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Seismic Analysis and Comparative Study of Elevated Storage Tank by GSDMA Guidelines

Prof. Amey R. Khedikar[1], Abhishek Pandey[2],
[1]Assistant Professor and Head of Dept. of Civil engineering, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Nagpur, Maharashtra, India
[2]Research Scholar, Dept. of Civil engineering, Tulsiramji Gaikwad-Patil College of Engineering and Technology, Nagpur, Maharashtra, India

Abstract: A container to store water in a huge amount of capacity can simply be called as the water tank. During the earthquakes, all these liquid storage tanks get collapsed or damaged heavily. 40 to 65 years is the feasible lifetime of an ESR in general. Shortage of drinking water, utilizing water, uncontrolled fires, etc are some unexpected events caused due to any damage or collapse of the tanks. Water tank parameters include various designs of tanks and different way of construction, materials, linings etc. Different materials are used for the construction and development of water tanks such as: - plastic, concrete, steel, fiberglass, etc. Therefore, to avoid all those unwanted events in the future various studies have been carried out regarding different types, shapes of water tanks. In this research, Elevated Service Reservoir (E.S.R) is being compared of shape Rectangular & Circular water tanks of capacity 5lakh litres and a total height of 18m with 3m, 4.5m staging height in Earthquake Zone V by Equivalent static analysis using STAAD.PRO software and referring GSDMA guidelines for the design of a tank and IS 1893 PART2-2014 code. By studying all the observations and results, it shows that Circular water tank is more preferable and economical for use.
Keywords: Elevated Service Reservoir, GSDMA Guidelines, Equivalent static analysis, shear stress.

I. INTRODUCTION

An elevated water tank can be explained as a large water storage container constructed for the use of holding water supply at a certain height and to pressurize the water distribution system effectively and efficiently. The liquid storage tanks are particularly subjected to the risk of damage, collapse due to earthquake-produced vibrations and causes damage. A large number of various elevated water tanks has been damaged or collapsed during the past earthquakes. Elevated water tanks are critical and strategic structures and any damage of these structures during the time of earthquakes may endanger drinking water supply, cause to fail in preventing large fires in the areas and substantial economic as well as sometimes human loss, etc. Since elevated tanks are commonly used in earthquake-prone regions hence, their seismic properties have to be investigated in full detail.

A. Types Of Water Tanks

In the present year, there has been much stress on water supply and it extends everywhere throughout the world, which is exceptionally essential for the social and modern improvement of the whole nation in all fields. The capacity difference of water tanks can be accessible relying on the necessity of utilization and purpose. The water tanks are classified based on shape are given below:

1) Rectangular tanks
2) Circular tanks
3) Intze tanks
4) Spherical tanks
5) Circular tank with conical bottom.

Also, there are three ways by which water tanks are classified based on the location:

a) Tank resting on grounds
b) Underground water tanks
c) Elevated or overhead water tanks.

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II. MODEL ANALYSIS

1) *For Case 1:* Comparative study of rectangular and circular water tank (using a circular column with 18mts height and 3-3 mts staging height)

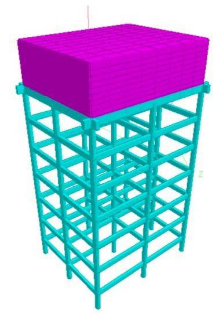

Fig 1: Overhead Rectangular Tank

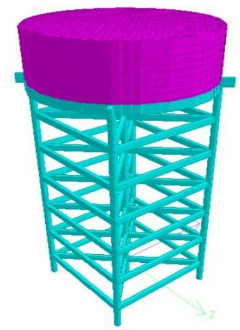

Fig 2: Overhead Circular Tank

The above figure shows the 3D image of an overhead rectangular and circular water tanks with circular columns. Both the tanks have 18meters of column height and 3-3 meters of staging height. 9 no of columns are present in a rectangular water tanks and 5 no of columns in circular water tanks which can be seen clearly in this above 3D image.

a) *General Specifications:* Parameters of Water Tank shown in fig 1(Overhead Rectangular tank), fig 2(Overhead Circular tank), and details are given below:

The grade of concrete & steel taken here in this rectangular water tank is M-30 & FE-500 and in a circular water tank is M-30 & FE-500. The volume of tank in rectangular water tank is 500 cum or 500000 LTS and in a circular water tank is 500 cum or 500000 LTS. As per the tender clause height of water stored in a rectangular water tank is 4mts and in a circular water tank is 4 mts. Free board in a rectangular water tank is 0.2 mts and in circular water tank is 0.2 mts. Height of a tank in a rectangular water tank is 18 MTS and in a circular water tank is 18 MTS. Rectangular water tank having total height of wall is 4.2 MTS and in a circular water tank is 4.2 MTS. Circular tank of plan area/dia in a rectangular water tank is 12.5X10.5 MTS and in a circular water tank is 12.6 MTS. Total no of the columns in a rectangular water tank is 9 and in circular water tank is 5. Sizes of column (circular) 0.50X0.50 MT2 in a rectangular water tank is 0.50X0.50 MT2. Rectangular water tank of bottom foundation in is 2 MTS and in circular water tank is 2 MTS. Plinth beam size in a rectangular water tank is 0.25X0.5 MT2 and in a circular water tank is 0.25X0.5 MT2. Floor beam size in rectangular water tank is 0.3X0.7 MT2 and in circular water tank is 0.3X0.7 MT2. In rectangular water tank the floor slab thickness is 0.25 MTS and in a circular water tank is 0.25 MTS. In rectangular water tank thickness of gallery is is 0.1 MTS and in circular water tank is 0.1 MTS. In rectangular water tank size of bracings is 0.25X0.50 MT2 and in circular water tank is 0.25X0.50 MT2.

2) *For Case: 2* Comparative study of rectangular and circular water tank (using rectangular column with 18mts height and 3-3 mts staging height)

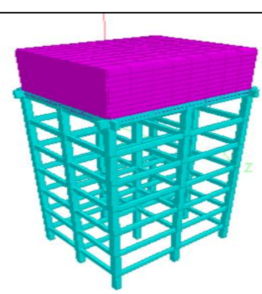

Fig :3 Overhead Rectangular Tank

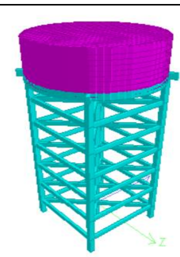

Fig :4 Overhead Circular Tank

Above figure shows the 3D image of an overhead rectangular and circular tanks with a rectangular column. Both the tanks have 18meters of column height and 3-3 meters of staging height. 9 no of columns in a rectangular water tank and 5 no of columns in circular water tanks are there which can be seen clearly in this above 3D image

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a) *General Specifications:* Parameters of Water Tank shown in fig 3(Overhead Rectangular tank), fig 4(Overhead Circular tank), and details as given below:

The grade of concrete & steel taken here in a rectangular water tank is M-30 & FE-500 and in a circular water tank is M-30 & FE-500. The volume of tank in a rectangular water tank is 500 cum or 500000 LTS and in a circular water tank is 500 cum or 500000 LTS. As per the tender clause height of water stored in a rectangular water tank is 4mts and in a circular water tank is 4 mts. Free board in a rectangular water tank is 0.2 mts and in a circular water tank is 0.2 mts. The height of tank in a rectangular water tank is 18 MTS and in a circular water tank is 18 MTS. The rectangular water tanks having total height of wall is 4.2 MTS and in a circular water tank is 4.2 MTS. A circular tank of plan area/dia in a rectangular water tank is 12.5X10.5 MTS and in a circular water tank is 12.6 MTS. The total no of columns in rectangular water tank is 9 and in circular water tank is 5. Sizes of column (circular shape) 0.50 MT2 in rectangular water tank is 0.50 MT2. Rectangular water tank of bottom foundation in is 2 MTS and in circular water tank is 2 MTS. In a rectangular water tank plinth beam size is 0.25X0.5 MT2 and in a circular water tank is 0.25X0.5 MT2. In rectangular water tank floor beam size is 0.3X0.7 MT2 and in a circular water tank is 0.3X0.7 MT2. In rectangular water tank floor slab thickness is 0.25 MTS and in circular water tank is 0.25 MTS. In rectangular water tank thickness of gallery is 0.1 MTS and in circular water tank is 0.1 MTS. In rectangular water tank size of bracings is 0.25X0.50 MT2 and in circular water tank is 0.25X0.50 MT2.

3) *For Case: 3* Comparative study of rectangular and circular tank water (using a column with 18mts height and 4.5-4.5 mts staging height)

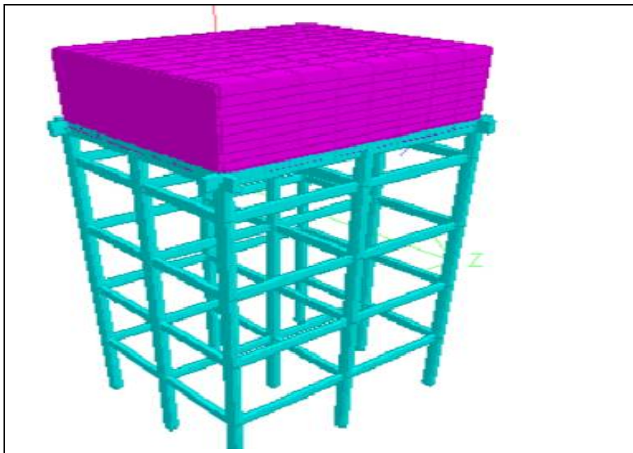	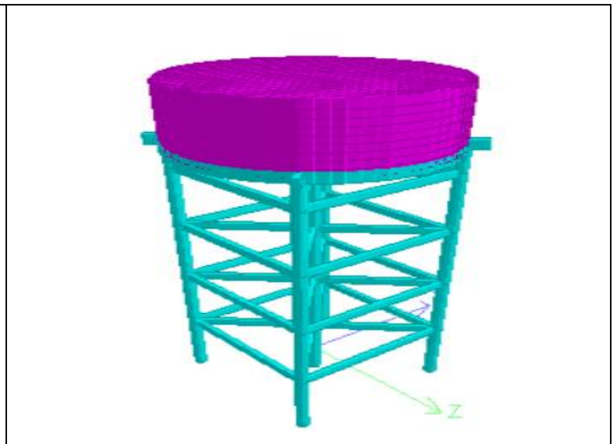
Fig :5 Overhead Rectangular Tank	Fig :6 Overhead Circular Tank

The figure above shows the 3D image of an overhead rectangular and a circular tank with circular columns. Both the tanks have 18meters of column height and 4.5-4.5 meters of staging height. 9 no of columns in a rectangular water tank and 5 no of columns in a circular water tanks are there which can be seen clearly in this above 3D image.

a) *General specifications:* Parameters of Water Tank shown in fig 5(Overhead Rectangular tank), fig 6(Overhead Circular tank) and details are given below:

The grade of concrete & steel taken here in a rectangular water tank is M-30 & FE-500 and in a circular water tank is M-30 & FE-500. The volume of tank in a rectangular water tank is 500 cum or 500000 LTS and in a circular water tank is 500 cum or 500000 LTS. As per the tender clause height of water stored in a rectangular water tank is 4mts and in a circular water tank is 4 mts. The Free board in a rectangular water tank is 0.2 mts and in a circular water tank is 0.2 mts. The height of tanks in a rectangular water tank is 18 MTS and in a circular water tank is 18 MTS. The rectangular water tank having total height of wall is 4.2 MTS and in a circular water tank is 4.2 MTS. A Circular tank of plan area/dia in a rectangular water tank is 12.5X10.5 MTS and in a circular water tank is 12.6 MTS. The total no of columns in a rectangular water tank considered is 9 and in a circular water tank is 5. Sizes of column (circular shape) 0.60 MT2 in a rectangular water tank is 0.60 MT2. Rectangular water tank of the bottom foundation in is

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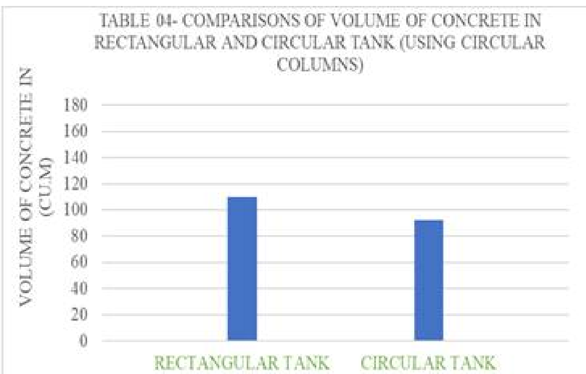
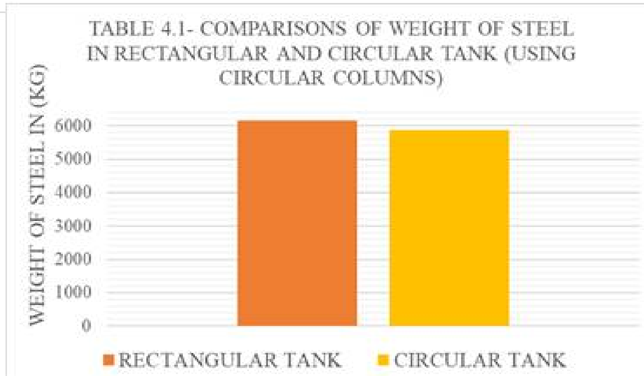
2 MTS and in circular water tank is 2 MTS. Plinth beam size in rectangular water tank is 0.25X0.5 MT2 and in a circular water tank is 0.25X0.5 MT2. The floor beam size in rectangular water tank is 0.3X0.7 MT2 and in circular water tank is 0.3X0.7 MT2. In rectangular water tank floor slab thickness is 0.25 MTS and in a circular water tank is 0.25 MTS. In a rectangular water tank thickness of a gallery is 0.1 MTS and in a circular water tank is 0.1 MTS. In a rectangular water tank size of bracings is 0.25X0.50 MT2 and in a circular water tank is 0.25X0.50 MT2

III. RESULTS AND DISCUSSION

1) *For Case 1*: After Analysing E.S.R. from Staad Pro having parameters, the following results and outcomes are carried out which are shown below in results and discussions below





Above fig shows the amount of concrete steel required

a) *Amount of Concrete Steel Required:* These two above graphs show 1) Total Volume of Concrete required in a rectangular water tank and a circular water tank and 2) shows Total Weight of Steel required in a rectangular (kg) and in a circular water tank. X-axis shows a rectangular and circular tank in two different colors while Y-axis shows volume of concrete in (cum) and weight of steel in (kg). Total Volume of Concrete in a rectangular water tank is found to be 109.8 m3 and in a circular water tank is 92.6 m3. Total Weight of Steel in a rectangular water tank is found to be 6164 kg and in a circular water tank is 5870 kg.
b) *Base shear, Base moment, and Time period:* In impulsive mode (kN) base shear in a rectangular water tank is 303 and in a circular water tank is 222. In Convective Mode (kN) base shear in a rectangular water tank is found to be 109 and in a circular water tank is 115. Total Shear to be applied at the CG of tank (kN) in a rectangular water tank is found to be as 323 and in a circular water tank is 250. In impulsive mode (kN-m) an overturning moment at the base of staging in a rectangular water tank is 6490 and in a circular water tank is 4735. In Convective Mode (kN-m) overturning mode at the base of staging in a rectangular water tank is 2844 and in a circular water tank is 2890. Total Overturning Moment (kN-m) in a rectangular water tank is found to be 7086 and in circular water tank is 5547 In Impulsive Mode (Ti) (sec) time period in a rectangular water tank is 1.46 and in a circular water tank is 1.84. Time period in Convective Mode (Tc) (sec) in a rectangular water tank is found to be 3.87 and in a circular water tank is 4.10.
c) *Plate Stress:* Plate stresses can easily be explained as the bending of plates because of application of loads on the plates results in the deflection of plates and the stresses in the plate can be calculated or find out from these deflections. Once the stresses acting on plates are known or calculated, then failure theories can be applied to find out whether these plates will fail under a given load or not.

S.no	Type of tank	SQX (n/mm2)		SQY (n/mm2)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-0.402	0.190	-1.470	0.915
2	Circular	-2.856	0.697	-0.598	0.395

Table 1: LOCAL SHEAR STRESS VALUES

The above table throws the light on the plate stresses introduced in a rectangular as well as circular water tanks. Different results were found out and after analyzing the following results from the table, we can clearly say that the circular water tanks are getting lower values of stresses induced. In this we clearly see that stresses value are also getting lower for a circular tank case type.

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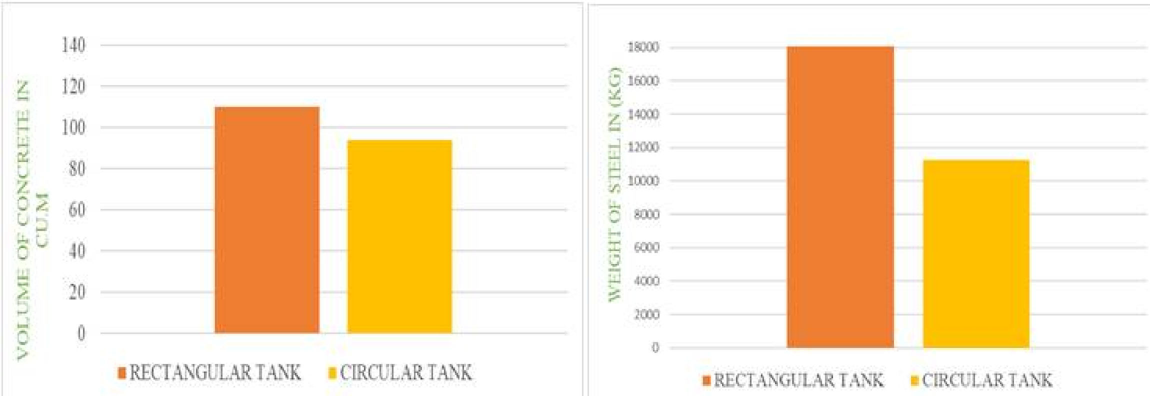
2) *For Case 2:* After Analysing E.S.R. from Staad Pro having parameters, the following results and outcomes are carried out which is shown below in results and discussions.



Above fig shows the amount of steel and concrete required

a) *Amount of Steel and Concrete Required:* These two graphs show 1) Total Volume of Concrete required in a rectangular water tank and in a circular water tank and 2) shows Total Weight of Steel required in a rectangular (kg) and in a circular water tank. X-axis shows rectangular and circular tanks in different color while Y-axis shows the volume of concrete in (cum) and weight of steel in (kg). Total Volume of Concrete in a rectangular water tank is found to be 110 m3 and in a circular water tank is 94 m3. Total Weight of Steel in a rectangular water tank is found to be 18056 kg and in a circular water tank is 11270 kg.
b) *Base shear, Base moment and Time Period:* In impulsive mode (kN) base shear in a rectangular water tank is 303 and in a circular water tank is 222. In Convective Mode (kN) base shear in a rectangular water tank is found to be 109 and in a circular water tank is 115. Total Shear to be applied at the CG of tank (kN) in a rectangular water tank is found to be as 323 and in a circular water tank is 250. In impulsive mode (kN-m) overturning moment at the base of staging in a rectangular water tank is 6490 and in a circular water tank is 4735. In Convective Mode (kN-m) overturning mode at the base of staging in rectangular water tank is 2844 and in circular water tank is 2890. Total Overturning Moment (kN-m) in rectangular water tank is found to be 7086 and in a circular water tank is 5547. In Impulsive Mode (Ti) (sec) time period in a rectangular water tank is 1.46 and in circular water tank is 1.84. Time period in Convective Mode (Tc) (sec) in a rectangular water tank is found to be 3.87 and in a circular water tank is 4.10
c) *Variation in Plate Stresses Value Shown Below (Final value)*

S.no	Type of tank	SQX (n/mm2)		SQY (n/mm2)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-0.138	0.189	-0.018	0.159
2	Circular	-0.316	0.429	-0.57	0.60

TABLE 2: LOCAL SHEAR STRESS VALUES.

d) *Variation in Plate Stresses Value Shown Below (With respect to moments along mention axis)*

S.no	**Type of tank**	**MX (KNm/m)**		**MY (KNm/m)**	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-103.2	94.1	-100	88.2
2	Circular	-90.3	58	90	57

TABLE 3: LOCAL SHEAR STRESS VALUES.

The above table throws light on the plate stresses introduced in a rectangular and a circular water tank. Different results were found out and after analyzing the following results from the table, we can clearly say that a circular water tanks are getting lower values of stresses induced. In this we clearly see that stresses values are also getting lower for the circular tank type.

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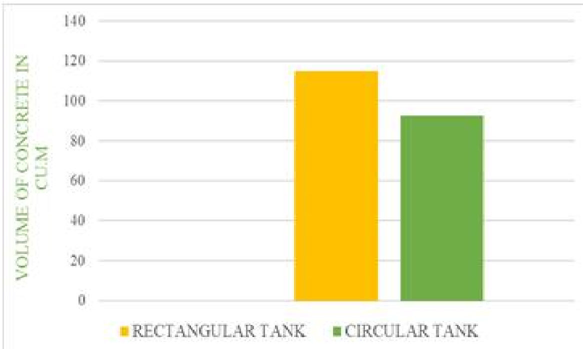
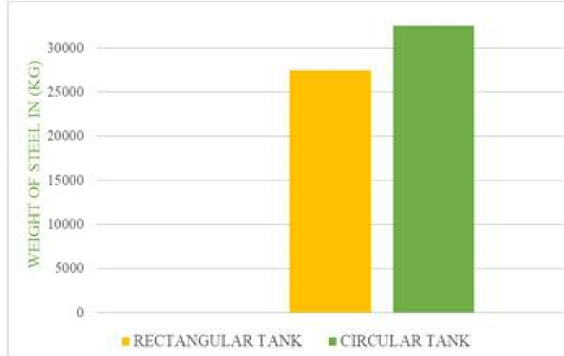
3) *For Case 3:* After Analyzing E.S.R. from Staad Pro software having different parameters, the following results and outcomes are carried out which is shown below in results and discussions.





Above fig shows the amount of steel and concrete required

a) *Amount of Steel and Concrete Required:* These two graphs show 1) Total Volume of Concrete required in a rectangular water tank and in a circular water tank and 2 (graph shows Total Weight of Steel in a rectangular (kg) and in a circular water tank required. X-axis shows rectangular and circular tanks in different color while Y-axis shows the volume of concrete in (cum) and weight of steel in (kg). Total Volume of Concrete found in a rectangular water tank is 110 m3 and in a circular water tank is 94 m3. Total Weight of Steel in a rectangular water tank found to be is 18056 kg and in a circular water tank is 11270 kg.
b) *Base shear, Base moment and Time Period:* In impulsive mode (kN) base shear in a rectangular water tank is 303 and in a circular water tank is 222. In Convective Mode (kN) base shear in a rectangular water tank is found to be 109 and in a circular water tank is 115. Total Shear to be applied at the CG of tank (kN) in a rectangular water tank is found to be as 323 and in circular water tank is 250. In impulsive mode (kN-m) overturning moment at the base of staging in rectangular water tank is 6490 and in circular water tank is 4735. In Convective Mode (kN-m) overturning mode at the base of staging in rectangular water tank is 2844 and in circular water tank is 2890. Total Overturning Moment (kN-m) in a rectangular water tank is found to be 7086 and in a circular water tank is 5547. In Impulsive Mode (Ti) (sec) time period in a rectangular water tank is 1.46 and in a circular water tank is 1.84. Time period in Convective Mode (Tc) (sec) in a rectangular water tank is found to be 3.87 and in a circular water tank is 4.10
c) *Variation in plate stresses value shown below (Final value)*

S.no	Type of tank	SQX (n/mm2)		SQY (n/mm2)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-0.138	0.189	-0.018	0.159
2	Circular	-0.316	0.429	-0.57	0.60

TABLE 4: LOCAL SHEAR STRESS VALUES.

The above table throws light on the plate stresses introduced in a rectangular as well as circular water tanks. Different results were found out and after analyzing the following results from the table, we can clearly say that circular water tanks are getting lower values of stresses induced. In this we clearly see that stresses value are also getting lower for the circular tank type.

d) *Variation in Plate Stresses value shown below (With Respect to Moments Along Mention Axis)*

S.no	Type of tank	MX (KNm/m)		MY (KNm/m)	
		Minimum	Maximum	Minimum	Maximum
1	Rectangular	-103.2	94.1	-100	88.2
2	Circular	-90.3	58	90	57

TABLE 5: LOCAL SHEAR STRESS VALUES.

In above figures or table, we can clearly see that even after changing bracing from 3 to 4.5 mts there is no change in stresses or moment along the axis. Reason behind this is that staging/bracing height has no connections regarding bottom of slab of tank it is connected or regarded with columns positions and total height of the tanks, so its final implementation doesn't affect the stresses or moment behavior of the tank.

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IV. CONCLUSION

A. *Case 1*

1) From economy point of view, circular water tanks are found to be more economical than rectangular water tank.
2) Total base shear is more in rectangular tank than circular tank.
3) For circular tank total overturning moment is less than the rectangular tank.
4) As per the results which we got; it can be said that in most of the region/cases plate stress are found to be less in case of circular tanks.

B. *Case 2*

1) By replacing circular column with rectangular columns, Circular water tank are found to be more economical than the rectangular water tank.
2) Total base shear is more in rectangular tank than circular tank.
3) For circular tank total overturning moment is less than the rectangular tank.
4) As per the results which we got, it can be said that in most of the region/cases plate stresses and moments are found to be less in case of circular tanks.

C. *Case 3*

1) By replacing 3.5mt bracings to 4.5 mts using circular columns, Circular water tank are found to be more economical than rectangular water tank.
2) Total base shear is more in rectangular tank than circular tank.
3) For circular tank total overturning moment is less than the rectangular tank.
4) As per the results which we got; it can be said that in most of the region/cases plate stress are found to be less in case of circular tanks.

V. ACKNOWLEDGMENTS

I would like to thank first my project guide Prof. Amey R. Khedikar for their continuous guidance and invaluable words of advice, support and help given to me to do this research paper. Secondly, I would like to thank my parents and friends for their appreciation and belief in me throughout the journey.

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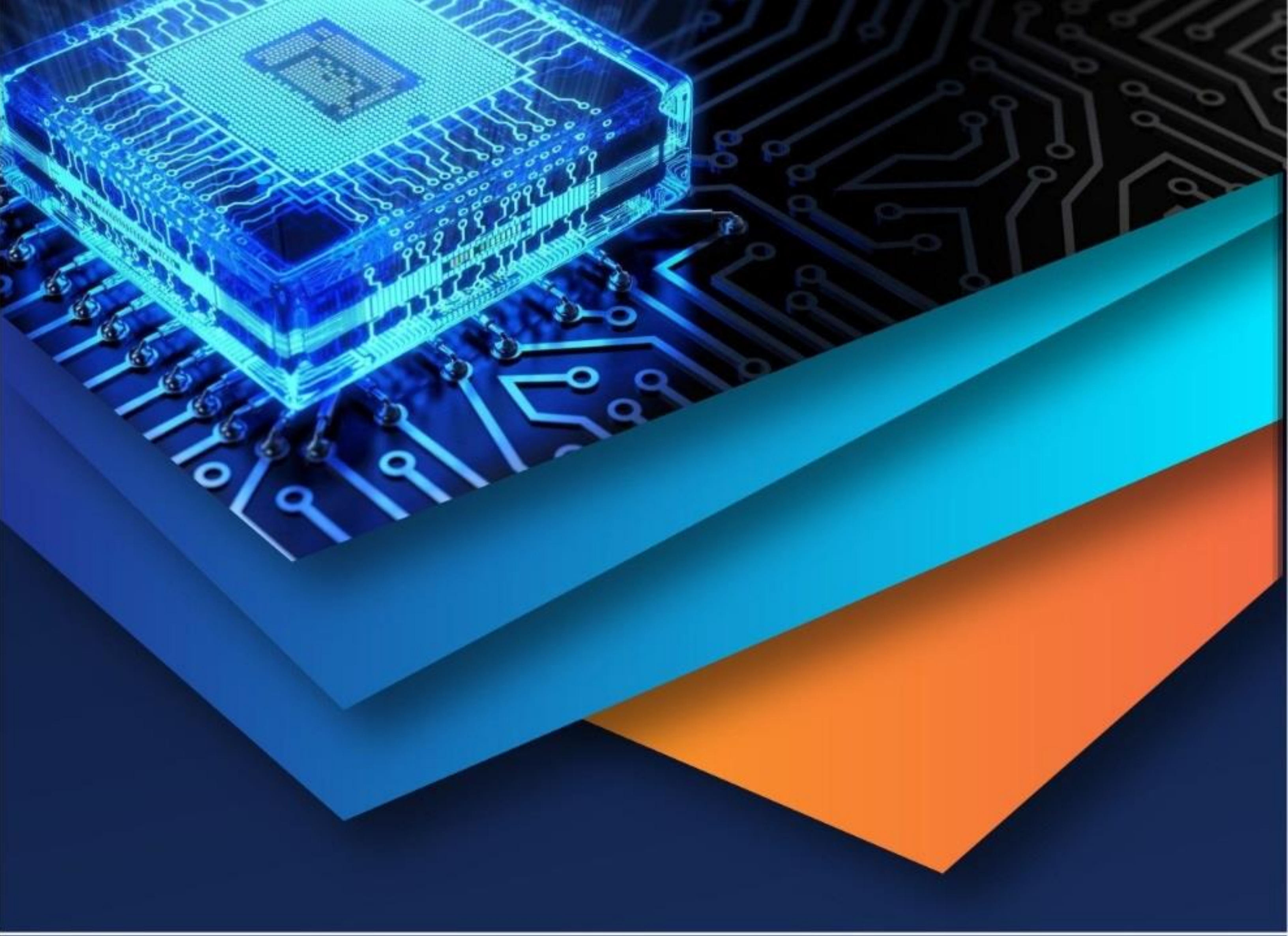

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