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Comparative Analysis of Circular and Rectangular Water Tank in Severe Seismic Zones

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Abstract: ***In the present work a comparative analysis for finding the optimized shape of water tank was performed. All models were then analyzed with action of loads and loading combinations prescribed by IS 1893 using STAAD PRO V8i SS5 series software for getting the most efficient and precise results. Total 08 models will be analyzed as per IS 1893 (part2), which are divided as 04 models of circular shape tank in all 04 seismic zones with tank empty condition and 04 models of rectangular shape tank in all 04 seismic zones with tank full condition after detailed analysis it was found that In tank full condition, rectangular tank shows lower values in zone -2 and zone-4 the increment is not much higher but in zone-3, circular shape shows very high about 19.92% higher values than rectangular tank. So, it can be concluded that use of rectangular shapes will prove efficient in all zones especially in zone-3. From this comparative graph it can be seen that rectangular tank gives higher values of displacement in all zones while circular tank shows lowest values in all zones. In zone-2 rectangular tank gives 4.45% and in zone-4 it gives 13.67% higher values than circular than.***

Keywords: STAAD pro., seismic zones, base shear, overturning moment, displacement

I. INTRODUCTION

Water is an increasingly vital necessity for every individual living on the planet, serving as a fundamental resource that sustains life. A raised Reinforced Concrete roundabout tank is specifically designed as a water storage facility, constructed with the primary objective of retaining a supply of water at a certain elevation to effectively pressurize the water distribution system. Over time, numerous innovative concepts and developments have emerged pertaining to the storage of water and various other liquid materials in a multitude of shapes and configurations. There exist several methods for the storage of liquids, including but not limited to underground tanks, ground-supported tanks, and elevated tanks, among others. The Indian subcontinent, in particular, faces great vulnerability to natural disasters such as earthquakes, droughts, floods, and severe winds, rendering many of its states or union territories susceptible to one or more forms of calamity. These natural disasters result in numerous casualties and extensive property loss on an annual basis. Among these disasters, earthquakes rank at the forefront in terms of risk and potential damage. According to the seismic code IS: 1893 (Part I): 2002, it has been indicated that over 60% of the geographical area of India is at risk of experiencing seismic activity. In the aftermath of an earthquake, while it is possible to recover from property losses to some extent, the loss of human life remains irrevocable and irreplaceable.

II. LITERATURE REVIEW

T. Karanjekar In this project, we have discussed about the design of rectangular and circular shape of water tank, Estimation of water tank and analysis by using STAAD-PRO software. From the analysis results concluding about the influence of shape factor in design loads and how shapes of the tanks play predominant role in the design and in stress distribution and overall economy. The result of design and estimation revealed that circular tank consumed lesser materials as compared to rectangular tank. Hence circular tank is more economical than the rectangular tank for large quantity.

Krishna Rao M.VThis paper compares the results of seismic analysis of overhead circular water tank carried out in accordance with IS: 1893- 1984 and IS: 1893-2002 (Part-2) draft code. The analysis is carried out for elevated circular tank of 1000 Cu.m capacity, located in four seismic zones (Zone-II, Zone –III, Zone-IV, Zone-V) and on three different soil types (Hard rock, medium soil, soft soil). Further, three different tank-fill conditions – tank full, tank 50% full, tank empty are also considered in this study. The seismic responses of circular tanks are computed and compared based on the theoretical procedures of IS: 1893-1984 and IS: 1893-2002(Part-2) draft code. The results of the analysis showed an increase in base shear and base moment are found to be in the range of 54% -260% in the analysis performed using draft code over the values of IS: 1893-1984. The hydrodynamic pressure increased in

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the range of 54%-280% with the use of draft code over the values obtained based on IS: 1893-1984. The results of SAP-2000 are found to be in agreement with those of the draft code.

Kishor G. Bhagat In this project, comparison of the design provisions of IS 3370:1965 and IS 3370:2009. In IS 3370:2009 limit state method considering two aspects mainly it limits the stress in steel and limits the crack width. All tanks are designed as crack free structures to eliminate any leakage. Results shows that the thickness of wall is decreases in limit state method. The size of member of ring beam is also decreases in limit state method. The quantity of material required is less in limit state method as compared to working stress method.

Jay Shah In this study, an attempt has been made to study the behavior of the reinforced concrete Intze type water tank with different staging patterns under the lateral loading. Various types of bracing configurations are used as the supporting frame staging of the Intze type water tank. In this paper, the study is carried out on the reinforced cement concrete Intze type water tank supported on frame type staging. The capacity of the Intze type water tank is taken as 18 Lac litres with staging height of 23 m. Grade of concrete and steel used are M-25 and Fe 415. Medium soil and seismic zone as III are considered in the analysis. Each model is analyzed for tank empty condition, tank partially filled condition and tank full condition. Analysis shows that the stiffness of the Intze type water tank with X-bracing configuration is maximum. The natural time period in impulsive mode for partially filled condition is lower than that of tank in full condition. This indicates that partially filled condition is more critical. The type of bracing configurations does not affect the natural time period in convective mode for a given depth of water, as the h/D is constant for a particular depth of water.

Mor Vyankatesh K This paper presents dynamic analysis of elevated water tanks supported on RC framed structure with different tank storage capacities. Objective paper is to understand the dynamic behavior of elevated water tanks under earthquake loading using latest Indian code IS 1893(part 2):2014. Parameters from seismic analysis of elevated water tanks and their comparison within different capacities including sloshing effects are calculated, lateral stiffness of frame staging is calculated using latest STAAD Pro V8i SS6 software. Results state that there is more threat of destruction to the tanks with higher capacities as compared to the tanks with lower capacities in a given zone.

III.METHODOLOGY

The project work will be work out in following phases

The whole work is divided into 3 Main Phases

A. Phase-I

a) To Decide Aim, Objective and Need of Work

Before starting any work, it is most important to first find out the current scenario of surrounding, in respect of need and availability of a particular facility. As India is a country of villages, with rapidly increasing population there is a vast demand of water storages in various remote area of our country. So, as a future structural engineer it is duty of everyone from this field to do continuous efforts towards achieving efficient and stable structures to compensate future demands. For this purpose, the present work aims to find the most efficient shape of water tank in various seismic zones of India

b) To Review Various Literatures, Codes and Journals

Once the aim of work is decided then the next step is to study various research papers, journals and books to get the exact work which was done by previous researchers and expertise so as to emphasize on the parameters which have to pay attention. To achieve this precision various literatures were studied to decide the path of this current work.

c) To decide the flow of work i, e Methodology

To achieve the appropriate results and the desired results it is more important to finalize various step involved in the work and their detail significance. To complete the work in an efficient form this work is divided in various standard phase to easily complete the work with high efficiency and with more precision

B. Phase-II

a) Detail Study of all possible Structural

Effects Before staring the actual project work it is required to have a thorough study regarding the topic such as types of patterns, effects of various parameters, and the available resources to work with. In the present all detailed study related to types of water tank various structural elements of RCC tank, details of public water supply and the population details has been conducted to finalized project parameters.

b) Effect of Earthquake and Its parameter

In the context of currently significantly varying seismic conditions of India it is must to study the effects of earthquake and design the structures to withstand these forces. Also, as this structure belong to public sector it is more important that this structure should fulfill the future capacity demands as well as the seismic demands. So, various models were analyzed in all current seismic zones as per IS-1893:2002

c) Types of loading and Methods of Analysis

After considering all general consideration, types of loads and their effect on structure must be find out and their respective values to be considered. In the present work as the structure is water tank the main load to be consider is of water ($10Kn/m^3$), then self-weight of structure and Earthquake load. This earthquake load varies according to zones which were considered and their values are taken from IS-1893:2002. For analysis purpose Static Co-efficient method is used, as it was found in many research papers that static analysis gives higher values of base shear than dynamic method.

d) Fixing All general Structural Data and Case Considerations of Models

Once the types of loads acting on structure and their intensities are finalized the last step of phase-2 is to decide the structural constants and material constants. In the present work three basic geometric shapes were considered which are, Circular, Rectangular and Square. Their capacities and dimensions are calculated on the basis of population and future forecast of population. Reinforced cement concrete of grade M-30 and steel of grade Fe-415 were considered as material constants for all shapes of water tanks and in all seismic zones.

C. Phase –III

a) Analyzing all the selected model patterns

All predefined models were then analyzed with action of loads and loading combinations prescribed by IS 1893 using STAAD PRO V8i SS5 series software for getting the most efficient and precise results. Total 16 models will be analyzed as per IS 1893 (part2), which are divided as 08 models of tank full condition and 08 models of tank empty condition.

b) Drafting of Comparative result Statements

After analyzing all models, a separate comparison will be made between all tanks within their respective zones and tank conditions, for various structural values obtained from analysis such as Base shear, Reactions, Overturning moment and Displacement.

c) Discussing all obtained Results

Depending upon the comparative results for above said water tank a detailed discussion will be carried out to understand all the possible perspective of various shapes and their behavior in different seismic zones and storage conditions.

d) Conclusions on results obtained after analysis and Discussion

Based on the results and discussions in the previous chapters final conclusions will be drafted to summaries the study which will help to decide the use of particular type of water tank in a specified seismic zone with varying storage conditions.

IV. CASE CONSIDERATION AND MODELLING

A. Calculation for Quantity of water Tank

According to census 2011 in India there are large numbers of villages having population between 500-1000 (Approx. 1,45,402) and also these villages are still suffering from water scarcity Therefore in this project we are focusing on this population. Increase in population as per census 2011 in 12.18 % and tank will be designed for 30 years with consideration of same increment

1000.00 x 1.1218 = 1121.80 ----------2021
1211.80 x 1.1218 = 1258.44----------2031
1258.44 x 1.1218 = 1411.71----------2041
1411.71 x 1.1218 = 1583.65 ----------2051
Say 1584.00
Considering water consumption as 135 lpcd.
Quantity of water = 1584 x 135 = 213840 lit
Volume of water = 213840 / 1000 = 213.84 cum ----------(1000 l/cum)

B. Calculation for Sizes of water tank

All tanks have height of 4m and free board of 0.30m

1) Circular Tank

Area (A) = 213.84 / 4 = 53.46 sq.m

$D = ((53.46 \times 4) / \Pi)^{0.50} = 8.25$ m

2) Rectangular Tank

Area (A) = 53.46 sq.m

Assuming B= 6 m

L = A/B = 53.46 / 6 = 8.91m

Table 4.1 General structural parameters for tanks

Sr. No.	Structural Component	Value
01	Concrete	M30
02	Structural Steel	FE-415
03	Zone	II/III/IV/V
04	Response Reduction Factor	2.5 (OMRF)
05	Importance factor	1.5
06	Type of Soil	Medium Stiff
07	Size of bracing Beam	300mm x 400mm
08	Size of column	-
	Circular Tank	550mm (dia.)
	Rectangular Tank	450mm x 530mm
09	Thickness of Side wall	200mm
10	Thickness of Top Slab	200mm
11	Thickness of Base Slab	300mm
12	Staging Height	3.00m
13	Depth of Foundation	1.5m

Table 4.2 Model details

Sr. No	**Model Details**	**Labels**
01	Circular shape water tank in Zone-II	M1
02	Circular shape water tank in Zone-III	M2
03	Circular shape water tank in Zone-IV	M3
04	Circular shape water tank in Zone-V	M4
05	Rectangular shape water tank in Zone-II	M5
06	Rectangular shape water tank in Zone-III	M6
07	Rectangular shape water tank in Zone-IV	M7
08	Rectangular shape water tank in Zone-V	M8

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C. Models of Various Shapes of Tank

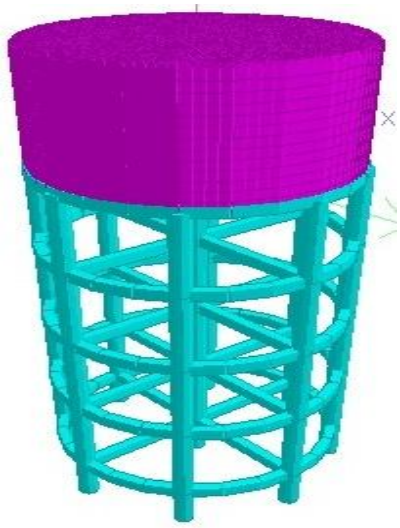


Fig 4.1 3D View of Circular water tank

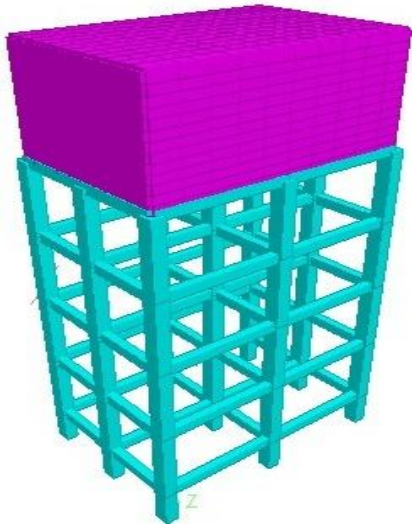


Fig 4.2 3D View of Rectangular Tank water tank

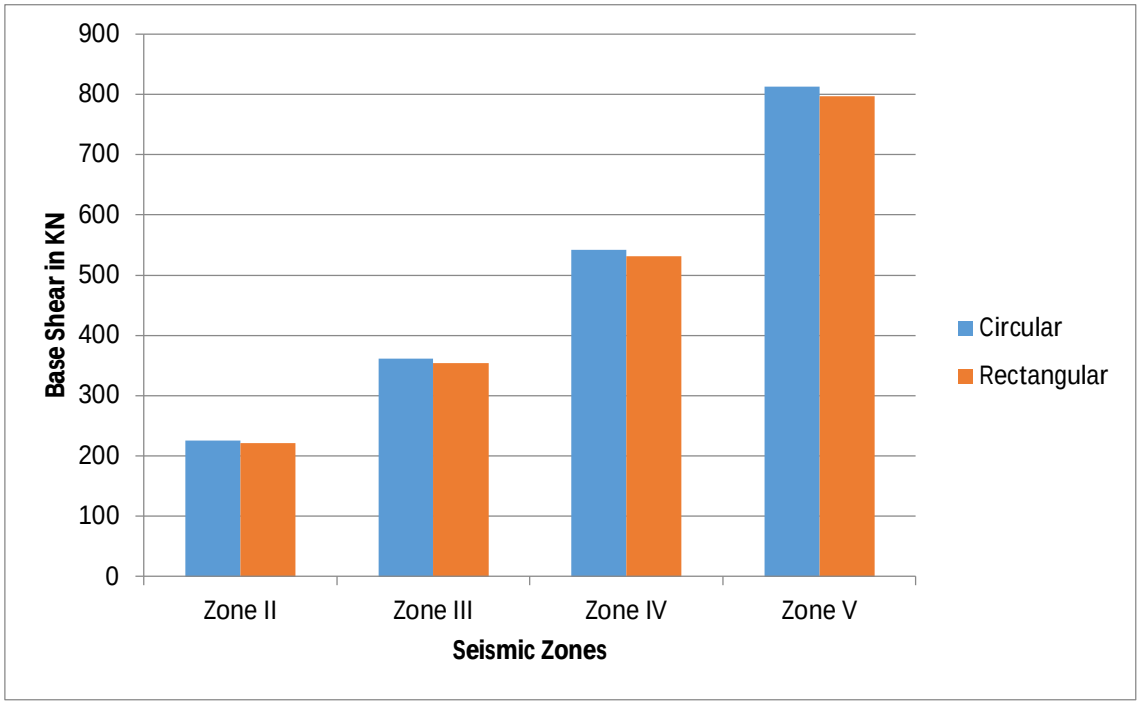
V. RESULTS AND DISCUSSIONS

A. Results for Base shear (kN)

Below table shows the comparative results of the Base Shear value calculated on STAAD Pro, of circular and rectangular tank in full condition. Table 5.1 represent the base shear values obtained after the staad.pro analysis considering the prevailing IS code condition of tank full condition for all seismic zones.

Table 5.1 Base shear comparison in tank full condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	245.19	392.30	588.45	882.67
02	Rectangular	239.29	328.86	574.29	861.43



Graph 5.1 Comparison of Base shear in tank full condition

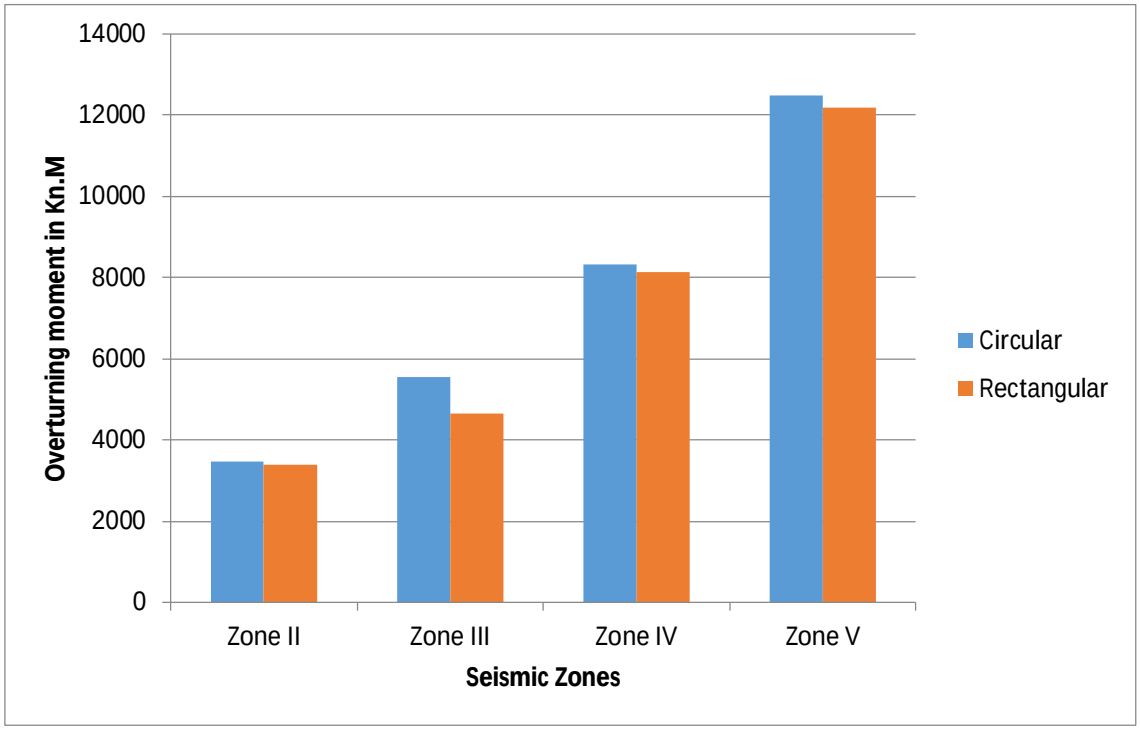
In tank full condition again, rectangular tank shows lower values in zone -2 and zone-4 the increment is not much higher but in zone-3, circular shape shows very high about 19.92% higher values than rectangular tank. So, it can be concluded that use of rectangular shapes will prove efficient in all zones especially in zone-3

B. Results for Overturning Moment at base (KN.m) -

Below table shows the comparative results of the Overturning Moment at Base calculated on STAAD Pro, of circular and rectangular tank in full condition. Table 5.2 represent the overturning moment values obtained after the staad.pro analysis considering the prevailing IS code condition of tank full condition for all seismic zones.

Table 5.2 Overturning moment comparison in tank full condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	3469.44	5551.05	8326.57	12489.78
02	Rectangular	3385.95	4653.37	8126.20	12189.23



Graph 5.2 Comparison of overturning moment in tank full condition

From the above comparison it can be seen that rectangular tank gives lower values of moment in all zones but this difference is most significant in zone-3. As rectangular tanks give lower values of base shear in all zones it gives lower overturning for same structural and seismic conditions than other shapes of tank.

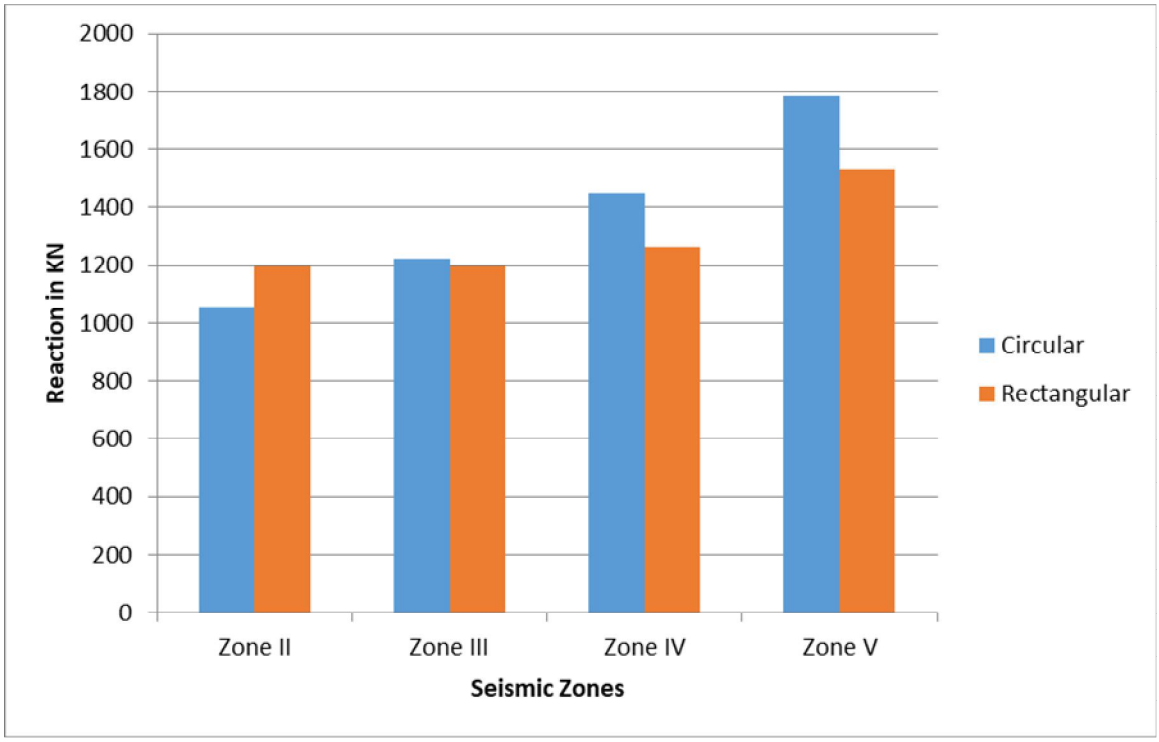
C. Results for Reactions (kN)

Below table shows the comparative results of Reactions calculated on STAAD Pro, of circular and rectangular tank in full condition. Table 5.3 represent the base reaction values obtained after the staad.pro analysis considering the prevailing IS code condition of tank full condition for all seismic zones.

Table 5.3 Reaction comparison in tank full condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	1135.07	1315.04	1555.01	1914.97
02	Rectangular	1232.09	1232.09	1369.29	1650.50

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Graph 5.3 Comparison of reactions in tank full condition

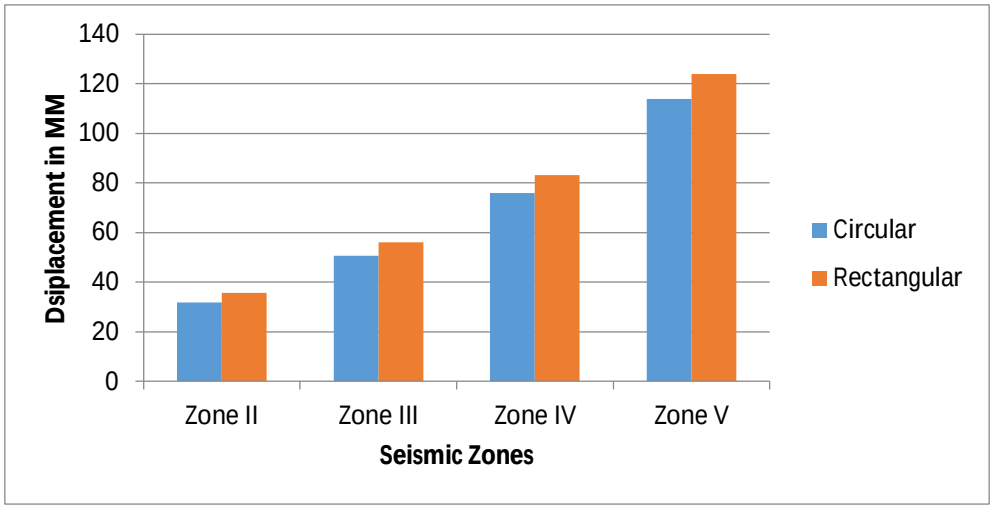
From this graph it can be concluded that rectangular tank can be efficiently used in all zones followed by circular tank.

D. Results for Maximum displacement (mm)

Below table shows the comparative results of Maximum displacement calculated on STAAD Pro, of circular and rectangular tank in full condition. Table 5.4 represent the displacement values obtained after the staad.pro analysis considering the prevailing IS code condition of tank full condition for all seismic zones.

Table 5.4 Displacement comparison in tank full condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	21.47	31.04	44.62	66.30
02	Rectangular	22.27	34.51	50.85	75.36



Graph 5.4 Comparison of displacement in tank full condition

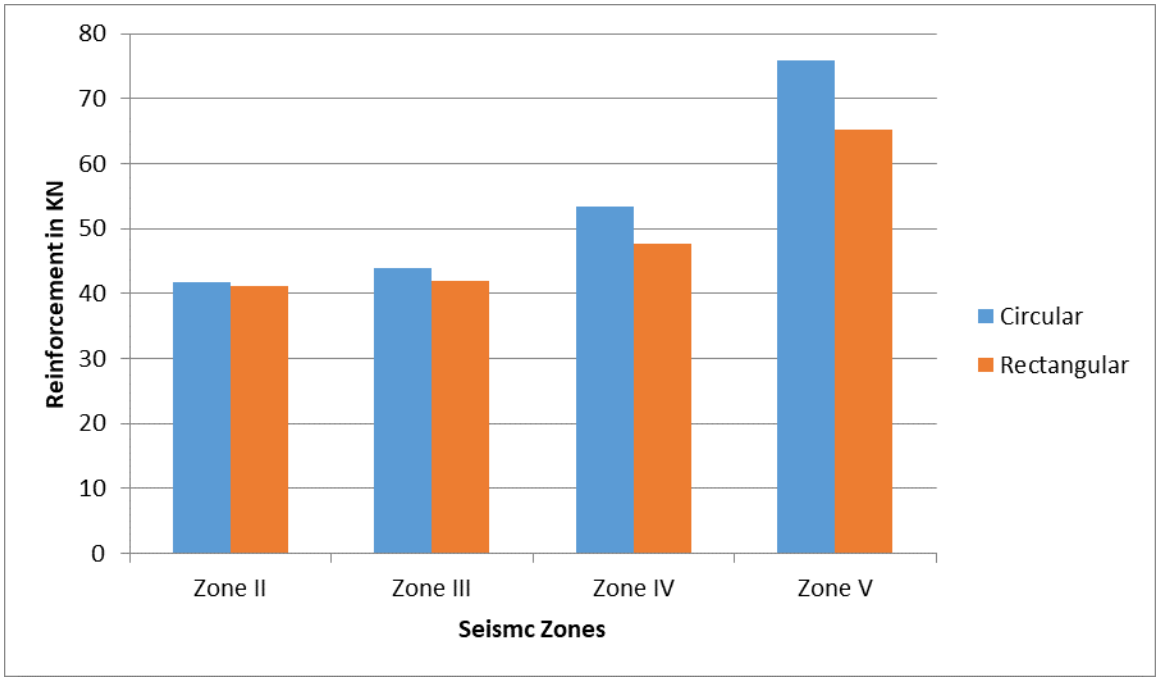
From this comparative graph it can be seen that rectangular tank gives higher values of displacement in all zones while circular tank shows lowest values in all zones. In zone-2 rectangular tank gives 4.45% and in zone-4 it gives 13.67% higher values than circular than.

E. Results for Reinforcement in staging (kN) -

Below table shows the comparative results for reinforcement in staging calculated on STAAD Pro, of circular and rectangular tank in full condition. Table 5.5 represent the staging reinforcement requirement values obtained after the staad.pro analysis considering the prevailing IS code condition of tank full condition for all seismic zones.

Table 5.5 Staging reinforcement comparison in tank full condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	41.70	43.93	53.37	75.92
02	Rectangular	41.09	41.96	47.70	65.21



Graph 5.5 Comparison of staging reinforcement in tank full condition

While comparing the amount of reinforcement rectangular tank gives lower values in low and medium seismic zones but as the seismicity increases rectangular tank gives lower values of reinforcement in all seismic zones.

VI. CONCULSIONS

1) Design of tank should be governed by tank full condition.
2) Rectangular tank gives lowest values of base shear, overturning moment and reactions.
3) Rectangular tank gives higher values of displacements, So more bracings are required to control displacement.
4) In low seismic zone there any shape can be used but as seismicity increases emphasis should be given on rectangular tank.
5) For the same capacity and seismic parameters rectangular tank gives more stable results than circular water tank.

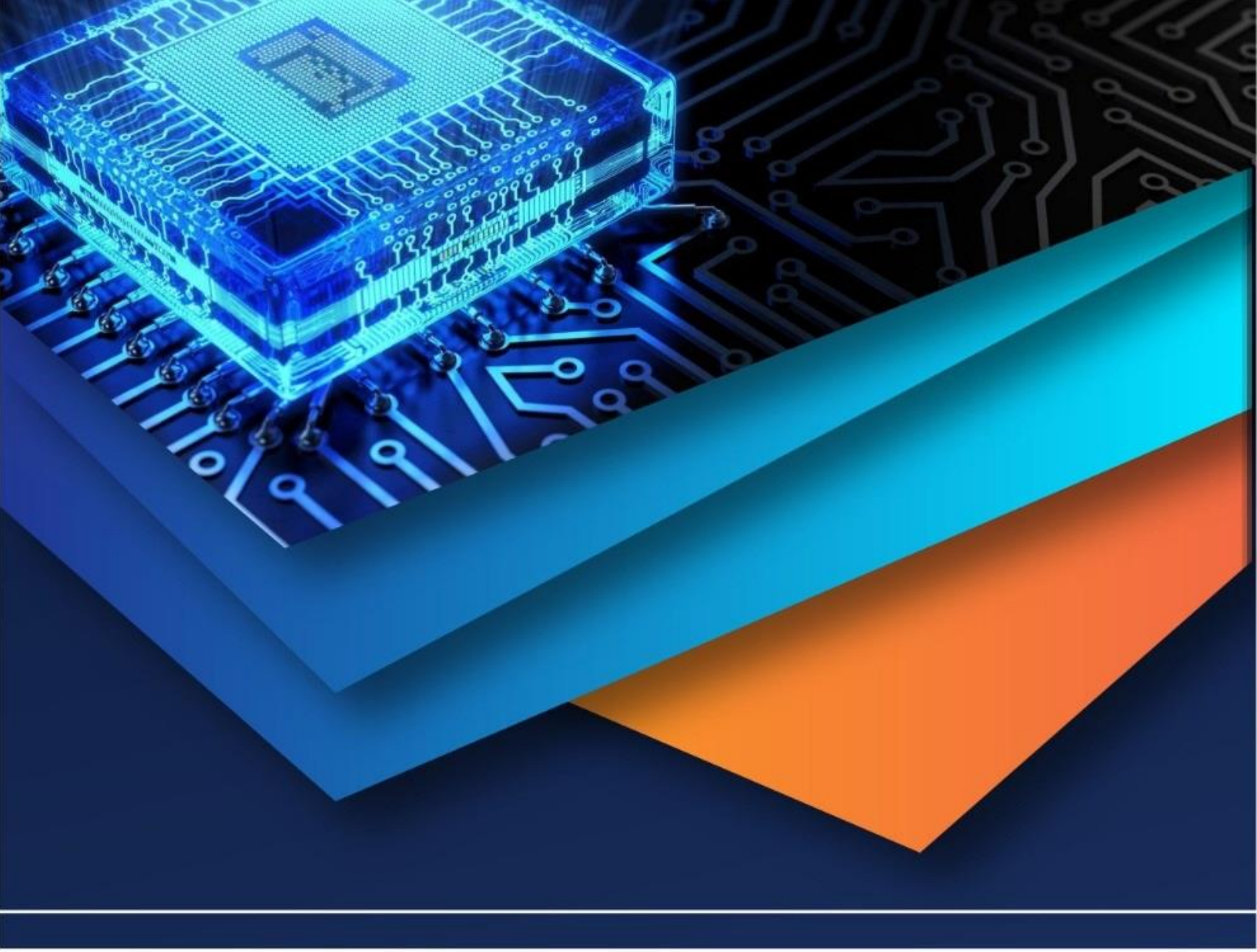
VII. ACKNOWLEDGMENT

It gives me great pleasure on bringing out the report entitled.
"*Comparative Analysis of Circular and Rectangula Water Tank in Severe Seismic Zones*"
No undertaking of the magnitude involved in the preparation of this project can be accomplished alone. Many have contributed till the successful acknowledge the assistance of the following individuals and would like to thank each one of them.

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