An Earthquake Resistant Design for an Overhead Intze Tank

Akshit Lamba[1], Dr. P.S. Charpe[2]

[1, 2] Department of Civil Engineering

[1 ,2]Kalinga Uinversity, Naya Raipur (C.G.), India

akshit.lamba@kalingauniversity.ac.in , p.s.charpe@kalingauniversity.ac.in

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Abstract - From the analysis of water tank for seismic loading in different mode shapes, it is decided that for the range of mode shapes 2nd to 4th proper damping is necessary or considerable strength must be provided to the reservoir by making the supporting column and foundation very much resilient falling under that frequency range.

Thus it has been found that sloshing effect and sloshing frequency is an important parameter in the seismic analysis of water tank. It is very important, in predicting damage of tanks, to evaluate ground motions in the long- period range, including the natural period of liquid sloshing of a large storage tanks and water reservoirs. Free board to be provided within the tank may be based on the maximum height of sloshing wave of water, if enough free board isn't provided, roof structure ought to be designed to resist the uplift pressure because of sloshing of water tank.

***Key Words*:** water tank, seismic load, damping, sloshing

1. INTRODUCTION

The majority of the time, tanks are used to store liquid products like water, liquid petroleum, petroleum products, and various kinds of fluids. They are also used to ensure the safety of the liquid they are storing and prevent accidental spills. When compared to the chemical degradation of the products, the structural analysis primarily reveals that the forces exerted by these reservoirs or tanks are roughly equivalent in importance. To prevent any leaks, the structures of all tanks are designed to be free of cracks. These tanks and reservoirs have reinforced concrete walls and retaining slabs with sufficient reinforcement cover. Because the liquids stored in these tanks, whether petroleum or water, may or may not react with concrete, no special surface treatment is being preferred for safety reasons. In this way, the actual tank ought to be self-resistible to these kinds of risks, whether it be substance or primary. Once in a while, various sort of squanders from better places like businesses and family tasks is gathered and furthermore handled in these tanks for reusing reason however with extremely severe exemption.

2. TANK WITH STACKED CONTAINERS

Commonly the water tank consists of two or three chambers, which can be separately emptied for cleaning. In severe climatic conditions, the external walls of the tanks must be insulated against freezing. Keeping the variation of hydraulic pressure within acceptable limits controls the height as well as the shape of tanks. The tank very widely, is depending on the size of the community, peak-hour supply requirements, etc. A typical layout for a pre-stressed concrete water tower with two chambers. The shaft of the tower consists of one or two cylinders. The inside cylinder serves to support the fall, rise and overflow piping and to carry the stairs, elevators, etc. The outside cylinder supports mainly the outside conical and inside cylindrical tanks. In many communities, the water tower serves also as an observation tower and is open to the public to view the surrounding countryside. In such cases, and also for relatively high towers, an elevator is a necessity. It is located inside the inner cylinder of the shaft or outside the water tower, A capacity of about 5,40,000 liters. The two chambers of the tank can be emptied for cleaning. The conical shells of tank and roof are protected against severe weather by a heat-insulating outer ribbed shell, which is not a part of the tank. German water towers, by local ordinance, commonly serve both for water storage and as observation towers. The Backing tower, consists of two tanks in a cylindrical building supported on a 6.9 m diameter cylindrical shaft, which houses offices and equipment. The upper tank capacity is 6,30,000 liters and that of the lower tank is 4,50,000 liters.

3. DESIGN REQUIREMENTS OF CONCRETE (I.S.I.) [IS 456:2000]

For structures that hold any fluid inside among, the nature of the substantial of which the retainer is comprised of ought to be profoundly faultless and exceptionally fine extent of fine and coarse totals should be blended in a quite certain extent to get an extremely top notch concrete. As a general rule, on the off chance that the substantial blender is more fragile than M20, it isn't ideal for retainer structure building reason. Additionally, how much concrete that should be restricted in the blend ought not be under 30 kg for each cubic meter.

The concrete mix to be formed should be highly compacted using vibrational equipment's from outside and the permeability of such a mix directly depends on the water cement mix ratio. At the point when the water concrete proportion is expanded it brings about an increment of penetrability of the blend and substantial blend in with extremely low concrete water apportion isn't not difficult to be compacted. The substantial in the holding structures should be stayed away from corruption and other such reason that prompts the disappointment is the presence of spillage because of imperfections, for example, honeycombing, isolation, and so on. One more such reason for substantial disappointment is the spillage through the joints which are to be made however much water tight that it very well may be in order to keep away from this glitch. The whole plan of holding structure is altogether different from that of RCC structure planning as it is exceptionally important to stay away from the development of breaks from the surface as well as from the inside of the construction. In this manner, all burdens that are being applied to the walls of these holding structures should be in all likelihood be under reasonable cutoff points.

4. MEMBRANE THEORY OF SHELLS

The figure below shows a representation of forces that may arise in a dome that can be analyzed so as to keep the stresses generated in the dome under considerable limits. The equilibrium condition in a dome element is obtained by maintaining a balance between the meridian as well as the latitude. Forces along the circumference are known as meridian forced and are denoted by $N_ø$ and the forces along the latitude in horizontal direction and also perpendicular to the meridian forces are known as hoop stress and are denoted by $N_θ$. The figure below shows also the representation of a dome element with the forces on it.

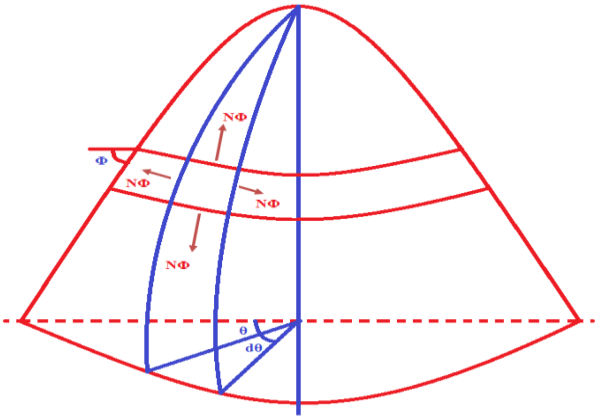

Fig 1: Representation of Membrane Forces

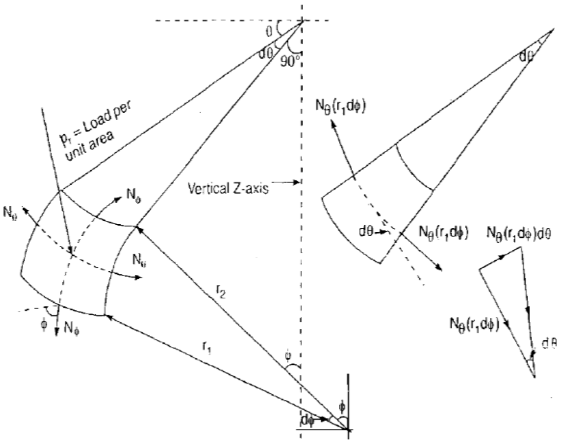

Fig 2:- Representation of Shells of Revolution

From Figure above, it is easily seen that the force $N_θ(rldø)$ again have horizontal resultant of magnitude $N_ø(rldø)dθ$. This force has a component $N_ø(rldø)dθsinø$ which is directed normal to the shell and pointing towards inner direction from the shell's surface. Thus, these two forces and the external force of magnitude $Pr(rdθ)$ that of the liquid must be in equilibrium.

Thus, $N_ø(rdθ)dø + N_ø(rldø)dθsinø + Pr(rdθ)(rldθ) = 0$

Again, $r = r_2sinø$,

Therefore, $\frac{N_ø}{r_1} + \frac{N_θ}{r_2} = -Pr = \text{presure normal to surface}$

In the equation above, Pr is considered positive when considered to be acting towards the inner side while the values for $N_ø$and$N_θ$canbe considered positive only if they are tensile in nature and negative if they are compressive.

5. METHODOLOGY

The methodology involved in this study involves designing Intz tank completely and then simulating the model of the reservoir in a virtual environment so as to study the effect of hydrostatic forces on the surface of the reservoir and also avoiding crack formation and propagation at the same time by optimizing the designed model characteristics. The entire methodology is broken down into two stages primarily – Design Phase and Simulation Work which is supported by analytical calculations so as to get the standard dimensions of the Intz reservoir to be modeled.

Design of RC Dome

Designing an RC (reinforced concrete) dome requires careful consideration of structural stability, load-bearing capacity, and construction techniques. Here are the general steps involved in designing an RC dome:

- **Determine the Purpose and Parameters:** Define the purpose of the dome, such as its function (e.g., sports arena, exhibition hall, or religious structure), occupancy capacity, and desired dimensions. Consider factors like the span, height, and shape of the dome.
- **Structural Analysis:** Conduct a structural analysis to determine the dome's stability under different loads, including dead loads (self-weight), live loads (occupancy and equipment), wind loads, and seismic loads. Use appropriate engineering software or consult a structural engineer to perform the analysis.
- **Dome Shape:** Select a dome shape that suits the purpose and aesthetics while providing structural stability. Common dome shapes include hemispherical, elliptical, and ovoid. The curvature and shape will affect the forces acting on the structure.
- **Reinforcement Design:** Determine the required reinforcement for the dome. This involves selecting the appropriate reinforcement bars (rebar) and calculating their distribution, spacing, and diameter based on the design loads and structural analysis. Consult relevant building codes and standards for reinforcement guidelines.
- **Support System:** Design the support system that will provide stability during construction and in the completed structure. This may involve temporary supports during construction, such as scaffolding or formwork, and permanent supports, such as columns or perimeter walls.
- **Construction Techniques**: Determine the construction techniques that will be used for the dome. This may include using precast concrete elements or in-situ casting. Consider the formwork, concrete placement, curing, and finishing methods.
- **Joints and Connections:** Design appropriate joints and connections to ensure structural integrity. Pay attention to the connections between the dome and its supporting elements, such as columns or walls.
- **Waterproofing and Insulation:** Consider the waterproofing and insulation requirements for the dome, depending on its intended use and location. This may involve applying waterproof coatings, using insulation materials, or incorporating a separate roofing system.
- **Maintenance and Durability:** Ensure the design accounts for long-term maintenance and durability. Consider factors such as corrosion protection for reinforcement, accessibility for repairs, and materials that can withstand environmental conditions.
- **Construction and Quality Control:** During construction, follow the design plans and specifications while implementing proper quality control measures. Regular inspections should be conducted to verify that the construction aligns with the design requirements.

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Design Procedure for Intze Tank

1. Dome at the top of the reservoir is almost 100 to 150 mm thick and reinforcements are provided along the latitudes and meridians of the reservoir.
2. Ring beam in the dome is to be provided so as to accommodate the horizontal component of the thrust force and resist the hoop stress induced on the surface.
3. Cylindrical walls are to be made to resist the hoop stress caused by the water pressure in horizontal direction.
4. Ring beam at the junction of the conical and cylindrical walls are to be provided so as to resist the hoop stress generated as a reaction of conical and cylindrical interface.
5. Conical Slab is to be considered in the reservoir in order to accommodate hoop stress due to water pressure.
6. Floor of the tanks may be circular or domed in nature.
7. The columns are designed in order to accommodate the total load acting on the reservoir. These are placed at fixed intervals and are to be designed in such a way that it resist the wind pressures or the seismic loads that the reservoir experiences.
8. Foundation is the base of any reservoir and is so designed that it bears all the load acting on the reservoir and also consists of a ring girder and a circular slab.

For calculating the different dimensions of the Intz tank we follow few assumptions to attain a volume accordingly:
Total Volume,
V = $0.585D^3$ as per Reynolds' assumption
Total Volume,
V = $0.3927D^3$ as per Greys' assumption and H=D/2

6. SEISMIC ANALYSIS BY SOFTWARE (STAAD-PRO)

For Modelling: The initial setup of STAAD Pro is very important so as to create a virtual environment that complies with our calculations and assumptions at the same time. The basic set up that is done and the most important feature that is used to model the water tank can be found on the section below.

1. Space-file name: Water tank design
2. Unit to be set: Metre, kN
3. Add beam
4. Finish
5. View from +Z –X_Y Plane .Snap Node/Beam
6. Use Circular Repeat tool.

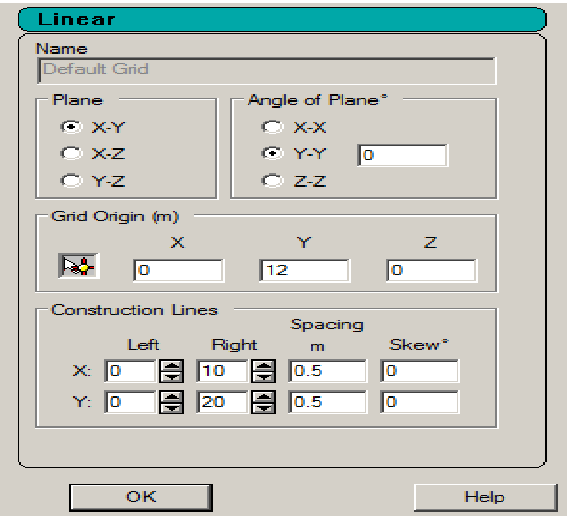


Fig 3: Grid Setting Snap

➢ The first step is to set the grid so as to draft the outline of the water tank. The grid is set as shown in the figure above.

➢ The next step is to draft the water tank outlines by beam elements with the designed dimensions as shown below.

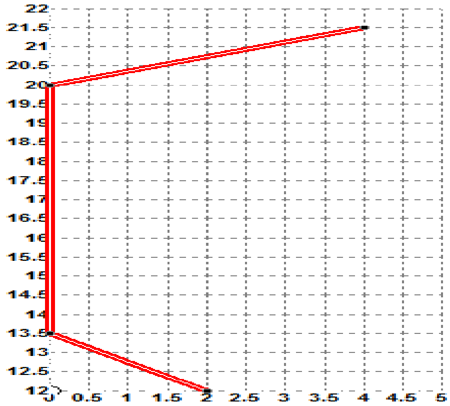


Fig 4: Beam Elements

➢ The next is to insert the nodes on the respective beam elements as follows.

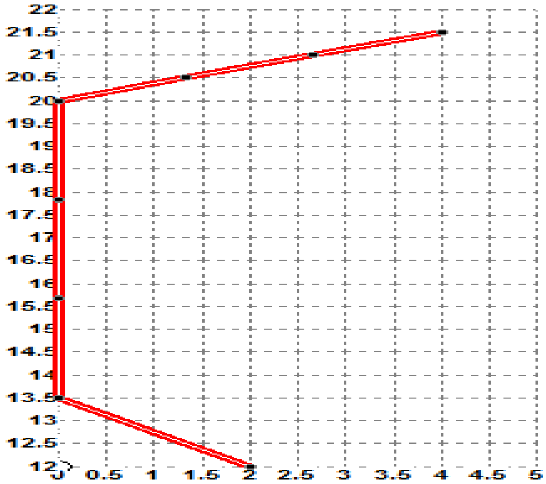
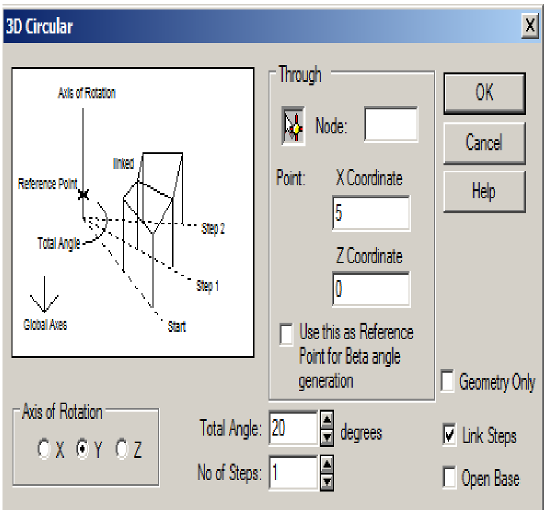


Fig 5: Multiplying the Beams by Adding Node Points

➢ The next step to be followed is to perform a circular repeat by selecting all the drafted beam elements by an angle 20 degrees and for only one instance with x = 5 being the rotational axis.



(a)

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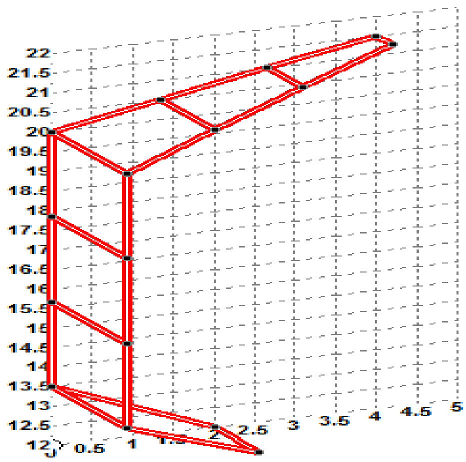


Fig 6 (a) & (b): Performing Circular Repeat on the Beam Element

- The next step is to fill all the beam elements with plate elements. For this purpose, we have to select all the beam elements and click on Create Infill Plates and then view them as shown below

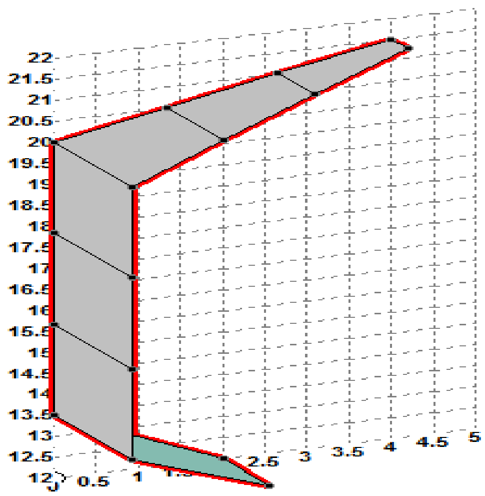
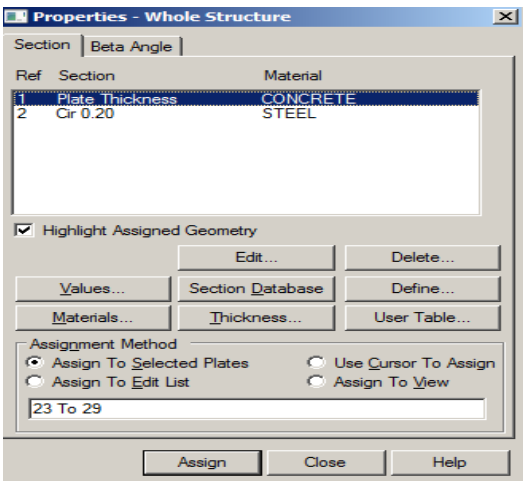


Fig 7: Adding Plates and Viewing the Plate Elements

- The last step of preparing the model is to add thickness to the plate element and assign concrete to them. This is supported by defining the cross section of the beam elements forming the. In this case the thickness is assumed to be 0.2 m and circular cross section of 0.2 m.



(a)

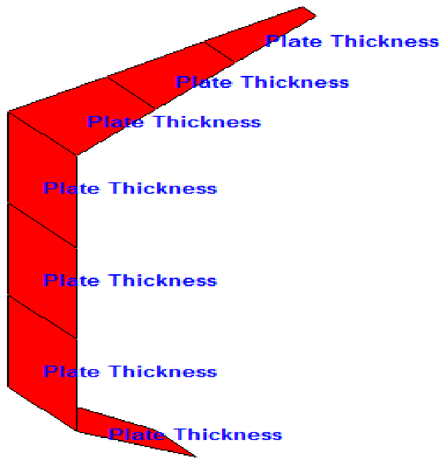


Fig 8 (a) & (b): Assigning Properties to Plate Elements

7. RESULTS

For Full Tank Condition

In the below table the comparison of base shear, base moment and sloshing height for different seismic zones are done per IS 1893 and Staad Pro analysis. From the data we concluded that base shear and base moment increases successively from zone III to V. The value of base shear & moment for zone III, IV & V are taking from clauses 4.2.

Table- 1: Summary of Base Shear of Different Seismic Zone by Conventional Method

Zone	Impulsive (KN)	Convective (KN)	Total (KN)
II	355.03	18.95	355.58
III	568.05	30.05	568.61
IV	852.18	45.78	853.39
V	1278	69.63	1280.32

Table- 2: Summary of Base Moment of Different Seismic Zone by Conventional Method

Zone	Impulsive (KNm)	Convective (KNm)	Total
II	5497.6	874.15	5566.12
III	8796.24	1388.5	8904
IV	13194.36	2108	13361
V	19791.5	3188.07	20046

Table-5.4: Summary of Forces of Different Seismic Zone by Conventional Method

Zone	II	III	IV	V
Base Shear(KN)	355.58	568.61	853.39	1280.32
Base Moment (KNm)	5566.12	8904	13361	20046
Sloshing Height(m)	0.17	0. 27	0.41	0.62

Table-5.5: Summary of Result Analysis of Different seismic Zone by Staad-Pro

Zone	II	III	IV	V
Base Shear (KN)	303.18	480	742.33	1098.8
Base Moment (KNm)	4878	7223.58	10501	17764

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Base Shear directly depends on the input seismic acceleration so if a structure is not expected to be subjected to high seismic forces, its design base shear would be low. **The design base shear should be smaller than the seismic weight of structure and from analysis the base shear is within limit** and from the comparison we found that values obtain from software analysis is low as compared to conventional method. As Lower values obtain from software analysis it makes the tank more economical.

Hydrostatic Results of Reservoir

The hydrostatic loading that was considered for the reservoir solid members (plates of concrete and beams of steel) followed simple hydrostatic fluid loads. For any vertical body that is being surrounded by liquid on one side, the walls are subjected to horizontal loads whose value increases with the depth of the vertical wall. For a vertical wall, maximum hydrostatic pressure is felt at the bottom of the vertical wall and zero pressure is seen at the top most region of the wall. Thus, the variation is triangular in nature and varies with the depth of the wall.

The results of the hydrostatic loading combined with the self-weight of the reservoir is given below.

In the figure shown below, it is seen that Maximum Von Mises Stress is found at the bottom conical dome part. The maximum value is found out to be equal to 1.61 N/mm^2. This value is well under the considerable limit for the concrete as well as that of steel.

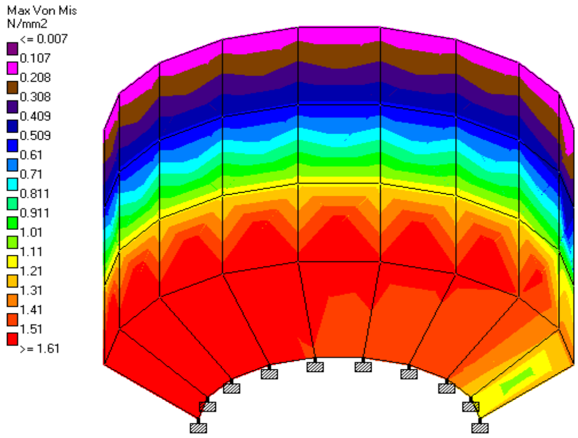


Fig 9: Maximum Von Mises Stress Distribution

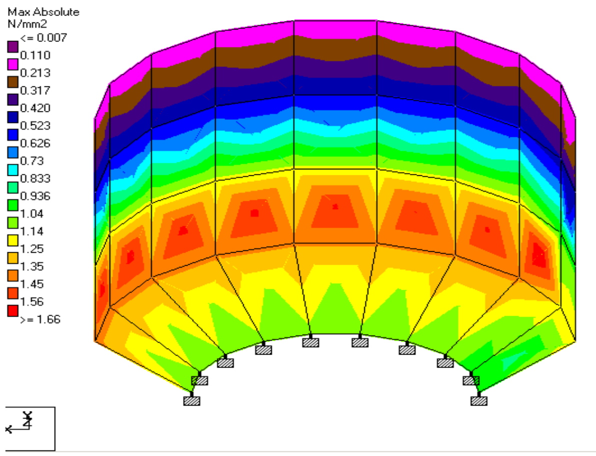


Fig 10: Maximum Absolute Stress Distribution

8. CONCLUSIONS

The storage of water and other liquids have become very much important for different day to day purposes, Water plays an important role in our life. We consume water starting from the moment we wake up from our bed till we sleep. For storing less quantity of water rectangular shaped tanks are used and for storing large quantity of water, the shape to be assumed is circular. In this study, we looked at a design strategy for an Intze-type water tank that is supposed to hold 300,000 liters of water and can meet the water needs of at least 1500 people. Major failures of elevated water tanks usually occur when there is an earthquake because supporting systems that are supposed to handle seismic forces fail. In this way, a seismic tremor makes supporting designs for raised water tanks very weak under parallel powers.

REFERENCES

1. Lamba, A., & Shrivastava, L. P. (2017). Intze Tank: A Brief Survey. *IRJET Journal of Civil Engineering, e-ISSN*, 2395-0056.
2. Lamba, A., & Shrivastava, L. P. (2017). Design, Analysis and Optimization of Intze Type Water Tank With Sloshing Effect.
3. Agrawal, M. S., Vanarotti, M. B., & Yashwant, K. M. (2022). Research on Emotion in Artificial Life and Artificial Intelligence: Dealing with Issues. *Telematique*, 860-864.

4. Agrawal, M. S. (2022). IMPACT OF HEAVY METAL ACCUMULATION IN GROUND WATER DUE TO LEACHATE & ASSESSMENT OF RHEOLOGICAL PROPERTIES. *Journal of East China University of Science and Technology*, *65*(2), 318-326.
5. Agrawal, M. S. (2022). A STUDY ON SEWAGE TREATMENT & GROUND WATER CONTAMINATION IN RAIPUR CITY. *Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology*, *54*(5), 187-191.
6. Agrawal, M. A., & Lamba, M. A. (2023) ANALYSIS AND DESIGN OF G+ 3 BUILDING IN DIFFERENT SEISMIC ZONES USING E-TABS.
7. Agrawal, M. S. (2022). IMPACT OF HEAVY METAL ACCUMULATION IN GROUND WATER DUE TO LEACHATE & ASSESSMENT OF RHEOLOGICAL PROPERTIES. *Journal of East China University of Science and Technology*, *65*(2), 318-326.
8. Agrawal, M. S. (2022). A STUDY ON SEWAGE TREATMENT & GROUND WATER CONTAMINATION IN RAIPUR CITY. *Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology*, *54*(5), 187-191.
9. Jaiswal, S., & Agrawal, S. (2021). Design of Horizontal and vertical alignment of Expressway for the speed of 150kmph–'A Review'.
10. Lamba, M. A., Agrawal, M. S., & Dubey, M. A. (2021). ANALYSIS OF USE OF SUGARCANE BAGASSE ASH FOR THE PRODUCTION OF GEO POLYMER CONCRETE. *International Research Journal of Modernization in Engineering Technology and Science*, *3*.
11. Agrawal, M. A., & Lamba, M. A. (2023) ANALYSIS AND DESIGN OF G+ 3 BUILDING IN DIFFERENT SEISMIC ZONES USING E-TABS.
12. Lamba, M. A., Tamrakar, M. G., & Gaur, M. H. (2022). A comparative analysis on CI turbine act and emissions resorting to a novel antioxidant preservative. *Telematique*, 523-535.
13. Lamba, A. (2022). FORMATIVE DESIGN OF HIGH-RISE SYSTEM IN STEEL STRUCTURE. *Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology*, *54*(6), 49-56.
14. Lamba, M. A. (2022). In-Structure Response Spectra Considering Nonlinearity Of RCC Structures: Experiments And Analysis. *Yantu Gongcheng Xuebao/Chinese Journal of Geotechnical Engineering*, *44*(5), 97-103.
15. Lamba, A. (2020). A Study On Geo Polymer Concrete Using Sugarcane Bagasse Ash. *Solid State Technology*, *63*(6), 13127-13134.
16. Shori, A., & Lamba, A. (2019). Performance of Concrete using Red Mud as Replacement Material with Basalt Fiber.
17. Padhy, M. A. P., Lamba, M. A., & Tamrakar, M. G. (2022). Impact of Process Limits on Cable and Curve Additive Production Process. *Telematique*, 512-522.
18. Sahu, M. K., Padhy, M. A. P., & Lamba, M. A. (2022). Preliminary Study on Interpretation Motion Traits of Moored Well-proportioned Wheeled vehicle for hauling-substitute in Common Waves. *Telematique*, 497-511.