Student Competition Paper

Nonlinear Static and Dynamic Analysis of Intze Type Overhead Reservoir (OHR) on Frame Staging

By Abhiroop Dutta,
Construction Engineering Department, Jadavpur University

Project summary

Introduction

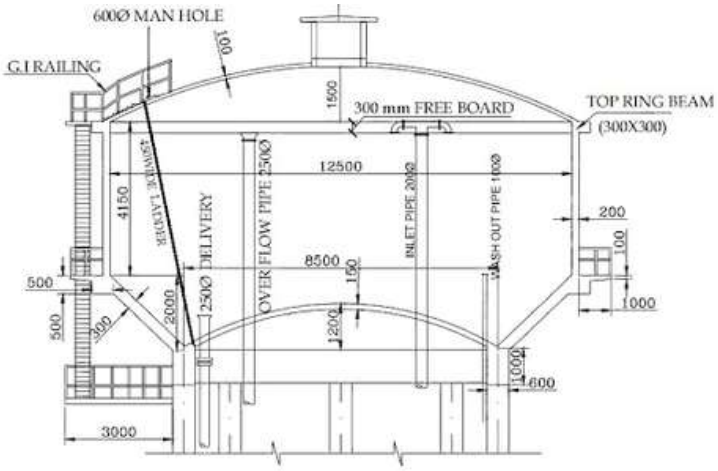
Frame Type OHR is one of the common water storages in public health infrastructure. There are several failure incidents of these OHRs, particularly during seismic events which has raised doubts regarding their seismic vulnerability. This study focused on the seismic performances of OHRs having different capacities adopting various linear and non-linear numerical analysis. Fragility curves of different OHR capacities have been developed for all the limiting performance levels of Immediate Occupancy (IO), Life Safety (LS), Collapse Prevention (CP).

Problem statement

Three Intze-type RCC OHR over frame staging structures of different capacities (300 cum, 600 cum & 900 cum) are modelled in the FE Platform for three types of analysis as follows.

1. Two Mass Modelling
2. Non-Linear Static Pushover Analysis (NLPOA)
3. Non-Linear Time History Analysis(NLTHA) and then Incremental Dynamic Analysis (IDA)

The various seismic parameters have been evaluated for different considered capacities. Comparative study with respect to their seismic performances, vulnerabilities and fragilities for OHRs of different capacities and for all the seismic performance levels have been made.



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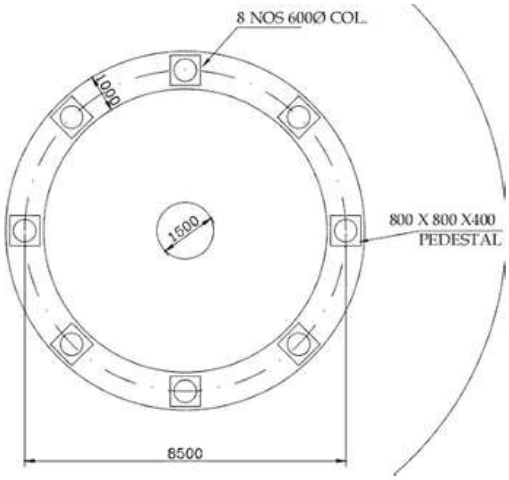


Figure 1a : Real life Existing Over Head Reservoir (OHR) and its Approved Drawings

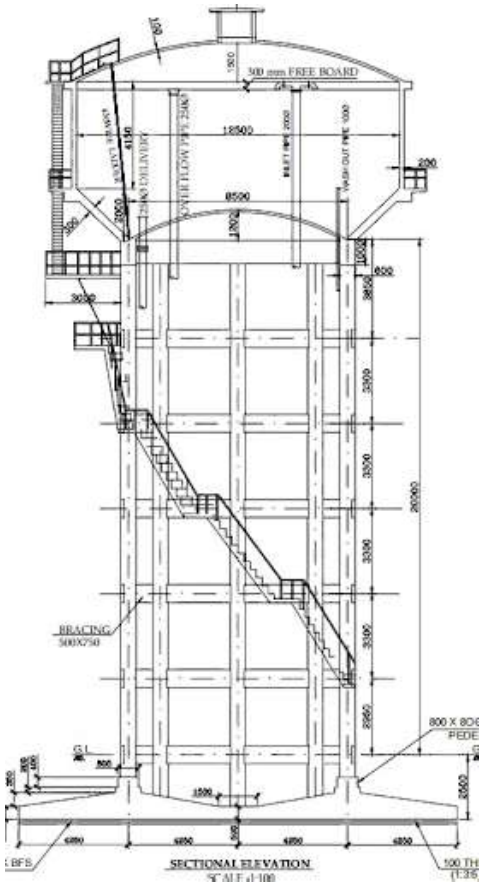


Figure 1b : Real life Existing Over Head Reservoir (OHR) and its Approved Drawings

Analytical/Numerical approach

The OHR structures have been modeled with frame and shell elements. Initially the iconic Housner's two mass model is adopted and subsequently Non Linear static Push Over Analysis (NLPOA) and Non-Linear dynamic Time History Analysis (NLTHA). Subsequently, Incremental Dynamic Analysis (IDA) with varying intensities have also been performed. Fragility Analysis have been attempted based on the results obtained from various IDA, to get an idea about their seismic vulnerabilities.

Potential outcomes/ Results/ Discussion

Numerical seismic analysis of Intze type of OHRs of different capacities in seismic zone of IV of IS 1893 Part-I (2016) adopting three different types of numerical models are compared as follows.
Housner's Two Mass Model provides Elastic Base Shear, also known as Design Base Shear of OHR structures, which have provided greater base shear margins for OHRs having lower capacities.

The Nonlinear Pushover Analysis (NLPOA) results, it seems that the ultimate base shear capacity at the performance level for 300 cum, 600 cum and 900 cum are about 870 KN, 2480 KN and 3270 KN. These base shear capacities are 4.26 times, 5.85 times and 4.20 times the respective linear design capacities. It seems that 600 cum OHR have better (40%) inelastic reserve capacity i.e. greater safety against MCE as compared to 300 cum and 900 cum capacities of OHRs.

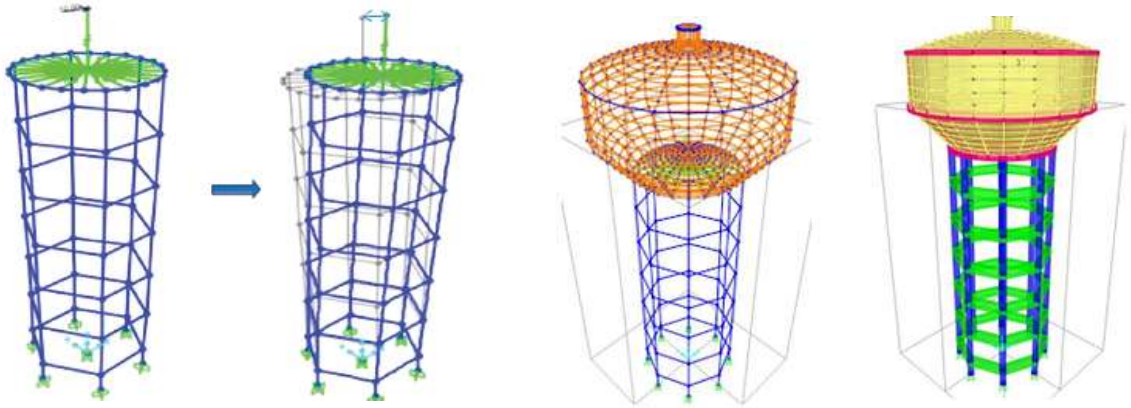


Figure 2: Numerical Models of OHR for Two Mass Model and for Frame+Shell FEM Model

The maximum inelastic top displacement of same staging height of 20 m forall the OHRs of 300 cum, 600 cum and 900 cum capacities seem to be 342 mm, 407 mm, 528 mm respectively, indicating greater flexibility & ductility for 900 cum OHR, which are in tune with the results of Two Mass Model impulsive time period.

The Global stiffnesses of 300 cum, 600 cum & 900 cum of RCC OHRs are about 10188 KN/m, 30172 KN/m and 50727 KN/m respectively. It seems that for Design Basis Earthquake (DBE) 300 cum OHR performs better than 600 cum capacity, which is better than 900 cum OHR. However, the performances of 900 cum OHR against Maximum Considered Earthquake (MCE) seems to be better than 600 cum, which is better than 300 cum OHR. The Global Ductilities of 300 cum, 600 cum and 900 cum OHR are likely to be 4.68, 6.90 and 11.26 respectively, which also indicate relatively greater ductility, toughness and safety margin for 900 cum OHR against MCE.

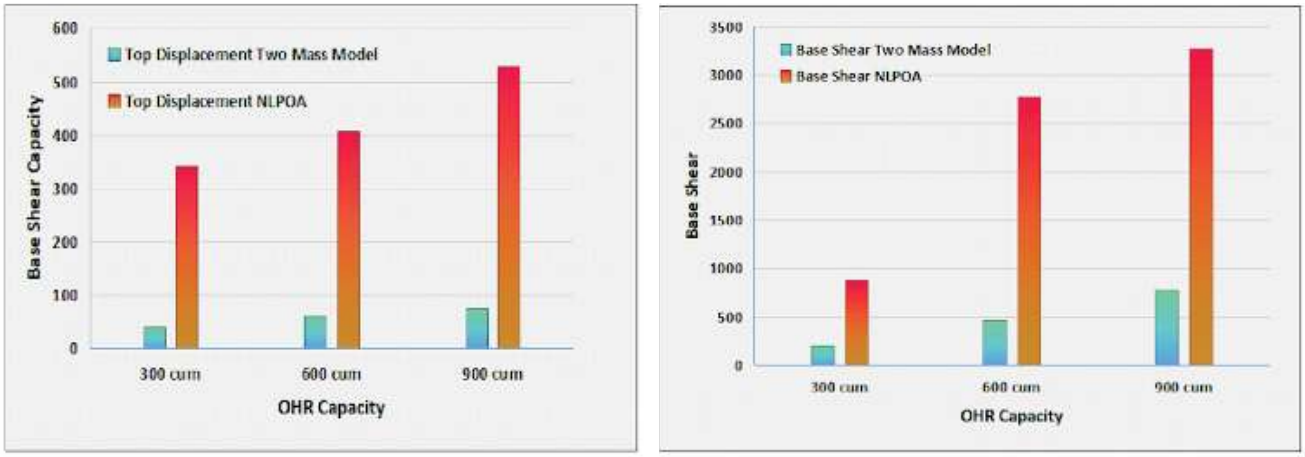
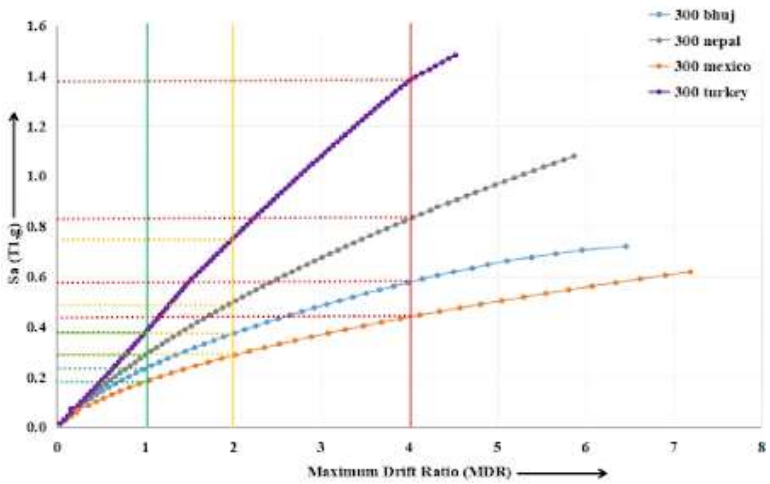


Figure 3: Comparison of Design and Ultimate Base Shear Capacity and Inelastic Top Displacements of OHRs

The greater Fragility of OHRs for the capacities in the decreasing orders of 300 cum, 600 cum & 900 cum for all the performance levels of IO, LS, CP, which are in tune with the NLPOA results.



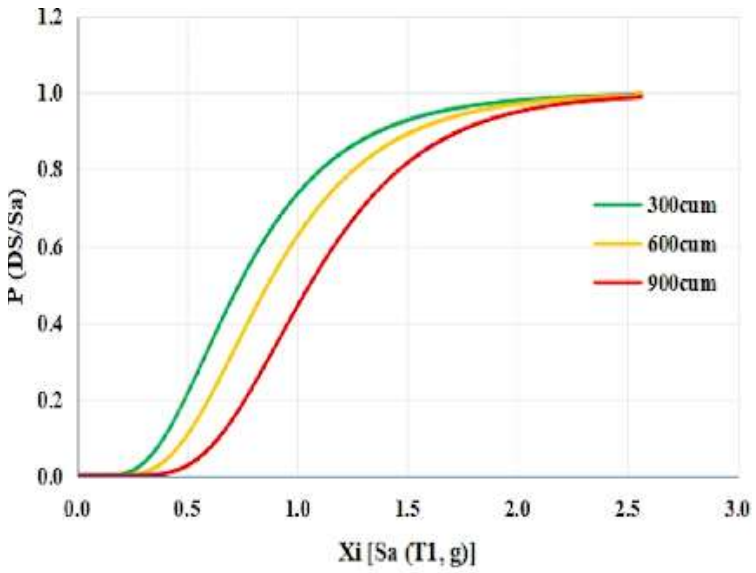


Figure 4: IDA Curve for 300 Cum OHR & Comparison of Fragility Curves at CP of different OHR Capacities

Conclusion

- It seems that the pushover analysis is approximate though computationally faster, where as incremental dynamic time history analysis based on non-linear time history analysis is more accurate but relatively with greater computational cost for the important infrastructure OHRs.
- Incremental dynamic analysis based on NLTHA outcomes seems to be more realistic and accurate for specific actual earthquake data.
- The Base Shear Capacities obtained from NLTHA based IDA are in tune with those from NLPOA, with greater details, indicating its importance and significance.
- In case of Immediate Occupancy (IO) performance level the fragility of these OHR structures are very close, whereas at Life Safety (LS) are well separated, and at Collapse Prevention (CP) are further separated indicating greater variations of seismic performances for different capacities of OHRs at higher performance levels.
- The fragility curves also become more inclined with lesser slopes indicating lesser rate of fragility increment at higher performance levels of greater capacities.
- Based on the linear and nonlinear static and dynamic numerical analysis of different OHR capacities with same staging height in Zone IV, greater risk may have imported for MCE though the design may be more reliable in case of lower capacity OHR.
- Nonlinear analysis may be suggested for Intze and other types of OHRs to ensure greater safety and making resilient infrastructure of public utility system for sustainable growth.