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Seismic Behaviour of an Elevated Water Tank for Different Staging Patterns and Different Staging Heights

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ABSTRACT:
As we know from past records, many of reinforced concrete elevated water tanks were heavily damages or collapsed during the earthquakes all over the world. Most of the damages observed during the seismic events arise was might be due to the lack of knowledge regarding the proper behaviour of supporting system of the tank against dynamic effect and also due to improper geometrical selection of staging patterns. The main objective of this study is to understand the behaviour of supporting system which is more effective under different earthquake characteristics or earthquake zones with STAAD.Pro V8i software. Finally study discloses the importance of suitable staging configuration to remain withstands against heavy damage or failure of elevated water tank during seismic events. Tank responses including base shear, overturning moment and roof displacement have been observed, and then the results have been compared and contrasted.

KEY WORDS: earth quake, seismic force.

INTRODUCTION:
Water supply is a life line facility that must remain functional following disaster. Most municipalities in India have water supply system which depends on elevated tanks for storage. Elevated water tank is a large elevated water storage container constructed for the purpose of holding a water supply at a height sufficient to pressurize a water distribution system. In major cities the main supply scheme is augmented by individual supply systems of institutions and industrial estates for which elevated tanks are an integral part. Elevated water storage tanks features to look for are strength and durability, and of course leakages can be avoided by identifying good construction practices. But in reality these structures do not often last as long as they are designed for.

These structures have a configuration that is especially vulnerable to horizontal forces like earthquake due to the large total mass concentrated at the top of slender supporting structure. So it is important to check the severity of these forces for particular region. The study of damage histories revealed damage/failure of reinforced concrete elevated water tanks of low to high capacity. Investigating the effects of earthquakes has been recognized as a necessary step to understand the natural hazards and its risk to the society in the long run. Most water supply systems in developing countries, such as India, depend on reinforced cement concrete elevated water tanks. The strength of these tanks against lateral forces, such as those caused by earthquakes, needs special attention. It is very important to analyze reinforced cement concrete elevated water tank properly.

OBJECTIVES:
The main objective of this study is to understand the behaviour of supporting system of Elevated liquid storage tanks, which is more effective under different earthquake characteristics or earthquake zones as per draft code of IS 1893 (Part 2) and GSDMA guide lines. A reinforced concrete elevated water tank, (Intz type) with 1500 cubic meters and with a staging height of 18m and 22.5m from ground level is considered. Here different supporting systems such as radial bracing, concentric column bracing and cross bracing are compared with basic supporting system for various fluid filling conditions. The seismic zones of Zone-III Zone-IV & Zone-V and the corresponding earthquake characteristics have been taken from IS 1893 (Part 1)-2002 & draft code IS 1893 (Part-2).

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Table 1 Model parameters

Capacity of water tank	1500 cu.m
Height of staging	18 m and 22.5 m
Diameter of the Cylindrical Portion (D1)	16 m
Height of water in the Cylindrical Portion (h1)	7 m
Height of the Conical Portion (h2)	3 m
Diameter of the tank at base of Conical portion (D2)	10 m
Height of the Bottom Dome (h3)	2 m
Radius of Bottom Dome (R1)	7.25 m
Height of the Top Dome (h4)	3 m
Radius of Top Dome (R2)	12.17 m
Cylindrical Wall Thickness	400 mm
Conical slab Thickness	450 mm
Thickness of Bottom Dome	200 mm
Thickness of Top Dome	150 mm
Ring Beams at Bottom slab level	650 X 1200 mm
Column size	650 X 650 mm
Brace Beams	300 X 600 mm
Ring Beams at Top slab level	400 X 400 mm

ANALYSIS:

Finite element modelling procedure is adopted for analysis and finite element model is prepared in Staad Pro V8i software by using members and plane elements. The Figure: 1 shows the Columns, bracing beams, floor beams and finite element mesh generated to model tank portion. The diameter of the staging is 10m and height staging is 18m and 22.5m. The bottom dome, conical slab, side wall and top dome are modelled in staad pro with 4 noded plate elements. The member specifications in terms of geometrical properties of the members are applied to the FEM model. The support condition of fixed is applied to the columns, because we are considering the foundation of tank as annular raft or combined raft. The seismic force is applied at C.G of the tank as nodal forces on tank element nodes.

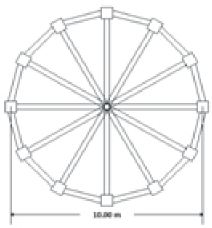

Fig 2: Radial bracing

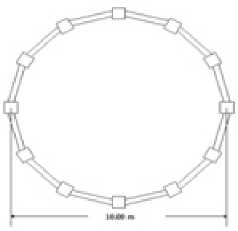

Fig 3: Basic bracing

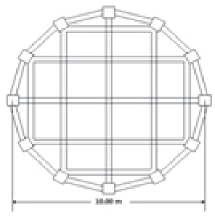

Fig 4: Cross bracing

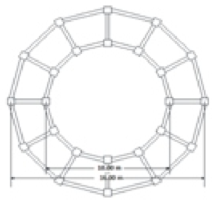

Fig 5 : Concentric columns

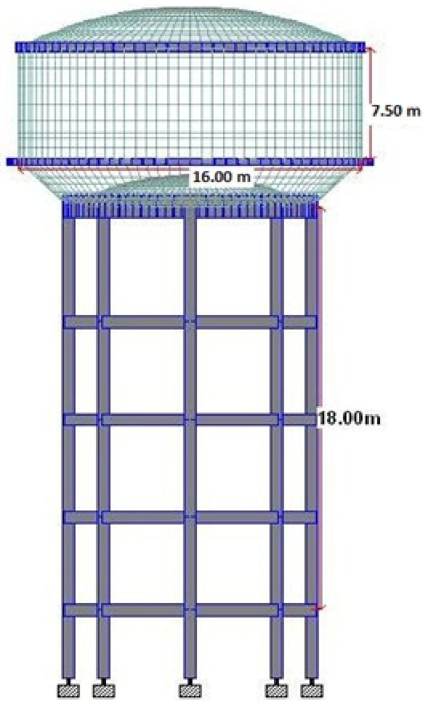

Fig: 1 FEM model of water tank

RESULTS AND DISCUSSION:

1.Roof displacements summary for

The Roof displacements for tank empty, tank half and tank full conditions are taken from staad by applying the respective Seismic forces to the FEM model. The Roof displacements in various tank filling condition for Basic, Radial, cross bracing and concentric column type system are can be clearly seen in fig: 6 and 7 for different zones. The roof displacement in the tank Empty condition is higher than the tank half and tank half condition.

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Hence tank Empty condition is the severest condition for design considerations. From this figure concentric column type staging is having less displacement and Basic bracing type staging is having max. Displacement in any zone. ESR with Staging height 18 m and 22.5 m, in Zone III Tank is safe, in Zone-IV Tank survives only in concentric column type staging pattern, and where as in Zone-V Tank fails in all patterns. (Limiting Displacement in Zone-III & IV is hs/500= 49.2 mm for first 3 and for concentric column it is 45mm). So, in Zone –V tank has to be modified or redesigned to reduce displacements.

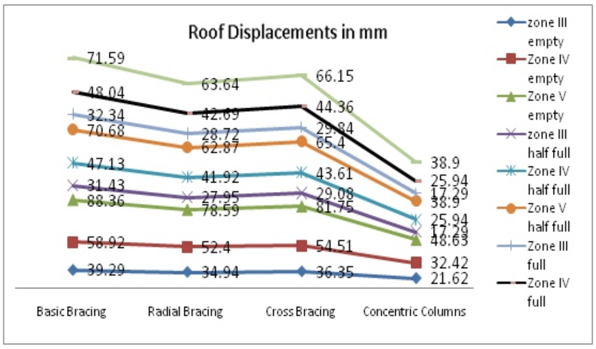

Fig: 6 Roof displacement summaries for Seismic load (18 m)

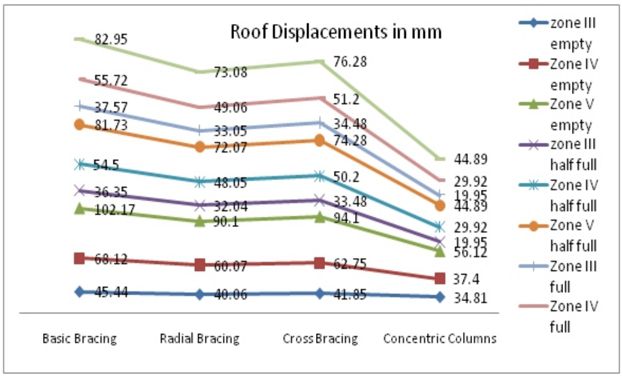

Fig: 7 Roof displacement summaries for Seismic load (22.5 m)

2.Lateral displacements

The lateral stiffness evaluated from the lateral displacement of staging by applying a horizontal force of 10kN at C.G of the tank. It varies for Basic bracing, Radial, cross bracing and concentric column type of staging. The above Fig: 8 and 9 shows which staging pattern has better lateral stiffness

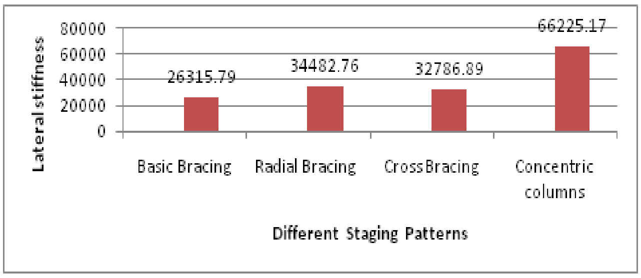

Fig: 8 Lateral Stiffness of stagings (18 m)

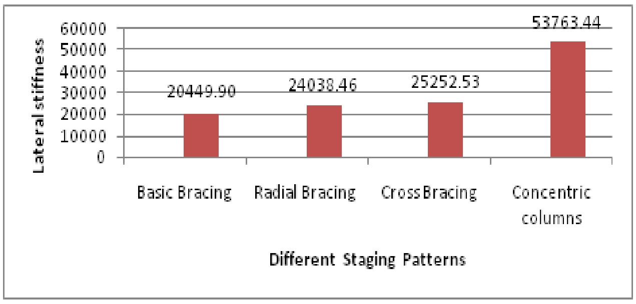

Fig: 9 Lateral Stiffness of stagings (22.5 m)

3.Base Shear

The Base shear with staging of height 18m for the earthquake characteristics of Zone-III Zone-IV and Zone-V are calculated from the Impulsive and convective modes with zones earthquake characteristics. There are variations in the Base shears, for the Basic, Radial, cross bracing and concentric column type staging systems, which can be clearly observed in fig: 10, 11. The Base shear of Basic bracing is lower than all other staging patterns in any Zone.

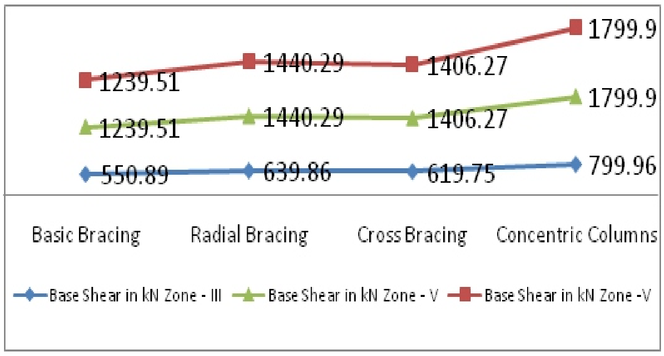

Fig: 10 Base Shear summaries for Seismic load (18 m)

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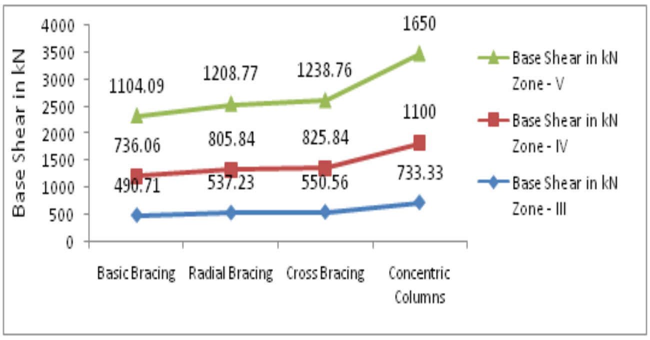

Fig: 11 Base Shear summaries for Seismic load (22.5 m)

4.Base Moment:

The Base moment with staging of height 18m for the earthquake characteristics of Zone-III ,Zone IV and Zone-V are calculated from the Impulsive and convective modes with two zones earthquake characteristics. There are variations in the Base moment, for the Basic, Radial, Concentric Column type and cross bracing systems. The Base moment of Basic bracing is lower than all other staging patterns in any Zone which can be clearly observed in fig: 12, 13.

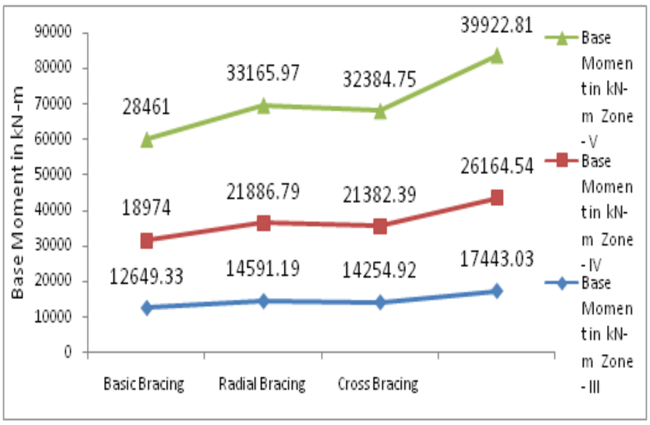

Fig: 12 Base Moment summaries for Seismic load (18 m)

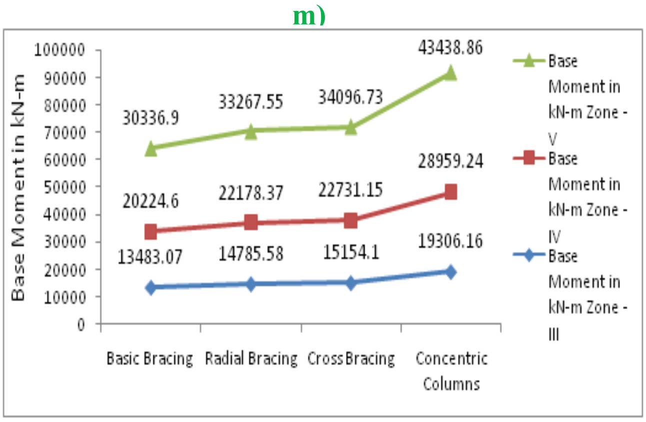

Fig: 13 Base Moment summaries for Seismic load (22.5 m)

CONCLUSIONS:

The above study demonstrates the considerable change in seismic behavior of elevated tanks with consideration of responses like stiffness, base shear, base moment, displacement etc. when supporting system is used with appropriate modifications. Finally study discloses the importance of suitable supporting configuration to remain withstand against heavy damage/failure of elevated water tanks during seismic events. Earthquake characteristics in three different zones, which cause excitation of responses such as base shear force, overturning moment and roof displacement, are compared and following conclusions are obtained

1.For ESR with Staging height 18 m and 22.5 m , in Zone III Tank is safe, in Zone-IV Tank survives only in concentric column type staging pattern, and where as in Zone-V Tank fails in all patterns. Hence in Zone V modification of configuration ESR itself (Staging pattern/Column sizes/bracing beams sizes), which will end up with decrease in roof displacement.

2.From the analysis of different types of staging patterns the Base moments in Radial, cross bracing and concentric column type staging pattern are higher than basic bracing which will affect the reinforcement design of staging members.

3.From the analysis of different types of staging patterns the Base Shears in Radial, cross bracing and concentric column type staging pattern are higher than basic bracing which will affect the reinforcement design of staging members.

4.In Zone-III for Seismic load ESR with 18 m height of staging, Basic type of Bracing (KS=26325.79kN/m) is sufficient and more appropriate compared to Radial bracing(KS = 34482.76 kN/m), Cross bracing (KS = 32786.89 kN/m) and Concentric columns(KS = 66225.17 kN/m)

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