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Study and Analysis of Circular and Rectangular Water Tank in all 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 empty condition after detailed analysis it was found that rectangular thank shows lowest values of reactions for same gravity and seismic loading in low seismic zone circular tank shows 6.62% higher values than rectangular tank. While in Severe seismic zone circular tank shows 15 % increase in its values. As like of structural stability economy is also a perspective for major high-cost work. Above graph of reinforcement requirement shows that in zone-2, zone-3, zone-4 circular tank requires be comparatively lower values of staging reinforcement. But in severe zone this scenario goes inverse showing higher values for circular shape tank. From this it can be concluded that from zone-2 to zone-4 circular tank should be preferred but in zone-4 rectangular shape tank should be preferred.***
Keywords: STAAD pro., seismic zones, base shear, overturning moment, displacement

I. INTRODUCTION

Water is an essential element for human survival and is crucial for daily activities. The efficient distribution of water depends greatly on the design and functionality of the water tank located in a specific area. An elevated water tank serves as a large storage container that is constructed to hold a supply of water at a certain height in order to help pressurize the water distribution system. Over the years, numerous innovative ideas and advancements have been created to improve the storage of water and other liquid substances in various shapes and styles. The storage of liquids can be achieved through different methods such as underground storage, ground-supported tanks, and elevated tanks, each serving a specific purpose based on the requirements. Municipalities and industries heavily rely on liquid storage tanks for housing water, flammable liquids, and various chemicals necessary for their operations. Therefore, the presence of water tanks holds significant importance in providing essential services to the public and supporting industrial water tank

II. LITERATURE REVIEW

Ruturaj V. Borkar The main aim of this study is to understand the 4724taging4724 of different staging, under different loading conditions and strengthening the conventional type of staging, to give better performance during earthquake. This paper presents the Importance of the supporting system of water tanks here this is considered different type of bracing and staging patterns. From the comparison between displacement for different bracing system and displacement for different alternate bracing it is conclude that new bracing pattern gives the minimum value of displacement.

Abba Mas'ud Alfanda This project therefore studies the efficiency of rectangular or circular tanks, 40,000 liters capacities were used in order to draw reasonable inferences on tanks shape design effectiveness, relative cost implications of tank types and structural capacities. The basic tanks construction materials include steel reinforcement, concrete and formwork obtained from the prepared structural drawings. Result of the materials take–off revealed that circular tank consumed lesser individual materials as compared to rectangular one. his will give circular shaped tanks more favored selection over the rectangular shaped tank, although some other factors must still be assessed.

Swati In this study a review of various literatures on calculative analysis of water tank was carried to understand the performance of elevated water tank under the action of various horizontal forces like wind load. From analysis it is seen that Horizontal Displacement in water tank due to wind is critical as they result in sloshing of water and additional displacement.

There is a need to investigate various methods to minimize this horizontal displacement. One method proposed in this direction is to adopt water tanks with different configuration of legs of staging.

Nandagopan.M.The main aim of this study is dynamic analysis of different types of RCC water tanks. Ground supported rectangular and circular water tanks, over head circular and rectangular water tanks are considered. Housner's two mass model for water tank is selected for dynamic analysis where the whole mass of water is divided in to two, impulsive liquid mass and convective liquid mass. Analysis is carried out to find the base shear and base moment. The manual dynamic analysis is done with varying height of water level in the tank using IS 1893 (Part 2) guide lines and study the effects due to change in height of water level. Based on the work in this study, it was summarized that Base shear and base moment are increases with increase in water level. Elevated water tank shows higher base reactions than ground supported tanks. So base reactions increase with increase in staging height. The base shear and base moment of ground supported rectangular tank exceeds ground supported circular tank by 6.89% and 6% respectively at full tank condition. So, geometry of water tank can influence base shear. The ground supported circular tank have fewer base reactions. i.e it is better than ground supported rectangular tank.

Prashant A Bansode The objective of this study was, to understand the behavior of different staging system, under different tank conditions. Response Spectrum Analysis is carried out on three different types of bracing systems of elevated water tank in all zones by using STAAD Pro V8i 2007. Comparison of base shear and nodal displacements of elevated water tank for empty and full condition is done. The spring mass model as per IS 1893:2002 Part 2 has been used for the analysis. From analysis work, it has been concluded that, Base shear increases as the level of bracing increases because, bracing system put on additional mass to the structure, which results into increase in base shear value. Similarly base moment is found to be increased as the level of bracing increases.

Ajagbe, W.O. This study therefore examines the efficiency of Rectangular and Circular tanks. Tanks of 30m3, 90m3, 140m3 and 170m3 capacities were used in order to draw reasonable inferences on tank"s shape design effectiveness, relative cost implications of tank types and structural capacities. Limit state design criteria were used to generate Microsoft Excel Spreadsheet Design Program, named MESDePro for quick and reliable design. The basic tank"s construction materials- steel reinforcement, concrete and formwork were taken-off from the prepared structural drawings. Results of the material take-offs showed that, for each of the shapes, the amount of each structural materials increase as the tank capacity increases. Also, Circular-shaped tank consumed lesser individual material as compared to rectangular ones. Hence, this will give Circular-shaped tanks a more favoured selection over the rectangular shaped tanks.

III. METHODOLOGY

The project work will be work out in following phases

The whole work is divided into 3 Main Phases

1) 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

2) 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.

3) 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

C. Models of various shapes of tank

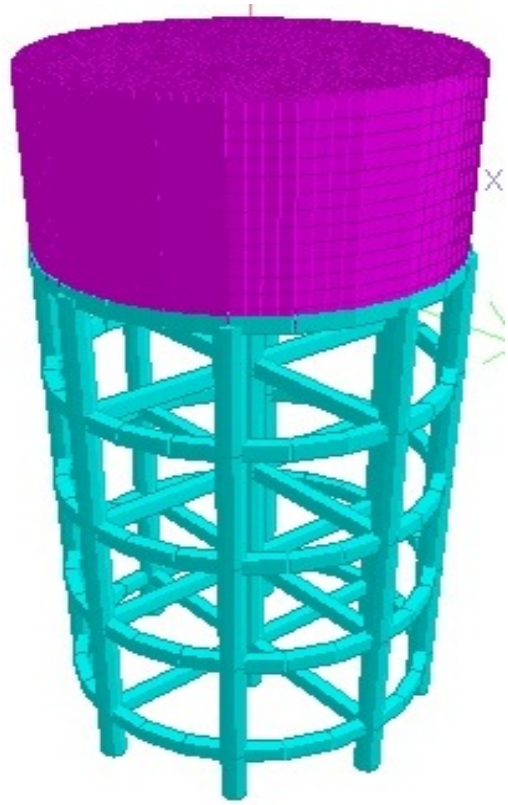


Fig 4.1 3D View of Circular water tank

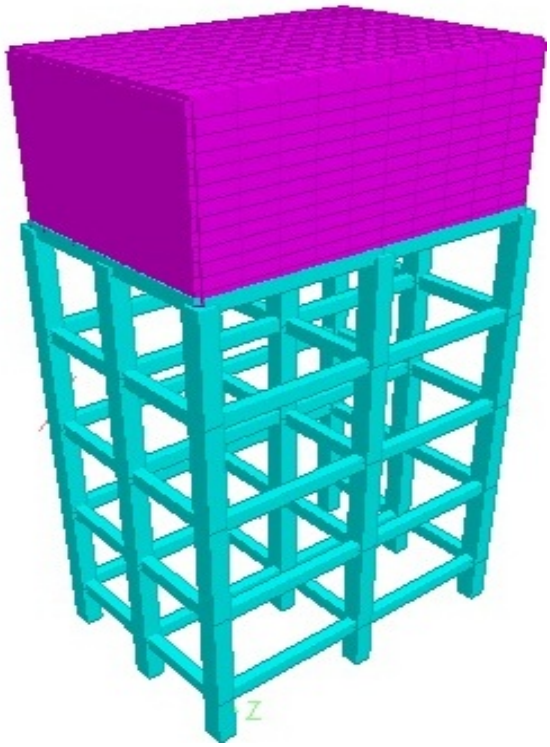


Fig 4.2 3D View of Rectangular Tank water tank

V. RESULTS AND DISCUSSIONS

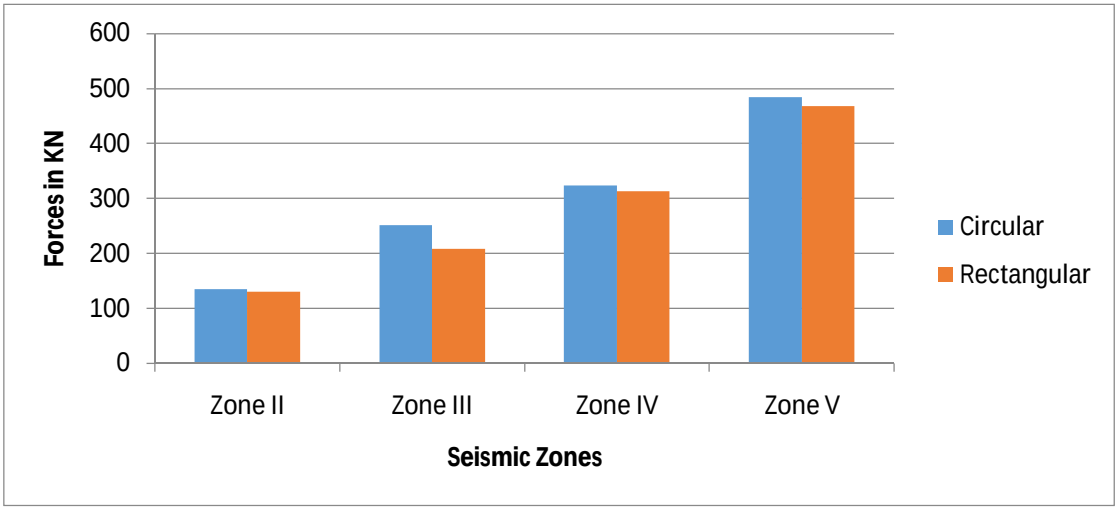
A. Results for Base shear (kN) –

Below table shows the comparative results of the Base Shear value calculated on STAAD Pro, of circular and rectangular tank in empty condition.

Table 5.1 represent the base shear values obtained after the staad.pro analysis considering the prevailing IS code condition of tank empty condition for all seismic zones.

Table 5.1 Base shear comparison in tank empty condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	134.60	251.36	323.05	484.57
02	Rectangular	130.07	208.15	312.23	468.35



Graph 5.1 Comparison of Base shear in tank empty condition

Above graph of comparison shows that for same capacity and material parameters rectangular shape tank show lower values of base shear in all seismic zones. In zone 2 there is not much more difference between all three shapes, this difference increases as the seismic zones goes on higher side. In the most severe zone circular tank shows 3.46% higher values than rectangular tank. So, from base shear consideration rectangular tanks are efficient in all zones.

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

In tank centre of gravity as per IS 1893 (part2) 2014 can be calculated as follows: -

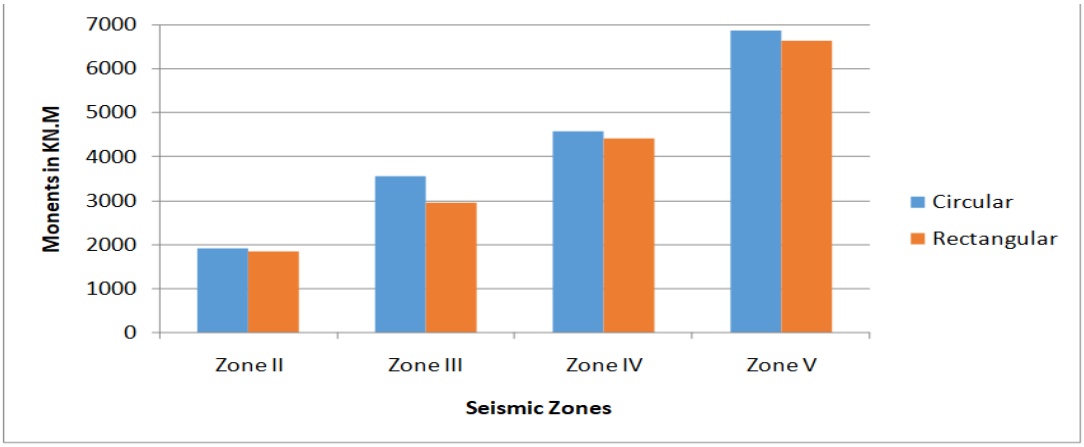
H = 4 x 3 + (4.3/2) = 14.15m ----------from top of foundation

Below table shows the comparative results of the Overturning Moment at Base calculated on STAAD Pro, of circular and rectangular tank in empty condition.

Table 5.2 represent the overturning moment values obtained after the staad.pro analysis considering the prevailing IS code condition of tank empty condition for all seismic zones.

Table 5.2 Overturning moment comparison in tank empty condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	1904.59	3556.74	4571.16	6856.67
02	Rectangular	1840.49	2945.32	4418.05	6627.15



Graph 5.2 Comparison of overturning moment in tank empty condition

From the above graph of overturning moment, it can be seen that in all zones rectangular tank gives lowest values compared to others. So, it can be concluded that rectangular shape is most efficient in all zones in view of overturning moment.

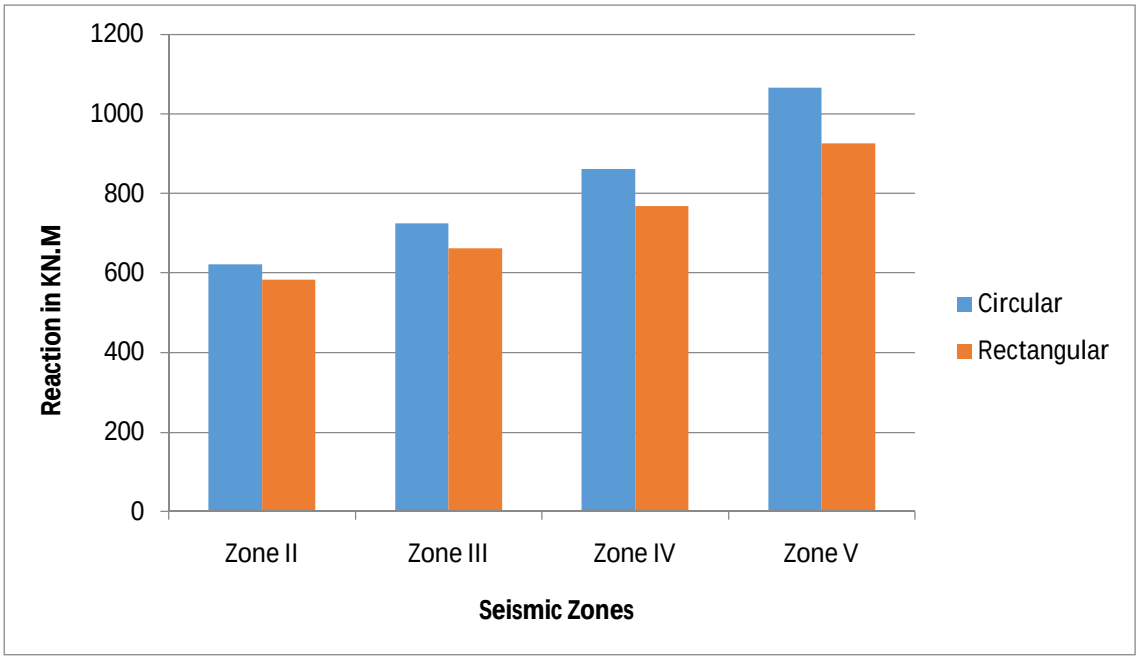
C. Results for Reactions (kN) -

Below table shows the comparative results of Reactions calculated on STAAD Pro, of circular and rectangular tank in empty condition.

Table 5.3 represent the reaction values obtained after the staad.pro analysis considering the prevailing IS code condition of tank empty condition for all seismic zones.

Table 5.3 Reaction comparison in tank empty condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	621.62	724.36	861.34	1066.82
02	Rectangular	583.05	662.40	768.21	926.92



Graph 5.3 Comparison of Reactions in tank empty condition

From the above graph it can be clearly seen that From this it can be concluded that from reaction comparison rectangular shape is efficient to use in all zones.

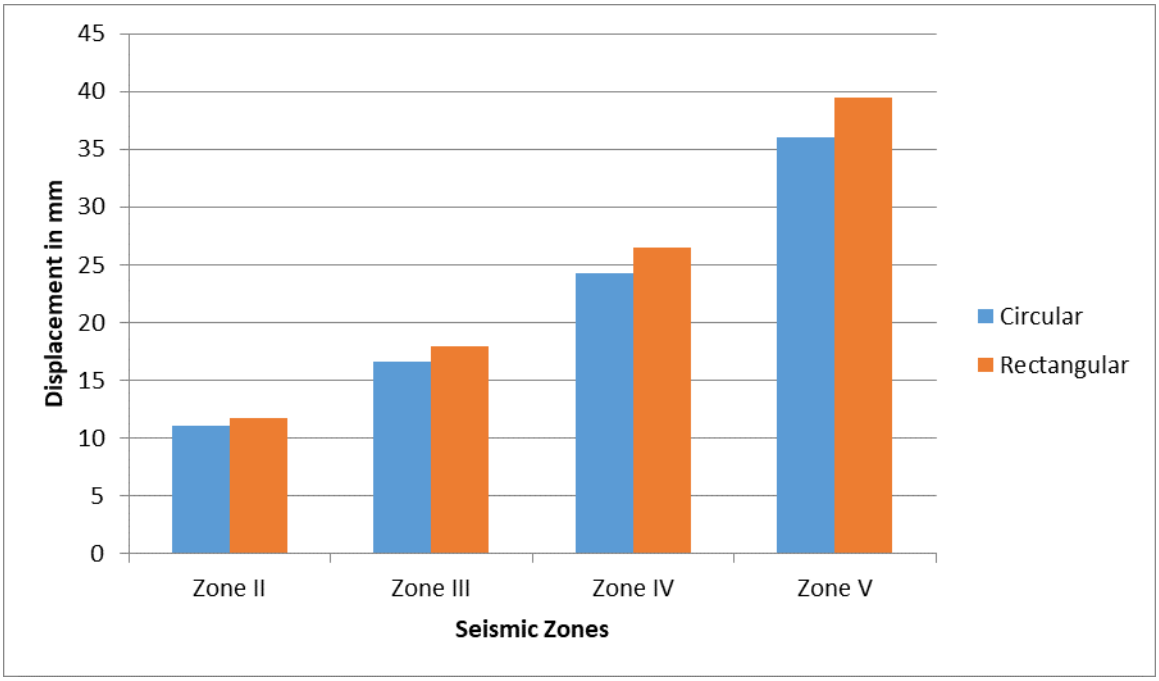
D. Results for Maximum displacement (mm) -

Below table shows the comparative results of Maximum displacement calculated on STAAD Pro, of circular and rectangular tank in empty condition.

Table 5.4 represent the displacement values obtained after the staad.pro analysis considering the prevailing IS code condition of tank empty condition for all seismic zones.

Table 5.4 Displacement comparison in tank empty condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	11.09	16.61	24.28	35.98
02	Rectangular	11.77	17.96	26.47	39.51



Graph 5.4 Comparison of displacement in tank empty condition

Displacement of a structure a major parameter for any type of structure, above graph represents the comparative statistics for displacement values of all models in various seismic zones. In this graph it can be clearly seen that amongst all shapes rectangular shape tank shows higher values in all zones than circular shape. In zone 2 this difference is negligible but in zone 4 it is slightly on higher side. In zone 4 rectangular tank have 9.81 % higher value than circular tank which has lowest values of displacement. So, it can be concluded that from displacement consideration in zone 2 any shape can be used but as the zone increases emphasis should be given on use of circular shape tank.

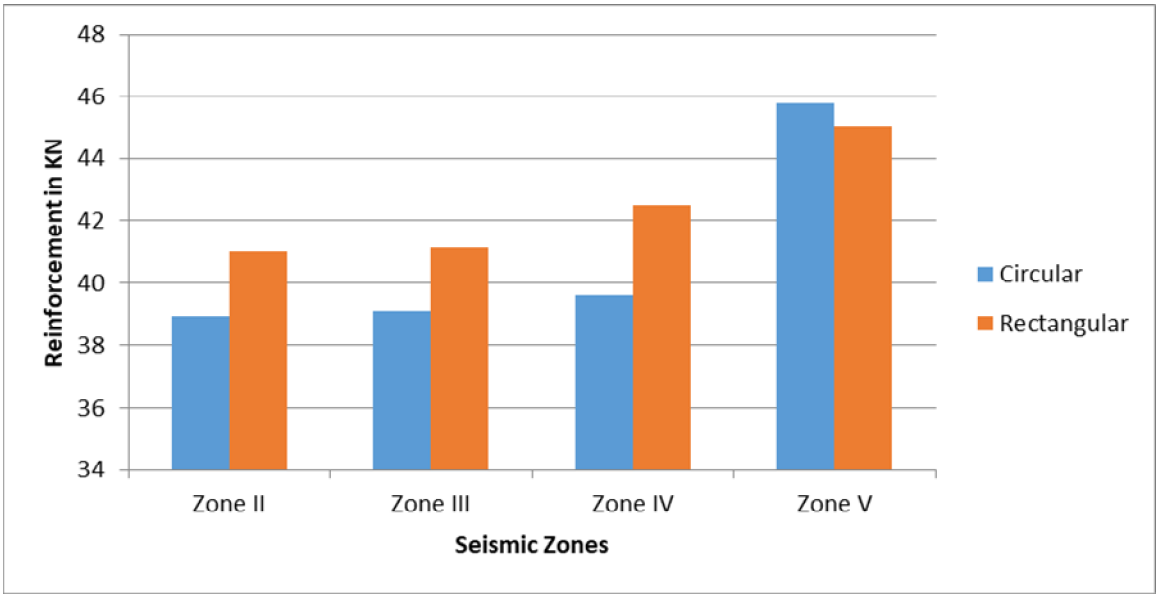
E. Results for Reinforcement in staging (kN) -

Below table shows the comparative results for reinforcement in staging calculated on STAAD Pro, of circular and rectangular tank in empty condition.

Table 5.5 represent the staging reinforcement requirement values obtained after the staad.pro analysis considering the prevailing IS code condition of tank empty condition for all seismic zones.

Table 5.5 Staging Reinforcement comparison in tank empty condition

Sr No.	Shape of Tank	Zone			
		II	III	IV	V
01	Circular	38.94	39.09	39.62	45.77
02	Rectangular	41.02	41.12	42.48	45.04



Graph 5.5 Comparison of Staging reinforcement in tank empty condition

As like of structural stability economy is also a perspective for major high-cost work. Above graph of reinforcement requirement shows that in zone-2, zone-3, zone-4 circular tank requires be comparatively lower values of staging reinforcement. But in severe zone this scenario goes inverse showing higher values for circular shape tank. From this it can be concluded that from zone-2 to zone-4 circular tank should be preferred but in zone-4 rectangular shape tank should be preferred.

VI. CONCULSIONS

1) The structural behavior of water tank for same capacity affects with the shape of container shape as the severity of seismic zone increases.

2) The design of the water tank must primarily be dictated by the condition of the tank when it is full. This entails that all engineering and structural considerations, such as material strength, shear forces, and overall stability, should account for the maximum load scenario, where the tank is completely filled with water, thus representing the most challenging conditions the tank must endure during its operational life.

3) Research indicates that rectangular tanks exhibit the lowest values when it comes to base shear, overturning moment, and reactions during seismic events. This suggests that rectangular configurations are inherently more stable and can effectively resist the dynamic forces generated during such occurrences without experiencing excessive stress or potential failure.

4) However, it is important to note that while rectangular tanks are advantageous in terms of shear forces, they also produce higher levels of displacements compared to other shapes. This means that to mitigate these displacements and ensure the tank remains within acceptable limits of movement, additional bracing must be integrated into the design to provide adequate support and maintain stability.

VII.ACKNOWLEDGMENT

It gives me great pleasure on bringing out the report entitled.

"*Study and analysis of Circular and Rectangular Water Tank in all 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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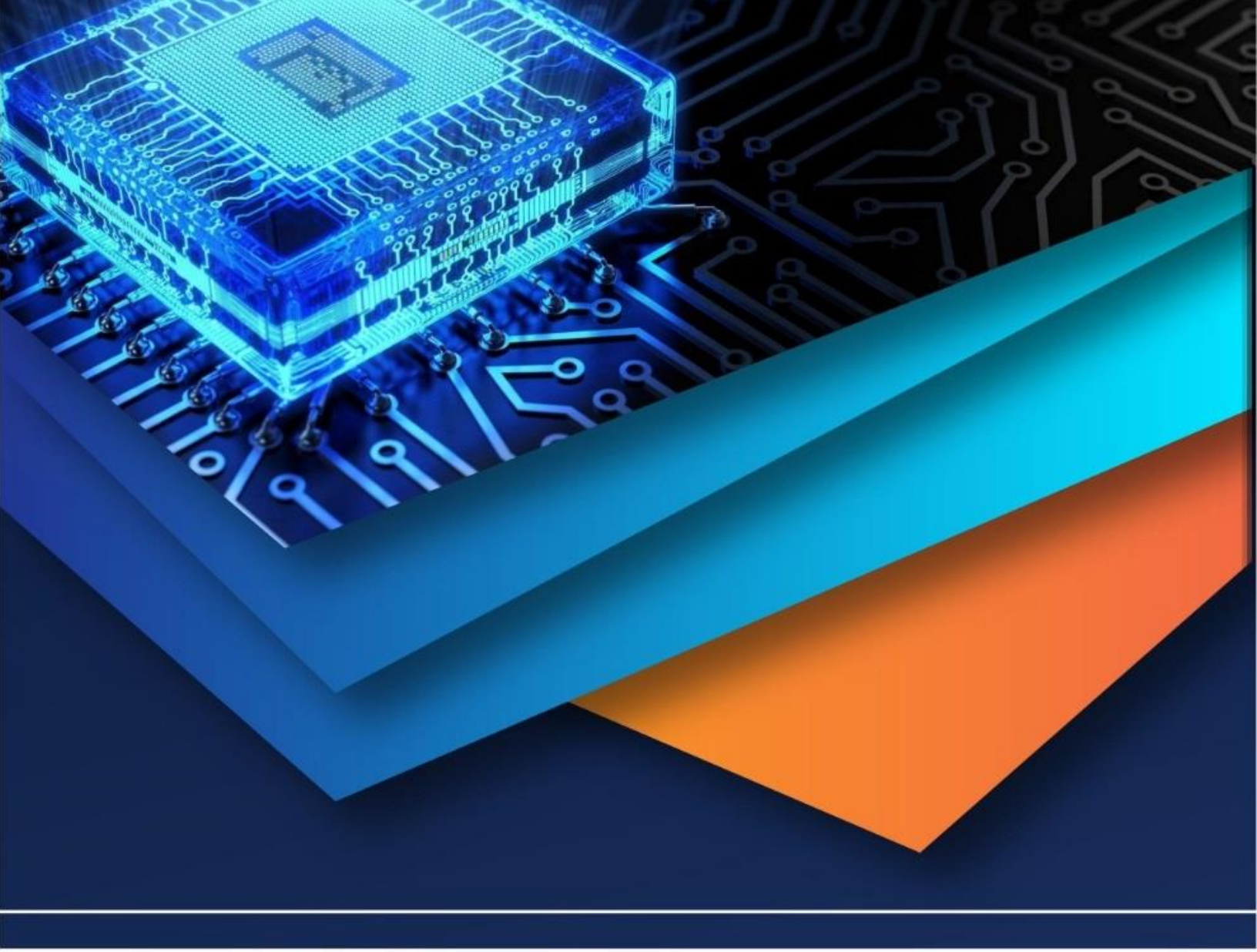

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