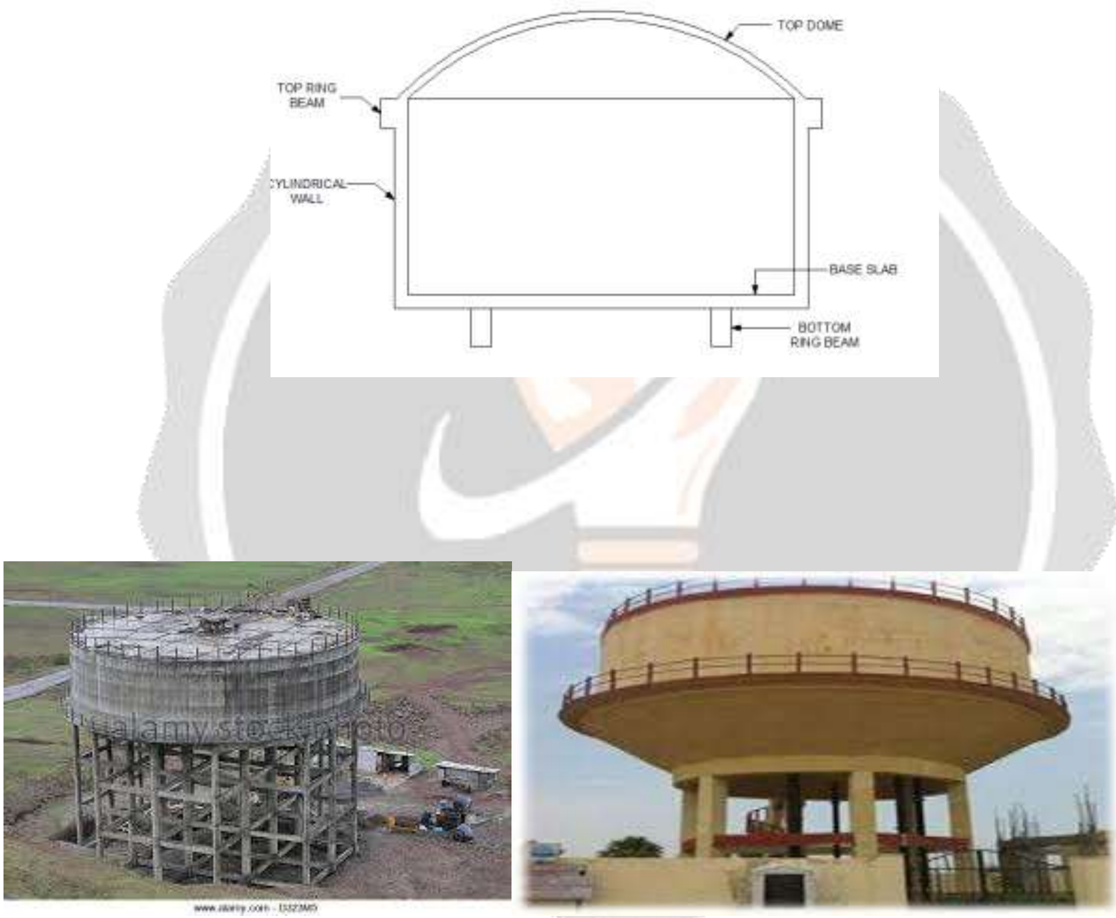


**Figure 0:2 General diagram of Circular water tank**

### 1.3.2. Intze tank

Water tanks are used to store the water. This kind of water tanks are mainly to reduce the cost, shape and size of the structure. The shape of water tank is influenced by the capacity of tank and also it depends on the nature and intensity of stress based on the shape of the tank. This type of tank is a circular in shape with a spherical top and conical dome at the bottom. In case of conical bottom tank, the Inward forces coming from the conical slab counteract the outward forces coming from the bottom dome which results less stress.

Due to lesser stresses, the thickness of the concrete bottom slab reduces and reducing the amount of concrete required which has direct influence on the cost of the water tank.


**Figure 0:3 Intze Type Tank**

### 1.3.3. Rectangular Water Tank

The rectangular tanks are easy to construct. However, the it is uneconomical if the capacity of the tank is more. The walls are tanks will be subjected to bending in a triangular portion. The Intersection of walls are subjected to direct tension. The walls will be treated as cantilever if the tank is open. Similarly, if the tank is a closed structure, it will be treated as propped cantilever. However, the magnitude of pressure will depend on length, breadth and height of the tank.

## 1.4. Joints in Water Tanks

The various types of joints may be categorized under three heads:

(a)Movement joints

(b)Constructions joints

(c)Temporary open joints.

**Contraction Joint.**

It is a movement joint with deliberate discontinuity without initial gap between the concrete on either side of the joint. The purpose of this joint is to accommodate contraction of the concrete. This type of joint is provided for convenience in construction. This type of joint requires the provision of an initial gap between the adjoining parts of a structure which by closing or opening accommodates the expansion or contraction of the structure. The joint is shown in Fig. (a)

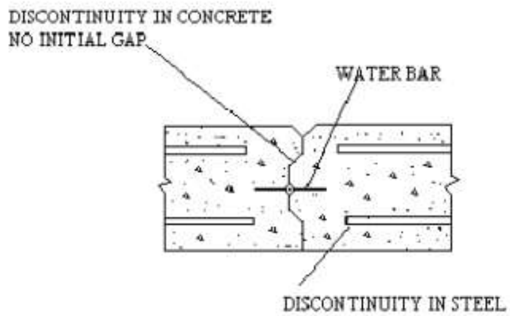


**Figure 0:4 Contraction Joint**

A contraction joint may be either complete contraction joint or partial contraction joint. A complete contraction joint is one in which both steel and concrete are interrupted and a partial contraction joint is one in which only the concrete is interrupted, the reinforcing steel running through as shown in Fig.(b). Figure

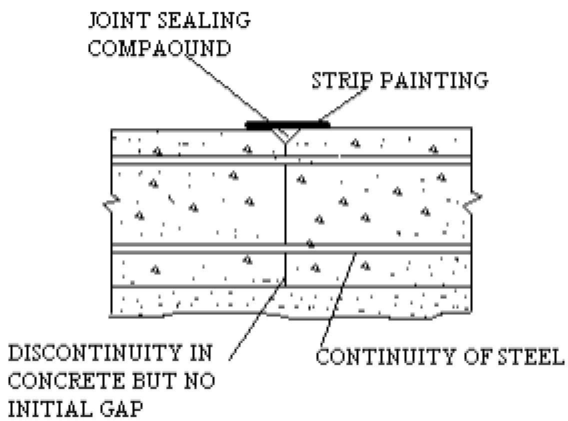


**Figure 0:5 Contraction Joint**

**Expansion Joint.**

It is a joint with complete discontinuity in both reinforcing steel and concrete and it is to accommodate either expansion or contraction of the structure. A typical expansion joint is shown in Fig.(c)

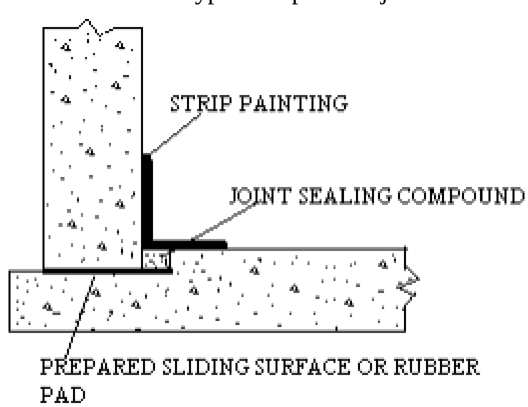


**Figure 0:6 Expansion Joint**

This type of joint is provided between wall and floor in some cylindrical tank designs.

## 2. Objectives:

The Main objective of this study are listed as below:

1. To the make a 3Dmodeling and assess the structural behavior of the rectangular and circular OHT by using staad software.

2. To assess the structural behaviour of a Rectangular water tank subjected to gravity load, earthquake load, seismic load ,water load and wind load as per I.S codes.

3. To assess the behaviour of the structure in terms of various parameters such as displacement, drift, wind, time period, BM & base shear.

4. To assess the modelling & analysis of different level of staging.

5. To assess the effects of wind loads on B racing's.

6. To assess the modelling & analysis of Different Capacity of water tanks.

7. To assess the modelling & analysis of Different height of water tanks.

# 3. MODELLING

## 3.1. General

StaddPro is a structural analysis and design computer program originally developed by Research Engineers International at Yorba Linda, CA in 1997. In late 2005, Research Engineers International was bought by Bentley Systems.

The commercial version, StaddPro, is one of the most widely used structural analysis and design software products worldwide. It supports several steel, concrete and timber design codes.

## 3.2. Modelling Using STADD

In this chapter, the general procedure of modeling of overhead tank by using Staddpro is explained in detail.

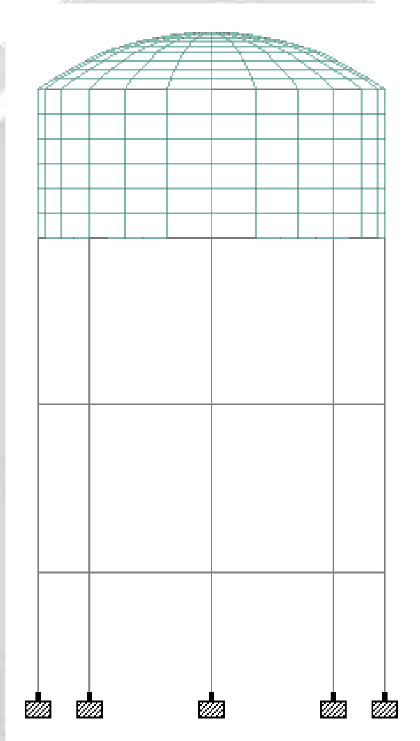

**Figure 0.3 Elevation View – Circular Tank**

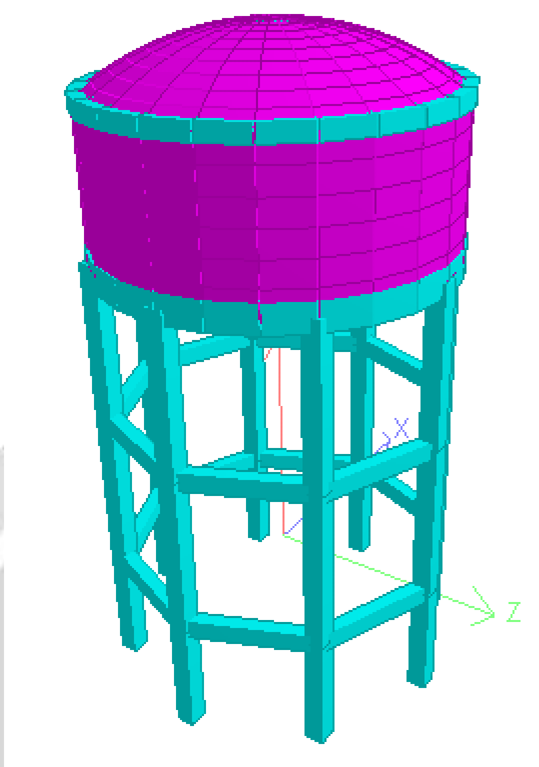


**Figure 3.4 3D View – Circular Tank**

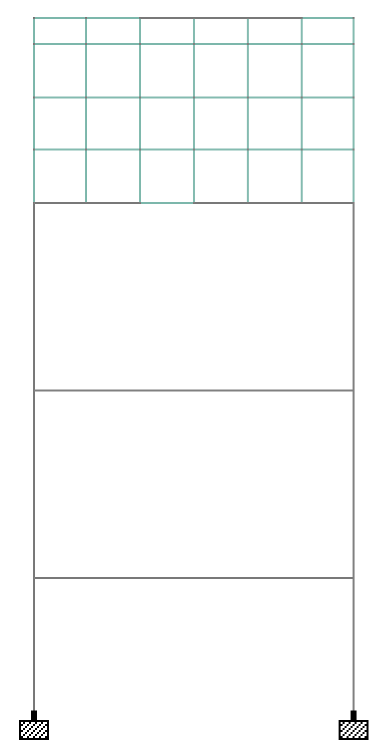

**Figure 0:5 Elevation View – Rectangular Tank**

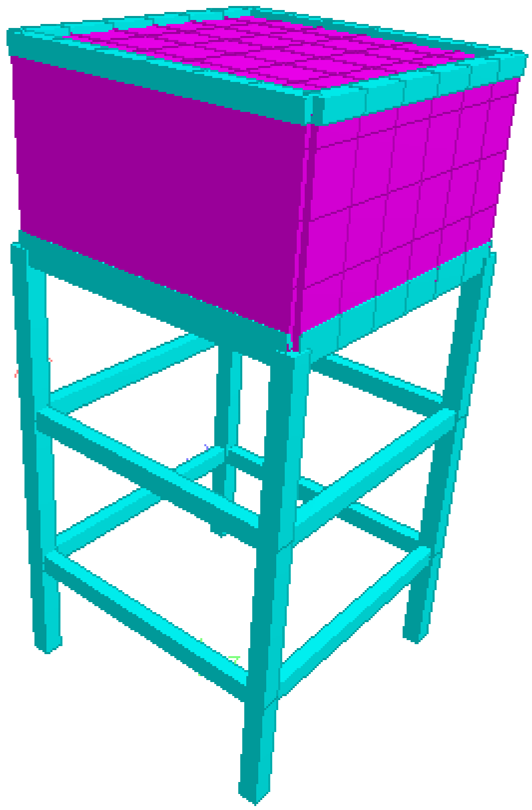

**Figure 0:5 3D View – Rectangular Tank**

**2.1. Defining Loads and Load combinations:**

The loads considered are as below:

1. **Dead Load**
   It includes Self Weight of the structures.
2. **Live Load**
   It includes the temporary or movable loads of 1.5kN/m2 for maintenance or other purposes.
3. **Water Load.**
   The water loads are acting on the bottom slab. It is 34kN/m2. However, the trapezoidal load is considered on the walls. (i.e., Uniformly varying load of 34kN/m2 at bottom and zero at the top)
4. **Earthquake Load.**
   The seismic forces are considered for the analysis of water tank in both the direction.

**2.2. Modelling Information & Details**

In the Present Study, a Total of 6 models are created. The details of the models are presented as below.

Model Type C1 – Circular Water Tank of 1Lakh Liter Capacity with 2 Level Staging.

Model Type C2 – Circular Water Tank of 1Lakh Liter Capacity with 3 Level Staging.

Model Type C3 – Circular Water Tank of 1Lakh Liter Capacity with 4 Level Staging.

Model Type R1 – Rectangular Water Tank of 1Lakh Liter Capacity with 2 Level Staging.

Model Type R2 – Rectangular Water Tank of 1Lakh Liter Capacity with 3 Level Staging.

Model Type R3 – Rectangular Water Tank of 1Lakh Liter Capacity with 4 Level Staging

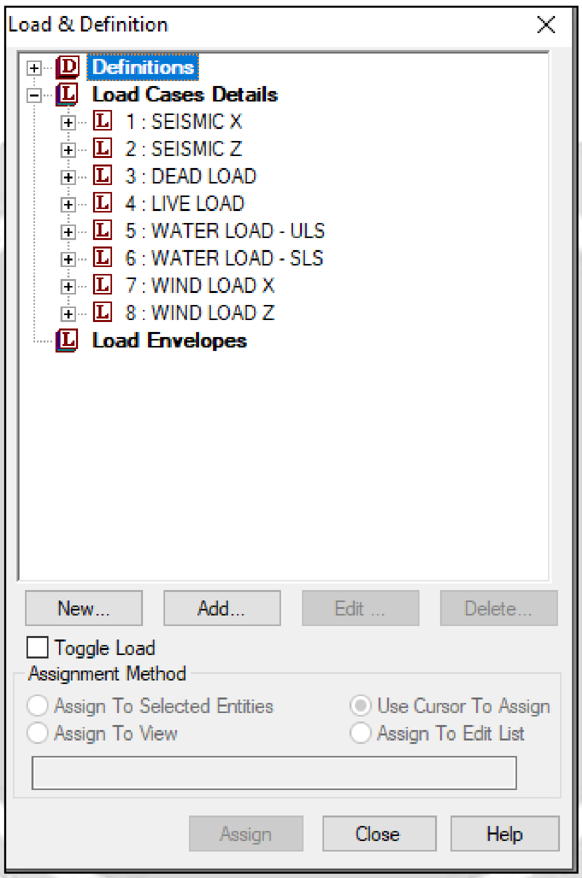


**Figure 0:6 Loads cases.**

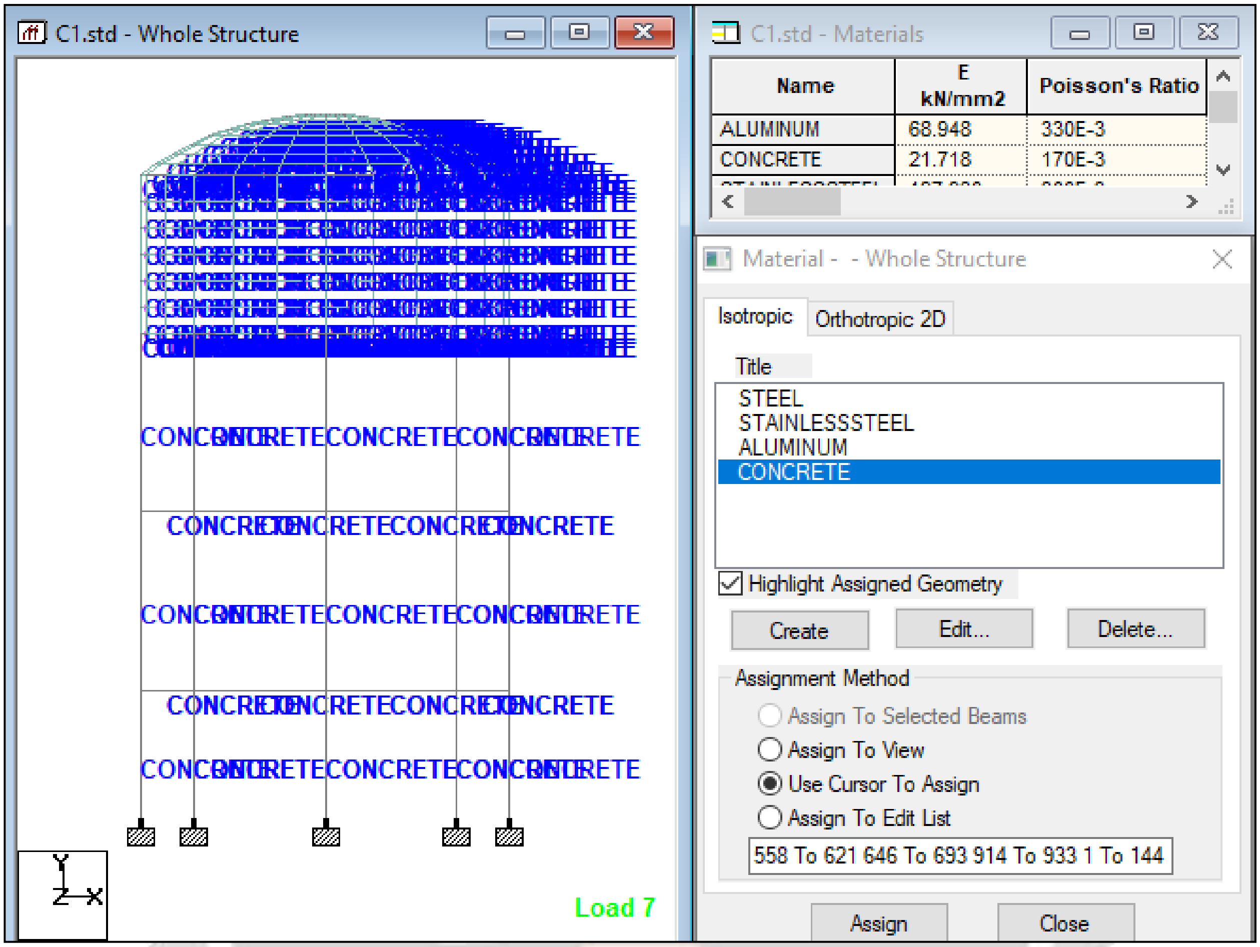


**Figure 0:7 Concrete Material.**

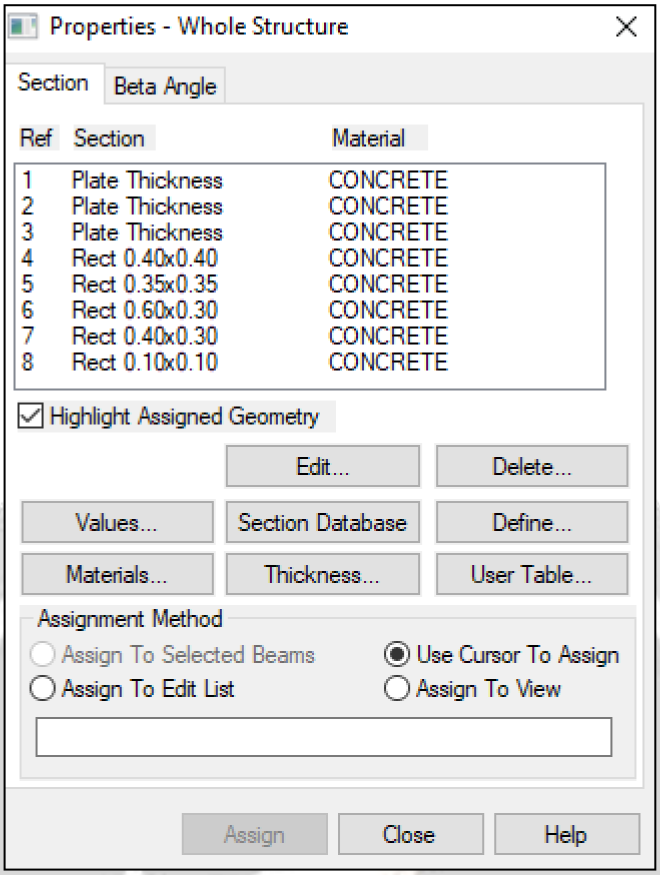


**Figure 0:8 Section Properties**

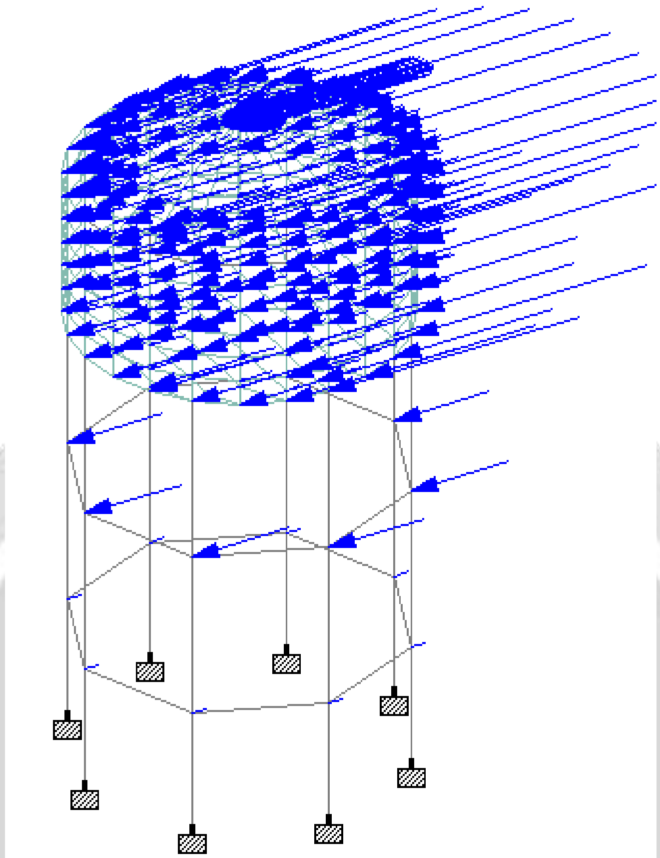

**Figure 0:9 Earthquake Load in X Direction**

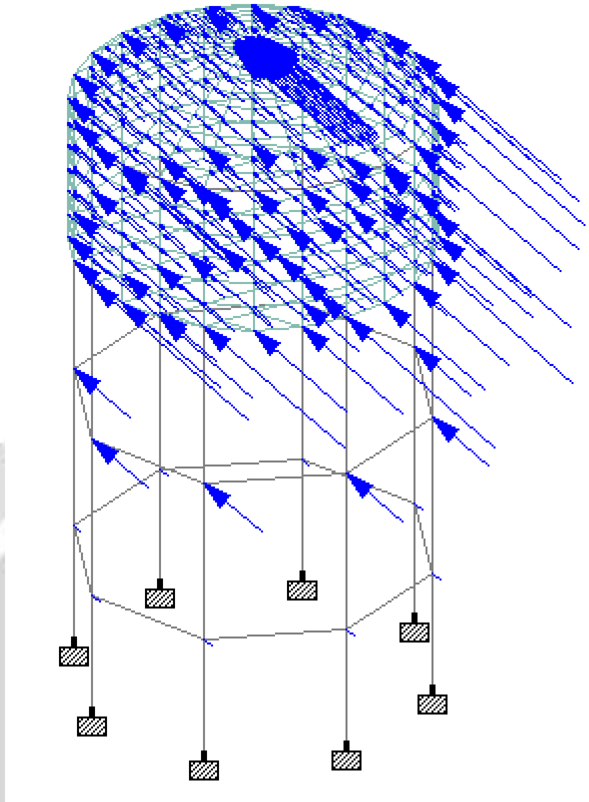

**Figure: 3.10 Earthquake Load in Z Direction**

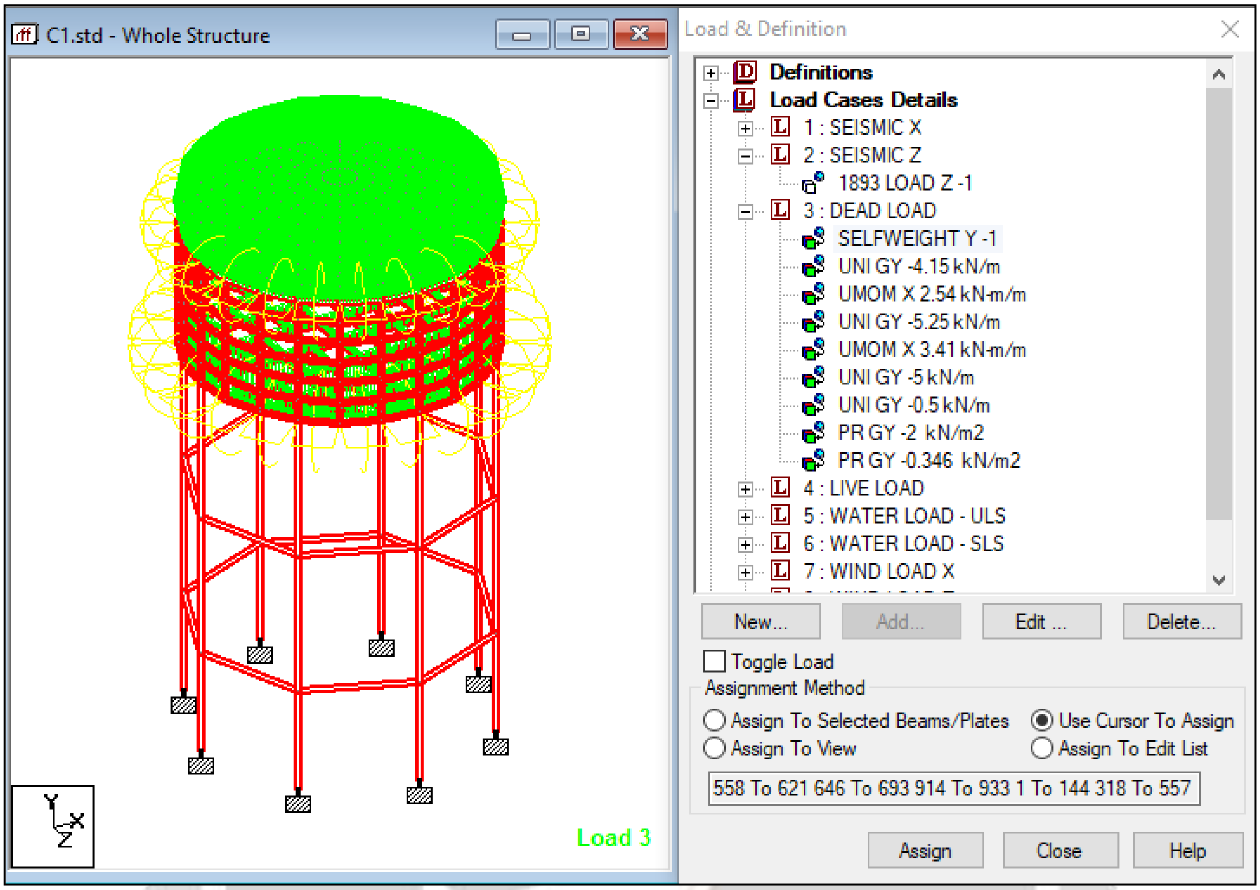


**Figure 0:11 Dead Load**

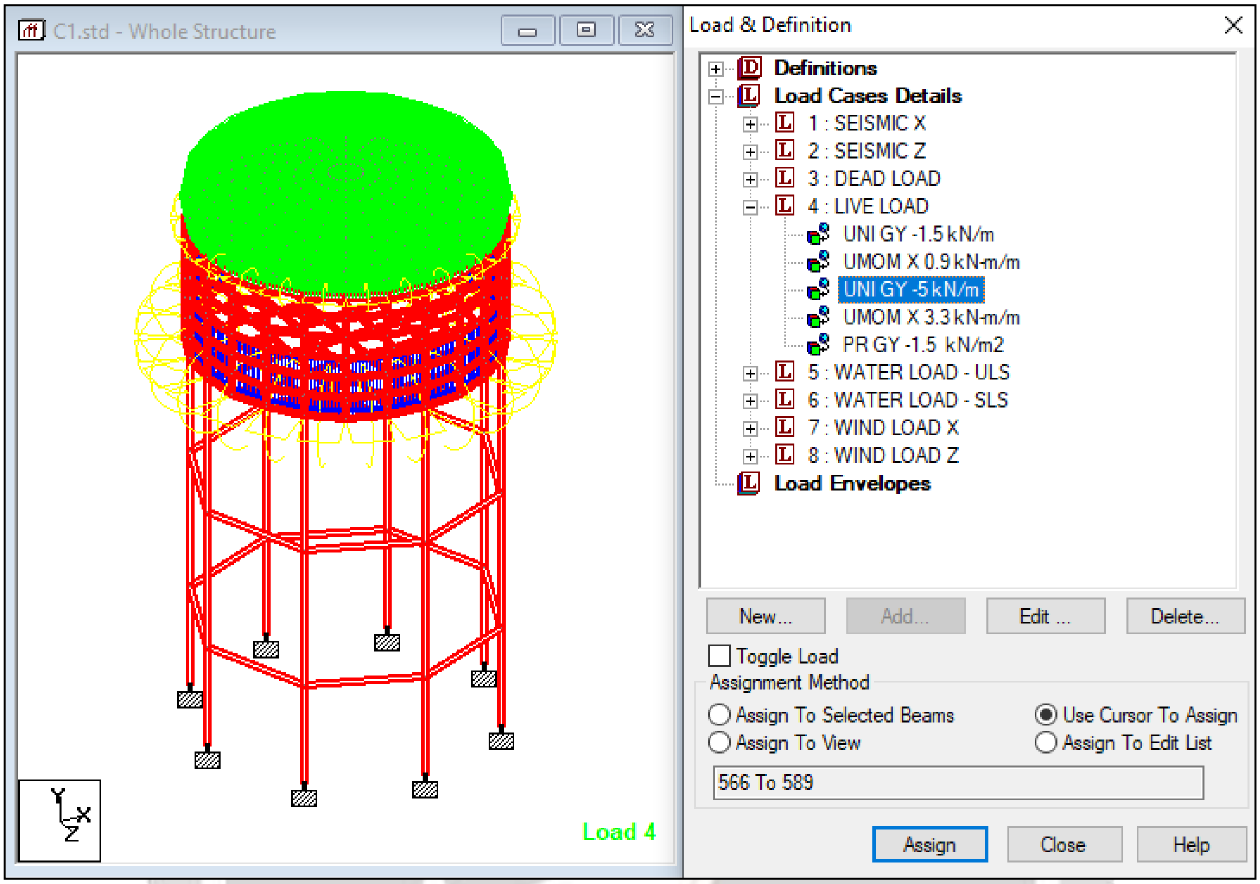


**Figure 0:12 Live Load**

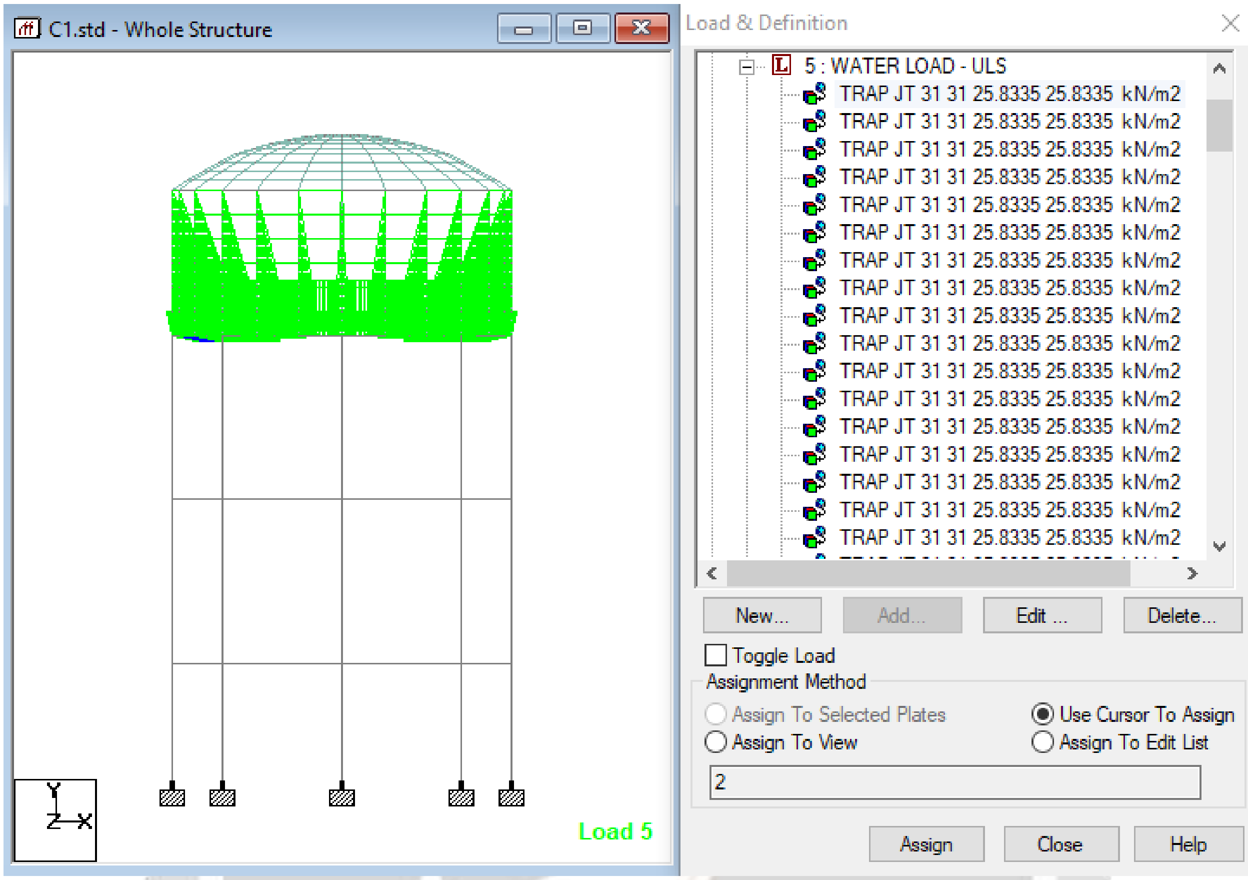


**Figure 0:13 Water Pressure**

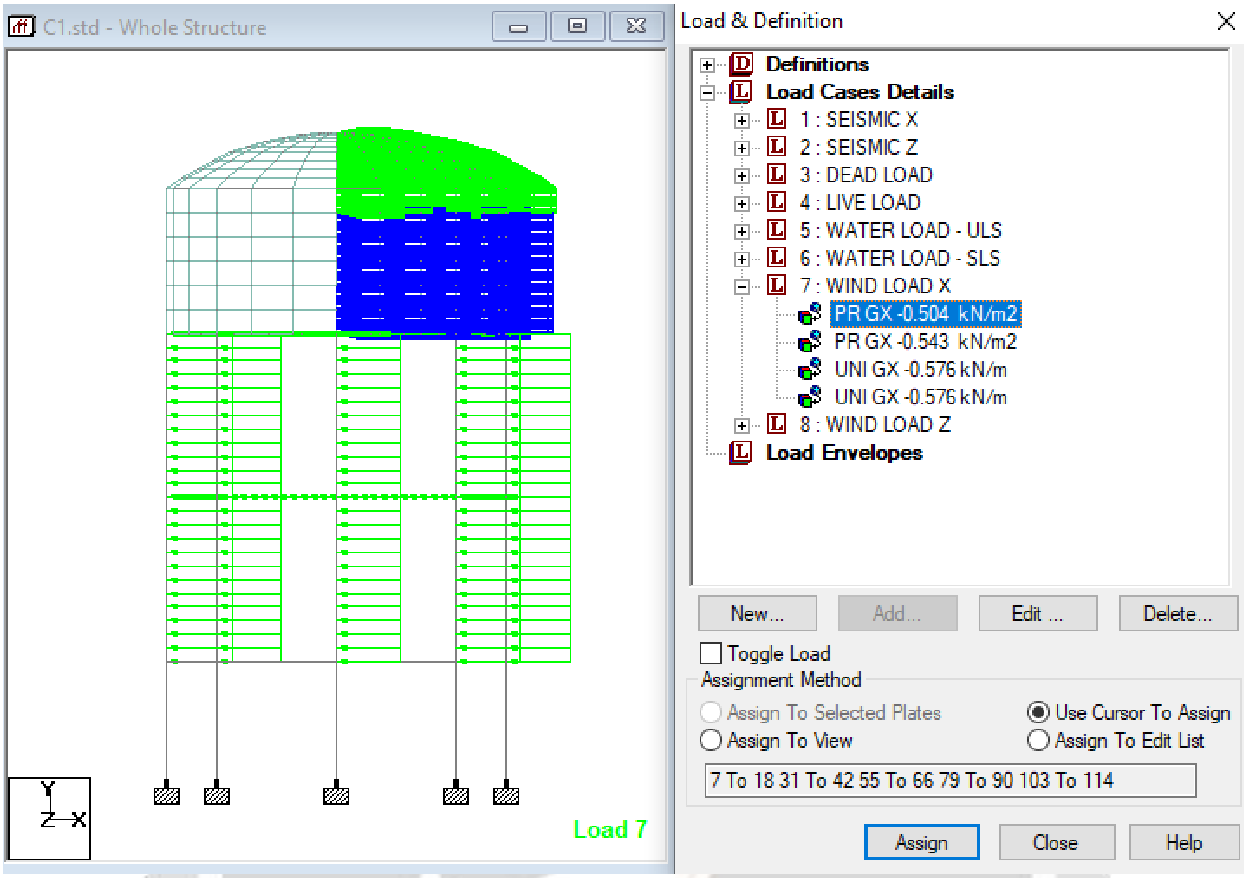


**Figure 0:14 Wind Load in X Direction**

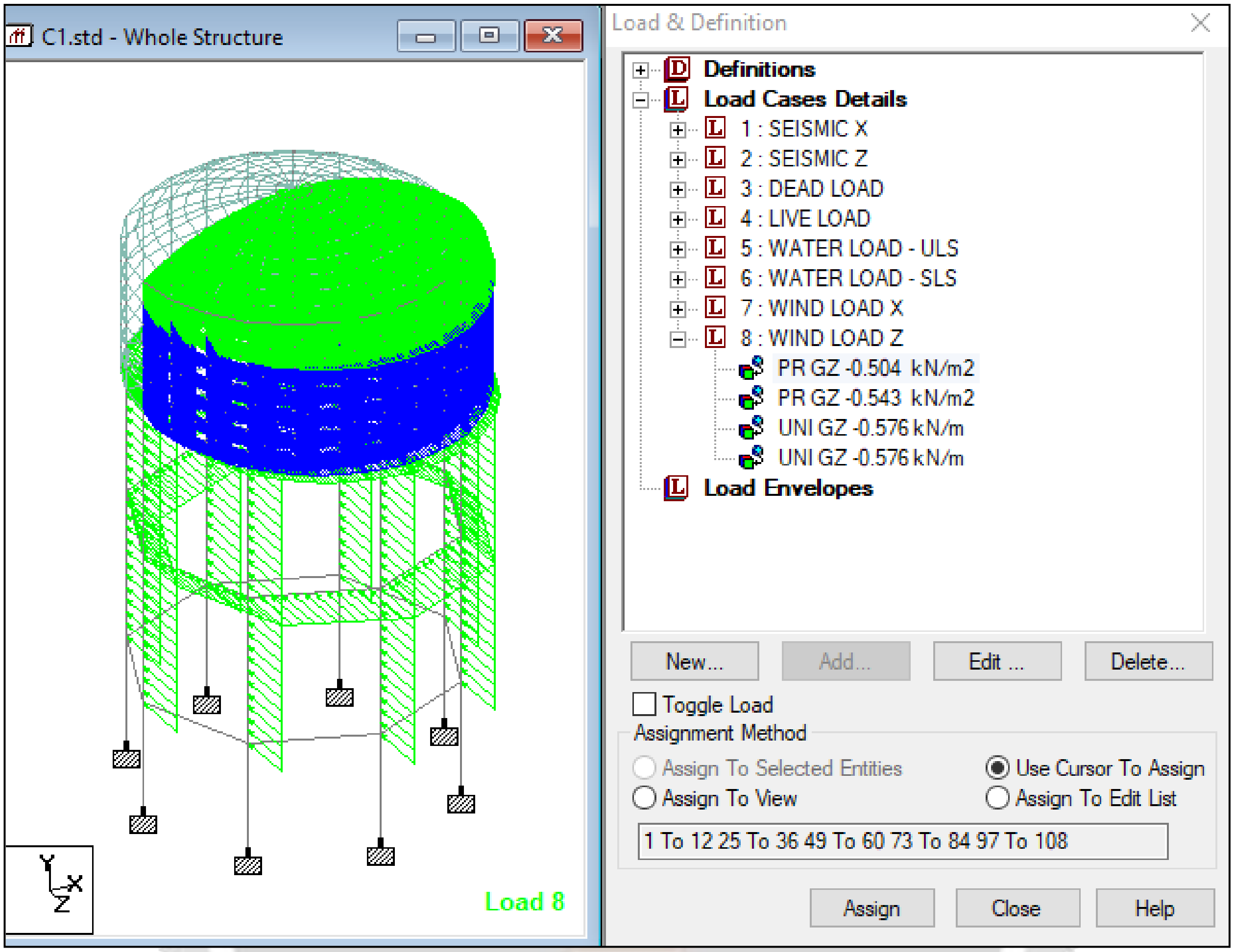


**Figure 0:15 Wind Load in Z Direction.**

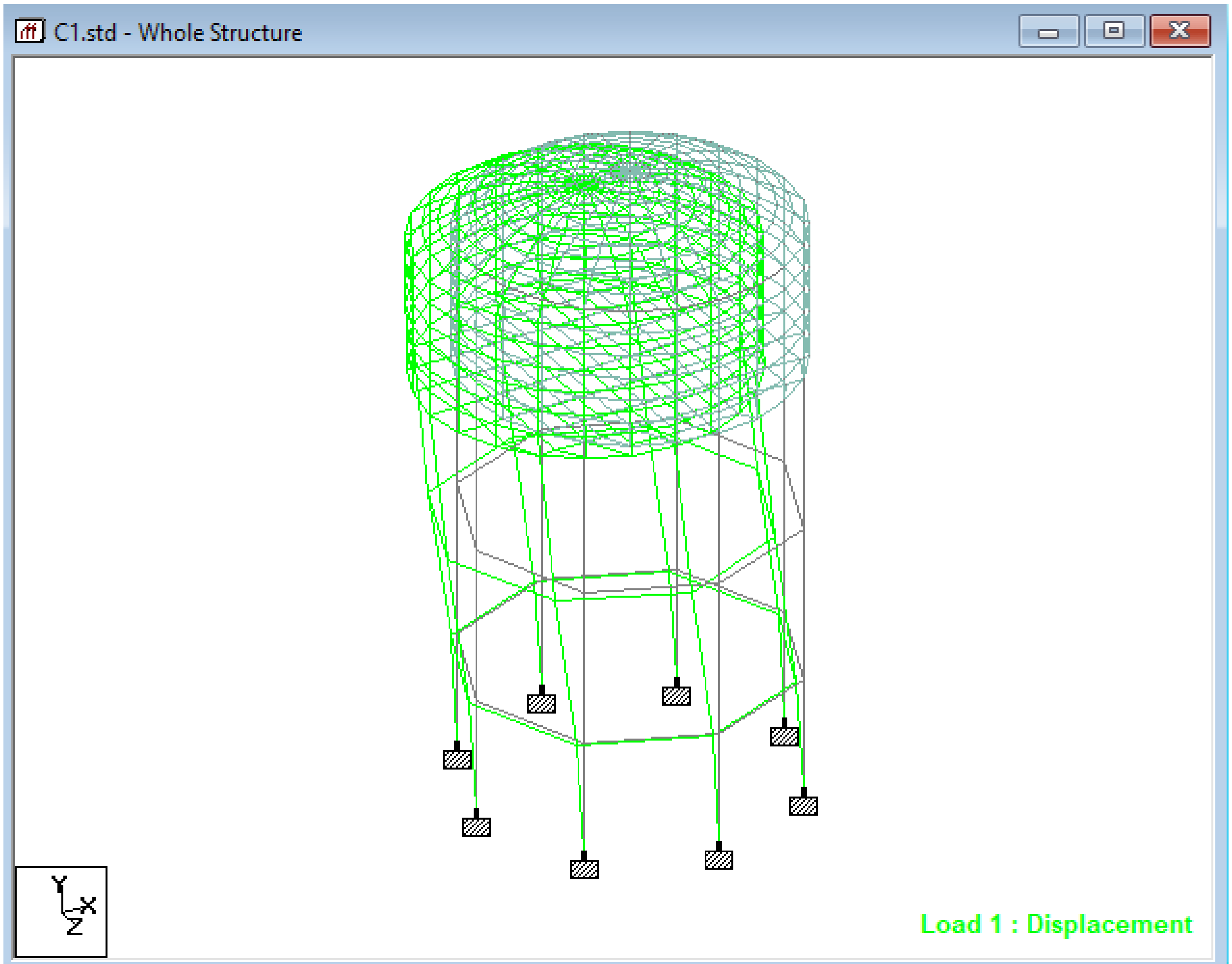


**Figure 0:16 Deformed Shape for Eq. Load – X Dir.**

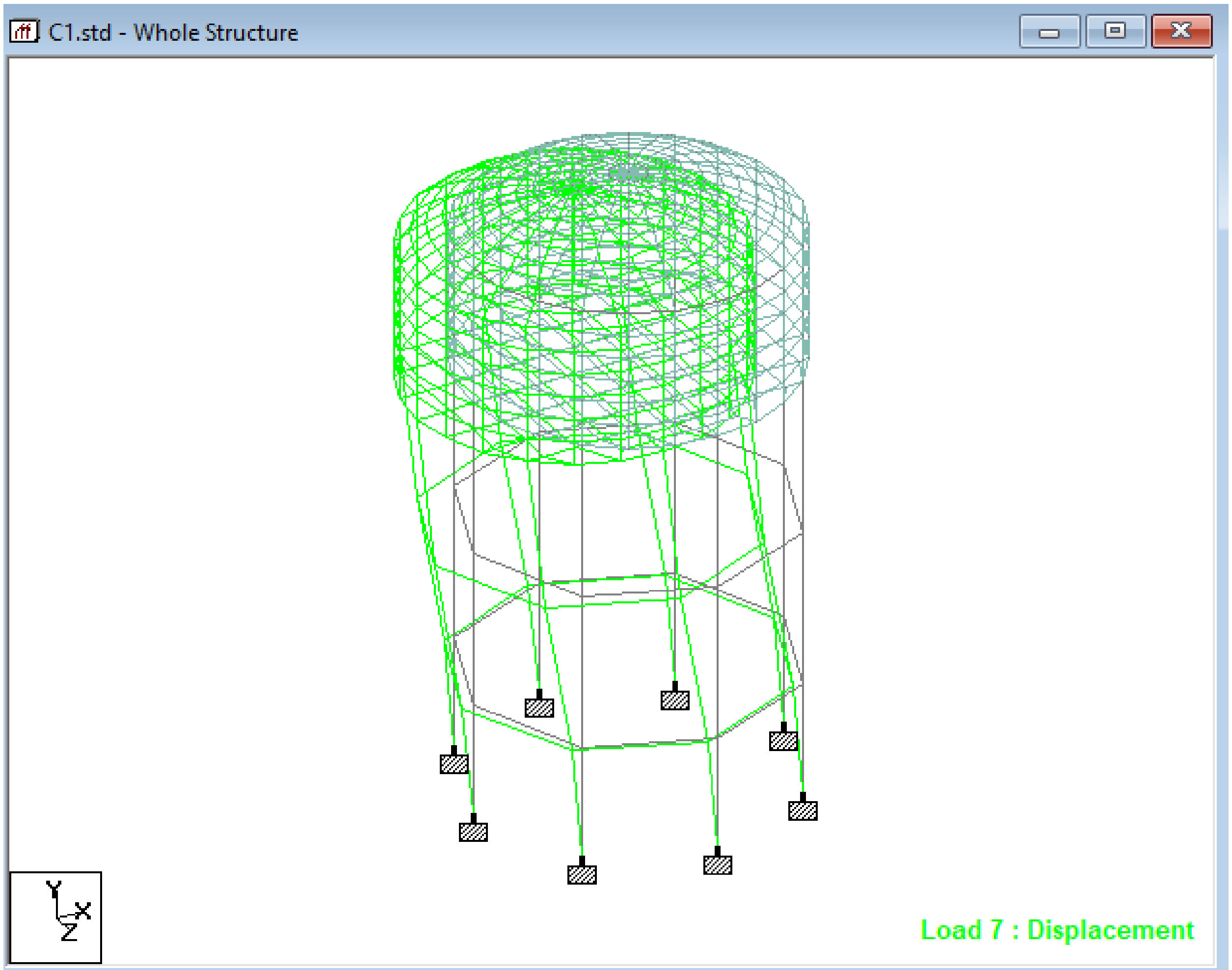


**Figure 0:17 Deformed Shape for Wind Load – X Dir.**

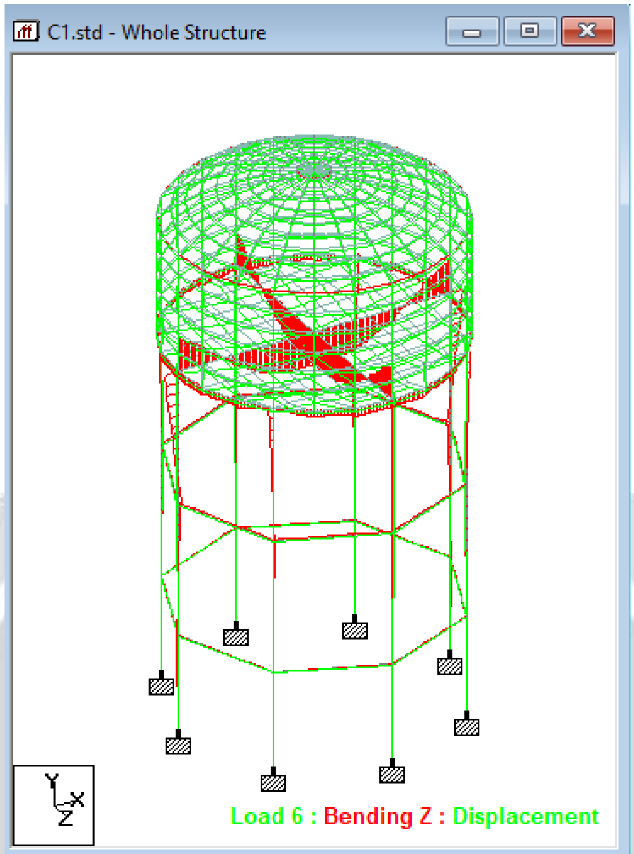


**Figure 0:18 Bending Moment Diagram for Gravity Loads.**

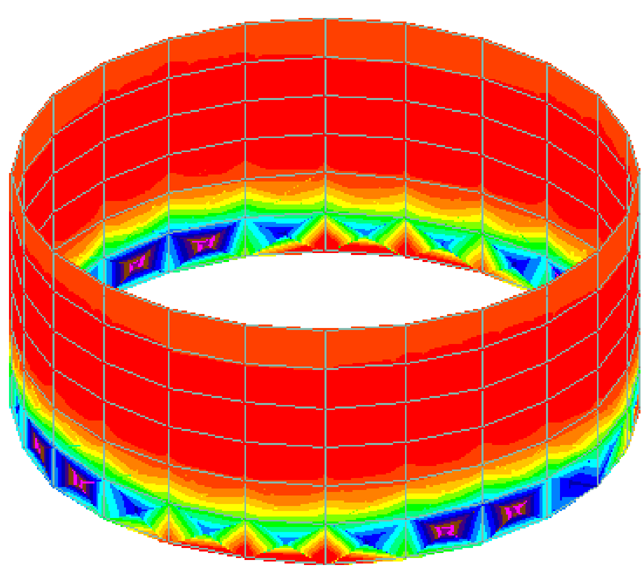

**Figure 0:19 Stresses in Walls due to water Load**

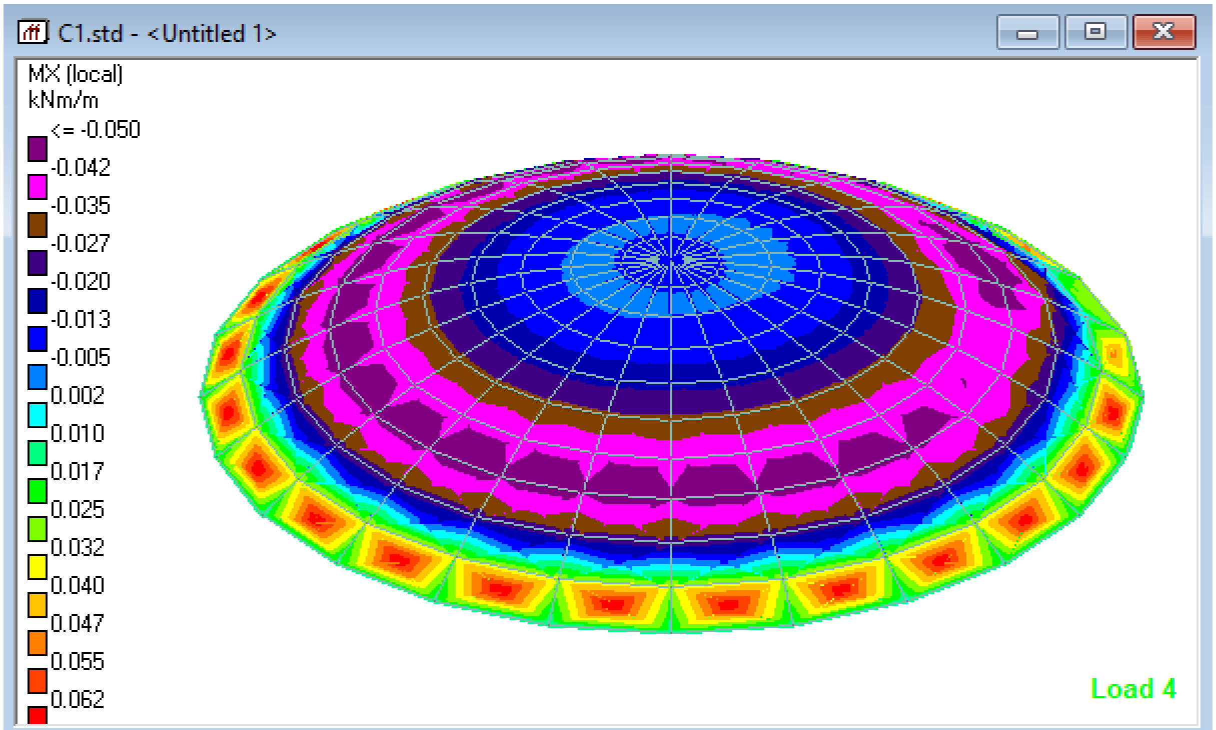


**Figure 0:20 Stresses in Top Dome due to Live Load**

## 4. RESULT AND DISCUSSION

The models are first loaded with gravity loads and then lateral loads are applied to check the behaviors of the models. The X direction results are extracted due to symmetrical in both directions.

### 4.1. Circular Tank

#### 4.1.1. Displacement_ EQX

The displacement in mm of Models in X direction is tabulated and presented below.

**Table 0.1-Displacement in X Direction_ EQX**

| | TYPE C1 | TYPE C2 | TYPE C3 |
|---|---|---|---|
| Top Slab | 4.319 | 7.432 | 11.113 |
| Side Wall | 4.272 | 7.352 | 10.988 |
| Columns | 2.684 | 5.529 | 8.920 |

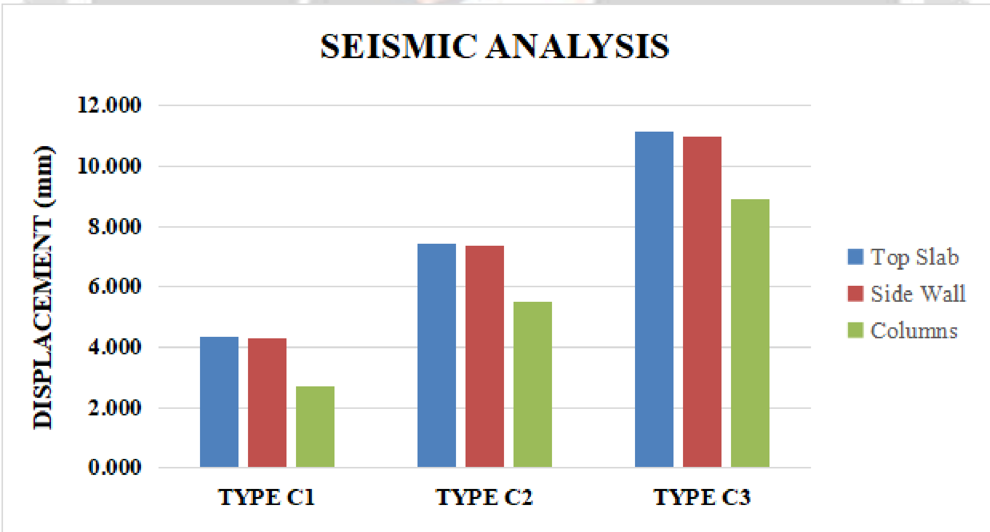


**Figure 0:1 Displacement of Different Heights Circular Tank**

From the above graph, it shows that the maximum displacement is found in the top of the tank. And the tank having maximum height is exhibiting the maximum displacement.

#### 4.1.2.Drift_ EQX

The displacement in mm of Models in X direction is tabulated and presented below.

| | TYPE C1 | TYPE C2 | TYPE C3 |
|---|---|---|---|
| **Top Slab** | 0.05 | 0.08 | 0.13 |
| **Side Wall** | 1.59 | 1.82 | 2.07 |
| **Columns** | 2.68 | 5.53 | 8.92 |

**Table 0.2-Drift in X Direction_ EQX**

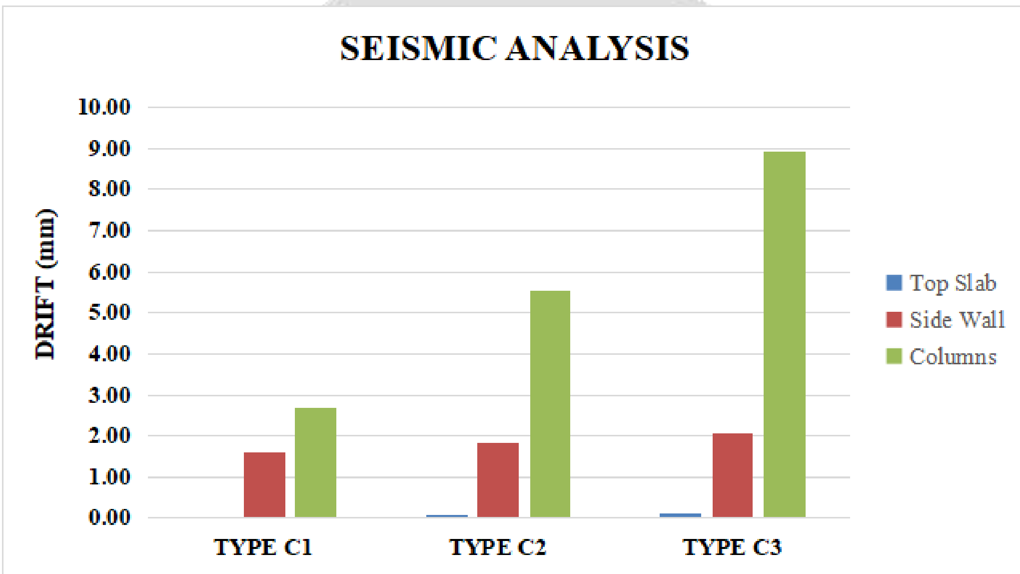


**Figure 0:2 Drifts of Different Heights Circular Tank**

The difference in the displacement i.e., the drift values are maximum noticed between column and tank bottom. The maximum height of the tank, Type C3 is having maximum drift values and the tank having lower height i.e., type C1 is having lesser drift values.

**4.1.3Base Shear_ EQX**

Base shear is the shear force at base or foundation level. The following table indicates the base shear value for different configurations.

**Table 0.3-Base Shear in X Direction_ EQX**

| | BASE SHEAR (kN) |
|---|---|
| **TYPE C1** | 66.66 |
| **TYPE C2** | 72.27 |
| **TYPE C3** | 77.87 |

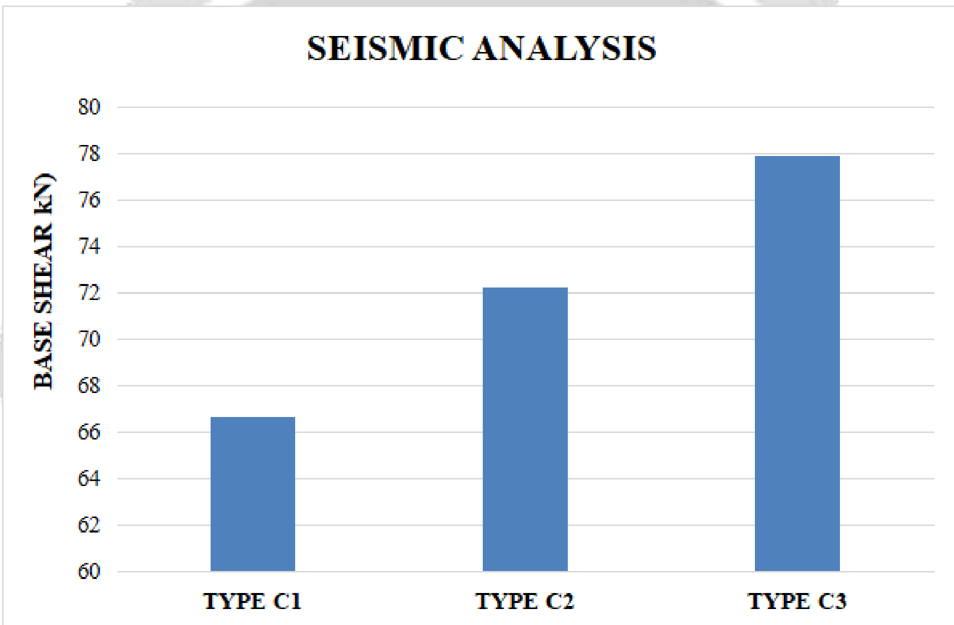


**Figure 0:3 Base Shear of Different Heights Circular Tank**

The Base shear of the structure increases with increase in the height of the structure and hence, type C3 is having maximum base shear value and Type C1 is having Lesser base shear value.

**4.1.4. Maximum Bending Moment**

The Maximum Bending moment in beams and columns are tabulated in the below table and compared & presented in the graph below.

**Table 0.4-Max. BM _ Circular**

| | MAX. BM | |
|---|---|---|
| | BEAMS | COLUMNS |
| TYPE C1 | 83.94 | 33.39 |
| TYPE C2 | 83.94 | 39.828 |
| TYPE C3 | 83.94 | 50.179 |

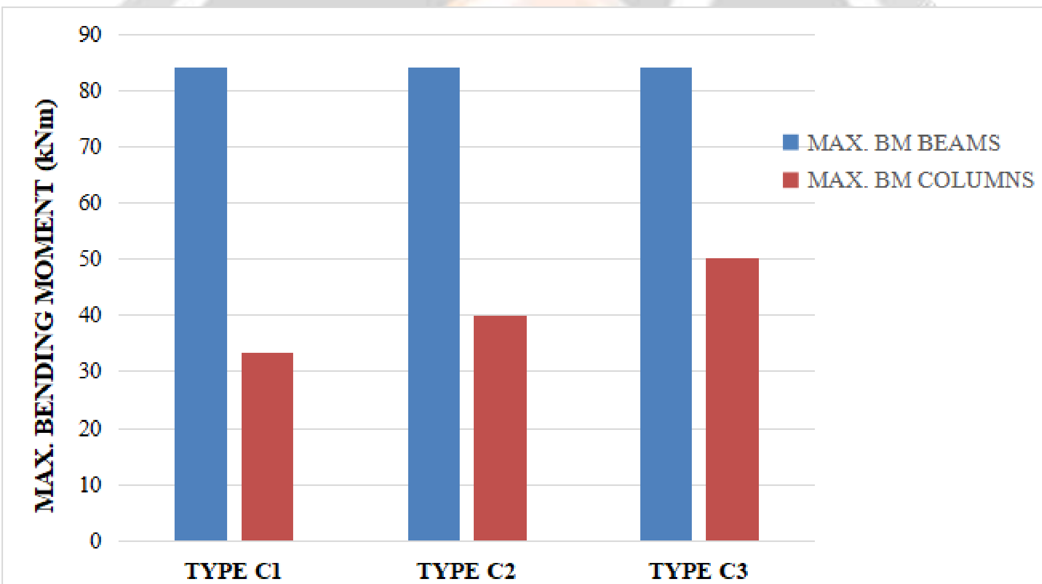


**Figure 0:4 Maximum BM of Different Heights Circular Tank**

From the graphs, it is noticed that, increase in the height of the structure is not causing any difference in the Bending moment value of Beams. However, the bending moment is varying in the column as per height of the structure. The Model Type C3 is having maximum bending moment in column and Type C1 is having lesser Bending moment values.

### 4.1.5. Maximum Shear Force

The Maximum Shear Force in beams and columns are tabulated in the below table and compared & presented in the graph below.

**Table 0.5-Max. SF _ Circular**

| | MAX. SF | |
|---|---|---|
| | **BEAMS** | **COLUMNS** |
| **TYPE C1** | 66.3 | 16.71 |
| **TYPE C2** | 66.3 | 22.85 |
| **TYPE C3** | 66.3 | 28.37 |

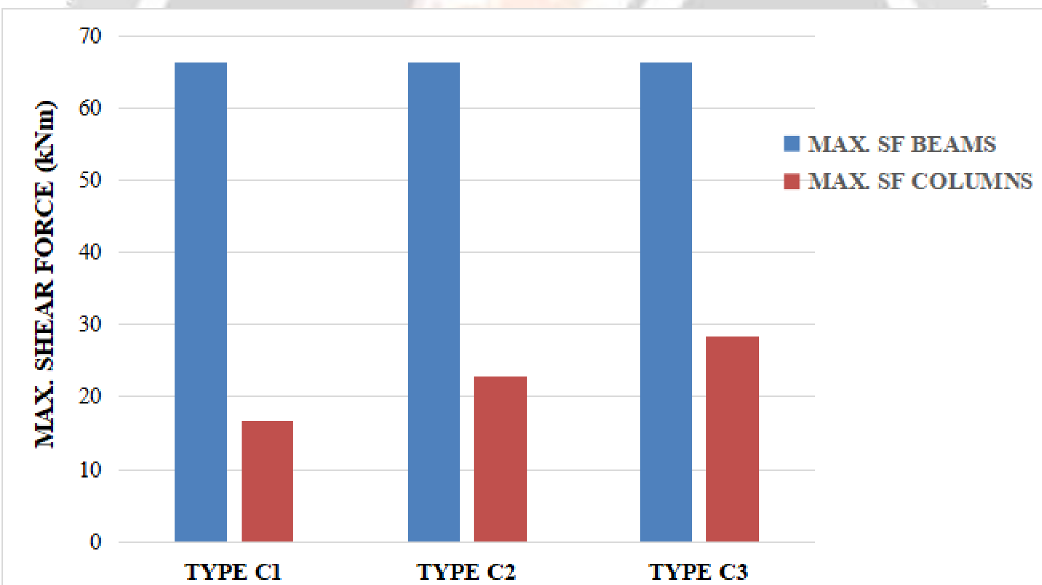


**Figure 0:5 Maximum SF of Different Heights Circular Tank**

From the graphs, it is noticed that, increase in the height of the structure is not causing any difference in the shear Force value of Beams. However, the bending moment is varying in the column as per height of the structure. The Model Type C3 is having maximum shear force in column and Type C1 is having lesser shear force values.

**4.1.6. Displacement_ WINDX**

The displacement in mm of Models in X direction is tabulated and presented below.

**Table 0.6-Displacement in X Direction_ WINDX**

| | TYPE C1 | TYPE C2 | TYPE C3 |
|---|---|---|---|
| **Top Slab** | 5.147 | 9.790 | 15.762 |
| **Side Wall** | 5.110 | 9.716 | 15.663 |
| **Columns** | 3.487 | 7.904 | 13.617 |

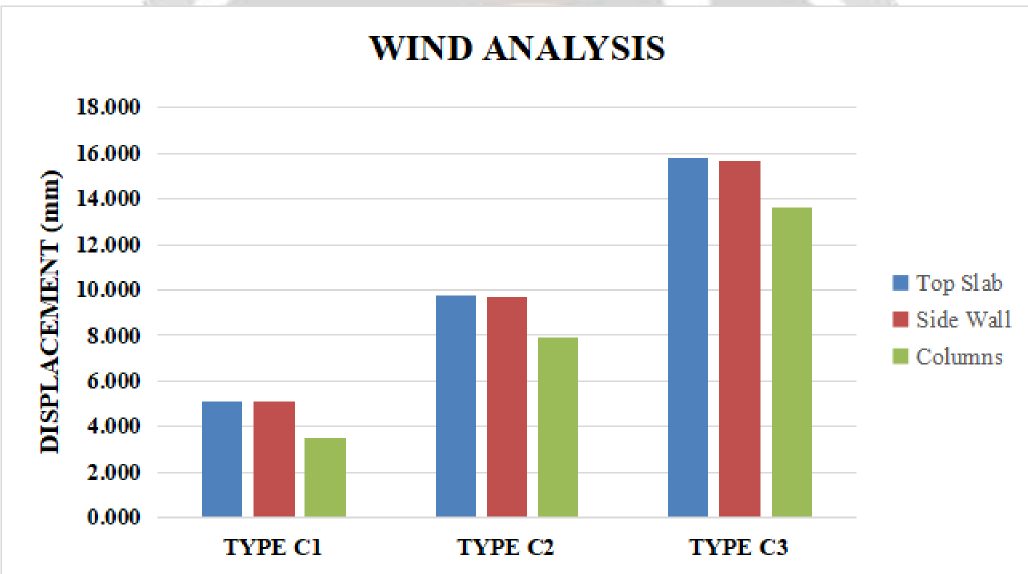


**Figure 0:6 Displacement of Different Heights Circular Tank for Wind**

From the above graph, it shows that the maximum displacement is found in the top of the tank. And the tank having maximum height is exhibiting the maximum displacement.

### 4.1.7. Drift_ WINDX

The displacement in mm of Models in X direction is tabulated and presented below.

**Table 0.7-Drift in X Direction_ WINDX**

| | TYPE C1 | TYPE C2 | TYPE C3 |
|---|---|---|---|
| **Top Slab** | 0.04 | 0.07 | 0.10 |
| **Side Wall** | 1.62 | 1.81 | 2.05 |
| **Columns** | 3.49 | 7.90 | 13.62 |

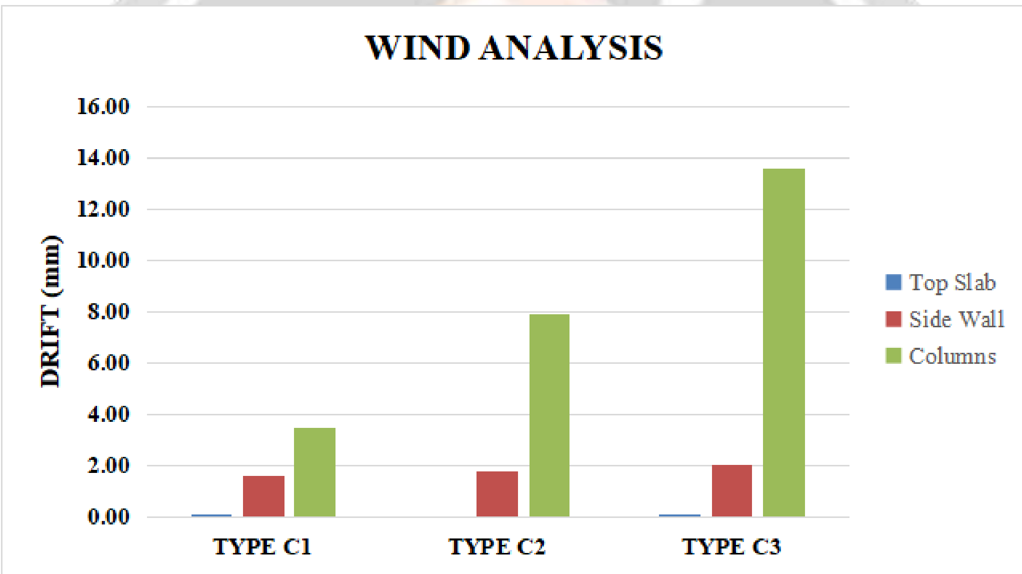


**Figure 0:7 Drift of Different Heights Circular Tank for Wind**

### 4.2. Rectangular Tank

#### 4.2.1. Displacement_ EQX

The displacement in mm of Models in X direction is tabulated and presented below.

**Table 0.8-Displacement in X Direction_ EQX**

| | TYPE R1 | TYPE R2 | TYPE R3 |
|---|---|---|---|
| **Top Slab** | 3.756 | 6.305 | 8.933 |
| **Side Wall** | 3.751 | 6.295 | 8.918 |
| **Columns** | 2.422 | 4.846 | 7.444 |

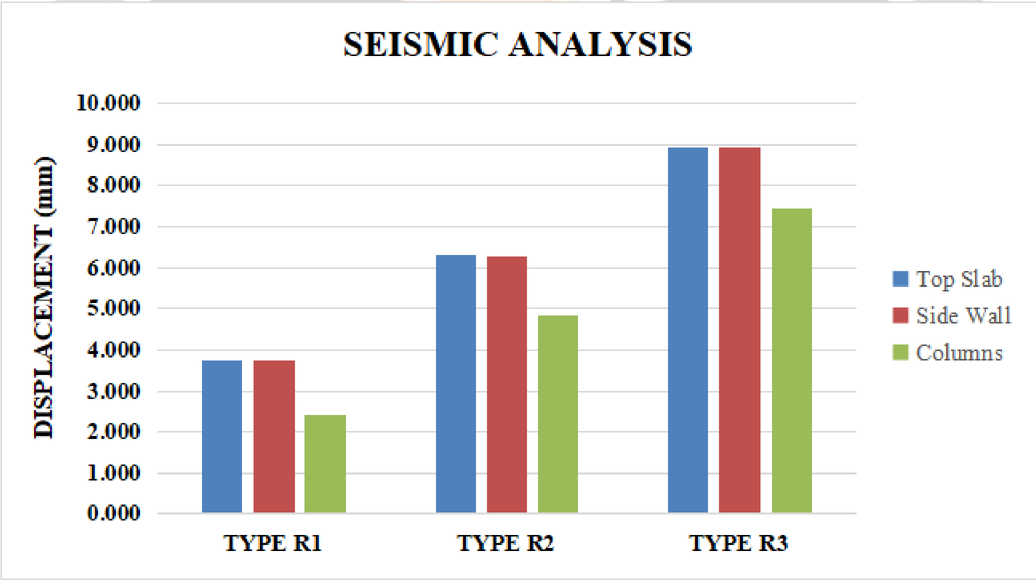


**Figure 0:8 Displacement of Different Heights Rectangular Tank**

From the above graph, it shows that the maximum displacement is found in the top of the tank. And the tank having maximum height i.e., Type R3 is exhibiting the maximum displacement. And Type R1 is exhibiting lowest displacement.

### 4.2.2. Drift_ EQX

The displacement in mm of Models in X direction is tabulated and presented below.

**Table 0.9-Drift in X Direction_ EQX**

| | TYPE R1 | TYPE R2 | TYPE R3 |
|---|---|---|---|
| **Top Slab** | 0.00 | 0.01 | 0.02 |
| **Side Wall** | 1.33 | 1.45 | 1.47 |
| **Columns** | 2.42 | 4.85 | 7.44 |

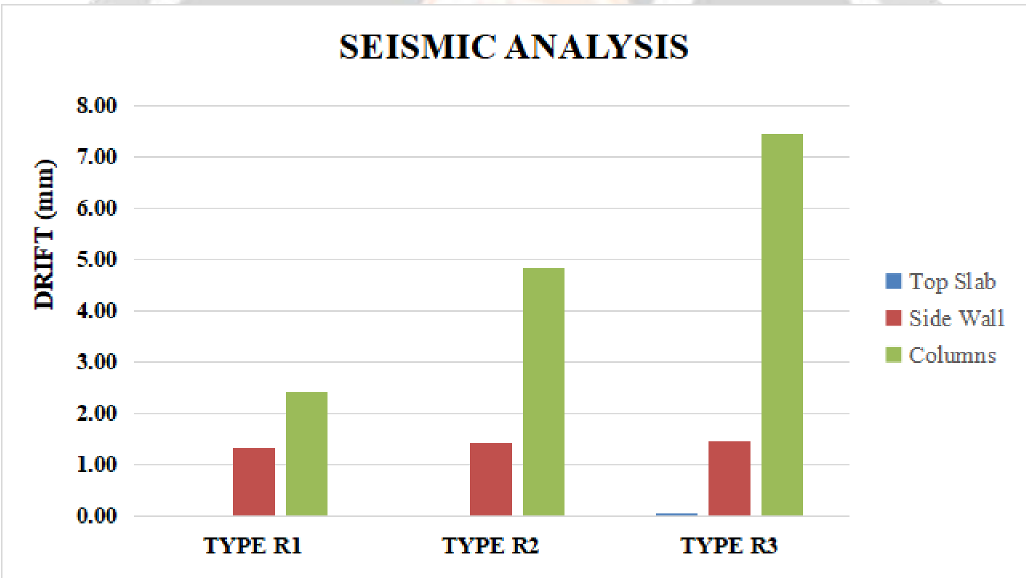


**Figure 0:9 Drift of Different Heights Rectangular Tank**

The difference in the displacement i.e., the drift values are maximum noticed between column and tank bottom. The maximum height of the tank, Type R3 is having maximum drift values and the tank having lower height i.e., type R1 is having lesser drift values.

### 4.2.3. Maximum Bending Moment

The Maximum Bending moment in beams and columns are tabulated in the below table and compared & presented in the graph below.

**Table 0.10-Max. BM _ Rectangular**

| | MAX. BM | |
|---|---|---|
| | **BEAMS** | **COLUMNS** |
| **TYPE R1** | 33.927 | 30.938 |
| **TYPE R2** | 55.436 | 44.585 |
| **TYPE R3** | 73.902 | 58.092 |

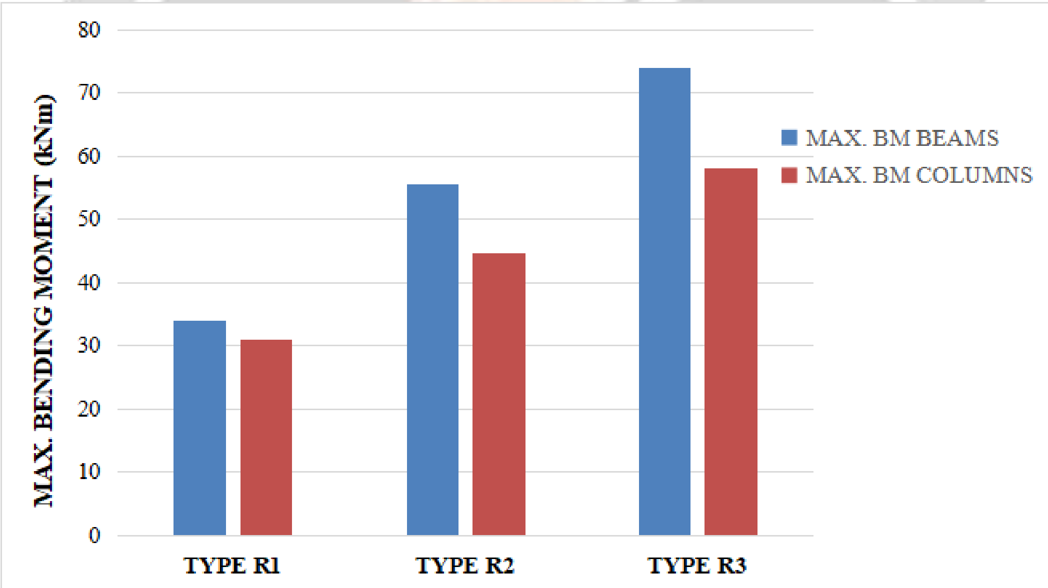


**Figure 0:10 Maximum BM of Different Heights Rectangular Tank**

From the graphs, it is noticed that, increase in the height of the structure is not causing any difference in the Bending moment value of Beams. However, the bending moment is varying in the column as per height of the structure. The Model Type R3 is having maximum bending moment in column and Type R1 is having lesser Bending moment values.

**4.2.4. Maximum Shear Force**

The Maximum Shear Force in beams and columns are tabulated in the below table and compared & presented in the graph below.

**Table 0.11-Max. SF _ Rectangular**

| | MAX. SF | |
|---|---|---|
| | BEAMS | COLUMNS |
| TYPE R1 | 19.59 | 13.59 |
| TYPE R2 | 22.83 | 19.06 |
| TYPE R3 | 24.63 | 24.534 |

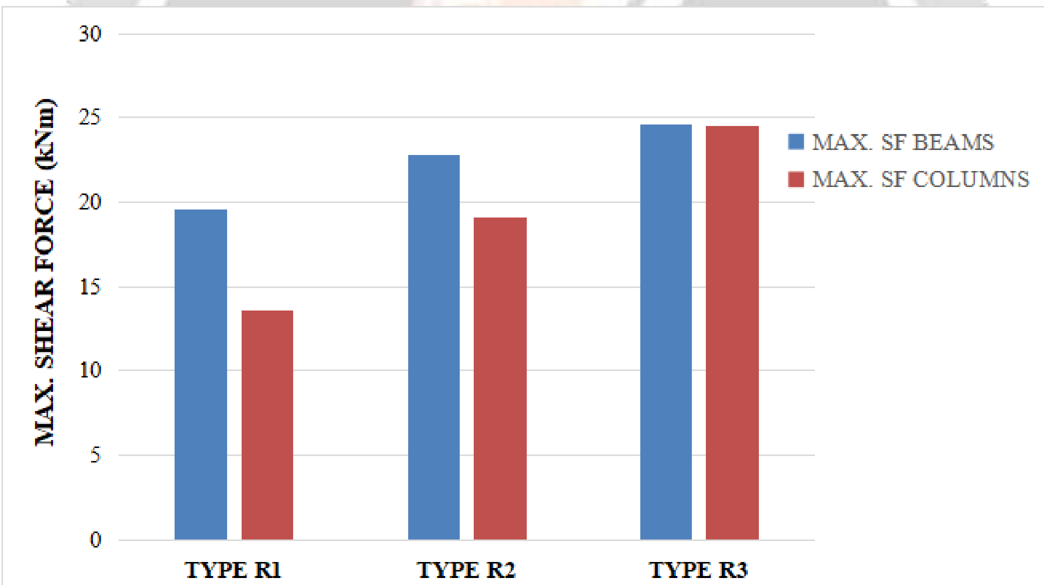


**Figure 0:11 Maximum SF of Different Heights Rectangular Tank**

From the graphs, it is noticed that, increase in the height of the structure is not causing any difference in the shear Force value of Beams. However, the bending moment is varying in the column as per height of the structure. The Model Type R3 is having maximum shear force in column and Type R1 is having lesser shear force values.

**4.2.5. Displacement_ WINDX**

The displacement in mm of Models in X direction is tabulated and presented below.

**Table 0.12-Displacement in X Direction_ WINDX**

| | TYPE R1 | TYPE R2 | TYPE R3 |
|---|---|---|---|
| **Top Slab** | 7.038 | 15.000 | 25.713 |
| **Side Wall** | 7.041 | 14.994 | 25.693 |
| **Columns** | 4.988 | 12.606 | 23.065 |

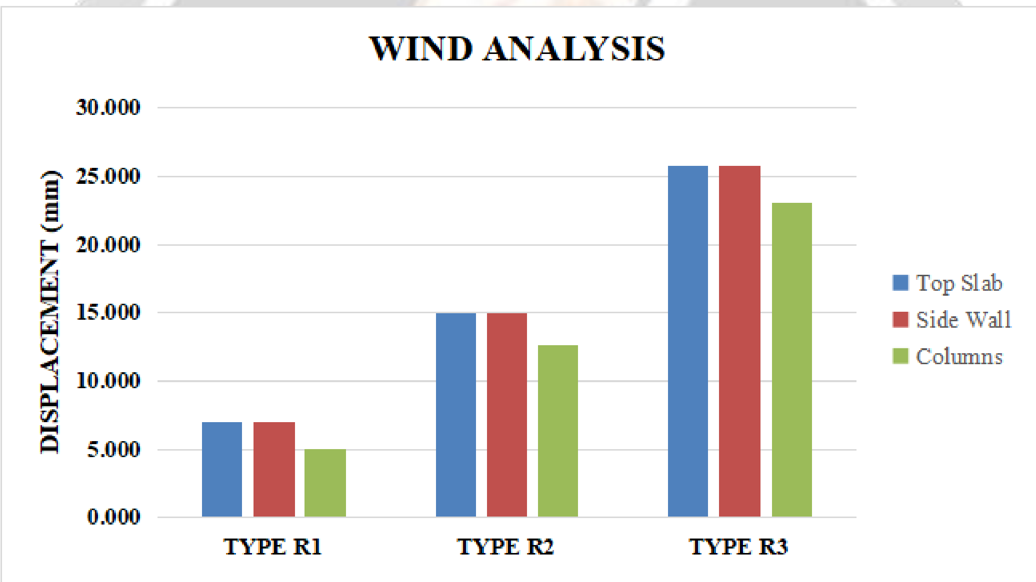


**Figure 0:12 Displacement of Different Heights Rectangular Tank**

From the above graph, it shows that the maximum displacement is found in the top of the tank. And the tank having maximum height i.e., Type R3 is exhibiting the maximum displacement. And Type R1 is exhibiting lowest displacement.

#### 4.2.6. Drift_ WINDX

The displacement in mm of Models in X direction is tabulated and presented below.

**Table 0.13-Drift in X Direction_ WINDX**

| | TYPE R1 | TYPE R2 | TYPE R3 |
|---|---|---|---|
| **Top Slab** | 0.00 | 0.01 | 0.02 |
| **Side Wall** | 2.05 | 2.39 | 2.63 |
| **Columns** | 4.99 | 12.61 | 23.07 |

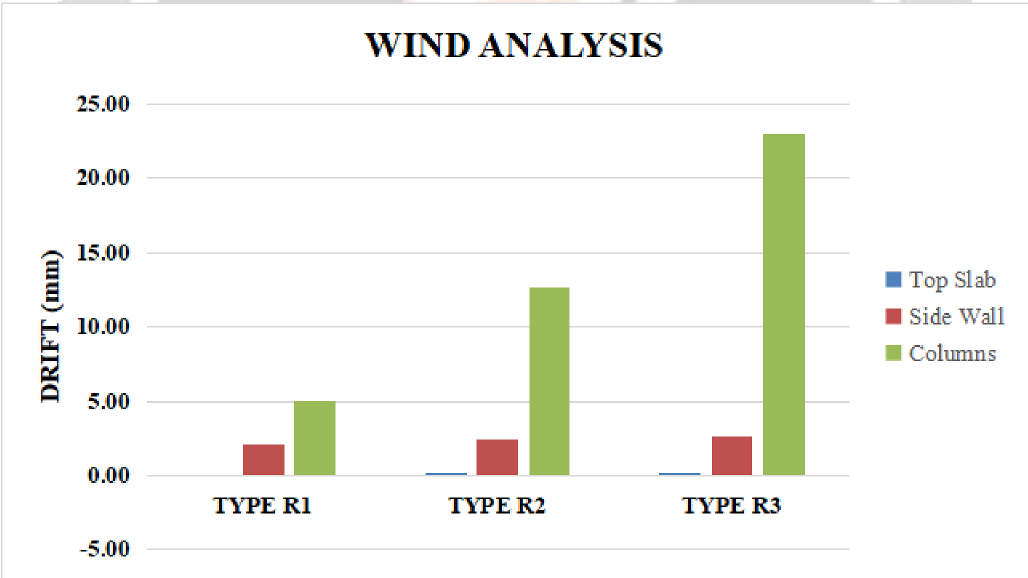


**Figure 0:13 Drift of Different Heights Rectangular Tank**

The difference in the displacement i.e., the drift values are maximum noticed between column and tank bottom. The maximum height of the tank, Type R3 is having maximum drift values and the tank having lower height i.e., type R1 is having lesser drift values.

## 5. CONCLUSIONS

In the previous chapter results are extracted and tabulated. The results are compared and final conclusions are drawn in this chapter.

- The displacement values of elevated tank show that, the displacement values depend on the height of the structure for the same capacity. The Increase in height increases the displacement.
- For Circular Tank, the increase in staging increases the displacement by 72% and 250% for model Type C2 and C3 when compared with Model Type C1
- When comparing the displacement of circular tank for seismic and wind analysis, Wind analysis shows maximum displacement compared with seismic analysis. The increase in percentage is around 19%, 31% and 41% for Model Type C1, C2 and C3 respectively.
- When the Rectangular tank is compared with Circular Tank, the displacement values reduce for rectangular tank in seismic and displacement values increases for rectangular tank in wind analysis.
- The Reduced values varies from 15% to 25% for seismic analysis. And increased values 36% to 63% for Wind analysis.
- The storey drift in all the models is found to be maximum between the interface between column and tank bottom. Since, it is due to sudden change in the stiffness. This can be reduced by providing suitable stiffener beams in columns.
- The base shear values increase with the increase in height of the structure. The Base shear also depends on the weight of the structure.
- The Maximum Bending moment is found in the Beams in case of circular water tank. The BM in beams is constant for different height of the structure. However, the Bending moment in columns increases with increase in tank height. The shear force are also in same line with Bending moment.

It can be concluded that, the Rectangular tanks are better for seismic prone areas and Circular tanks are better for critical wind areas.

## 6. ACKNOWLEDGEMENT

Interdependence is certainly more valuable than independence. This thesis is the result of one year of work whereby I have been accompanied and supported by many people. It is a pleasant aspect that I have now the opportunity to express my gratitude for all of them.

I deeply indebted to my guide **DR. B. S. KRISHNAMURTHY** whose help, stimulating suggestions and encouragement helped me in all the time of research and writing of the thesis. I would like to thank my guide for motivating me to undertake an interesting problem and for his guidance during the entire course of project work.

I would like to thank **Dr. B. R. Patagundi**, Head of Civil Department, and all faculty members of the department who have been extremely kind and helpful.

I express out deep gratitude to my renowned institute, **S. G. Balekundri Institute of Technology, Belagavi** which provided an opportunity and platform for fulfilling my dreams and desires to reach my goal. I sincerely thank **Dr. B. R. Patagundi, Principal, SGBIT** who is the constant source of inspiration, throughout the academics.

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