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Suitability of Software for Calculation of Staging Stiffness of OHSR

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Abstract: ***Overhead service reservoirs are tremendously vulnerable under lateral loads. According to the past earthquake studies, supporting system of overhead tanks known as staging are critically important than the other structural element. Due to the slender supporting structure holding up heavy concentrated mass at the top, overhead service reservoir (OHSR) became unsafe to horizontal forces. Stability of OHSR against lateral forces depends upon the supporting structure. This paper deals with behavior of supporting system or staging of reinforced concrete OHSR due to dynamic effect. Circular OHSR with radial bracing is analyzed with different sofwares such as STAAD. Pro, SAP200 and ETAB. Seismic response such as tank resultant displacement at the center of gravity of staging has been calculated and then the results have been compared.***
Keywords: ***Overhead service reservoir, staging, displacement, stiffness, STAAD.Pro, SAP 2000, ETABS***

I. INTRODUCTION

Water is a basic element for social-economic development, healthy environment and for the survival of human being. It is a core of various issues which are explicitly popularized by the peoples such as climate change, sustainable development etc. It is a connection between environment and civilization. Safe potable water is necessity of every sector such as human survival for drinking, industrial use, for domestic purpose, agricultural etc. Water resource management is an integral way to bring various users together by keeping environmental, economic and social aspect in mind.

To meet all the demands, water storage is necessary. Service reservoirs/ tanks are the constructed which stores clean water to balancing hourly fluctuation of water demand, to maintain constant pressure and to supply water during emergencies such as fire, repairs etc. The type of service reservoirs depends upon the population of community which influences the size of tank, terrain of that area and various other factors. There are many types of tanks such as ground level reservoir, underground reservoir and overhead service reservoir. To achieve the required water head and to provide constant supply of water in large area under the gravity action, overhead tanks are preferred in many areas. Overhead service reservoir (fig 1) is a vital part of water distribution system. It stores the energy in form of potential gravitational force and releases it later when the water is circulated in the area.

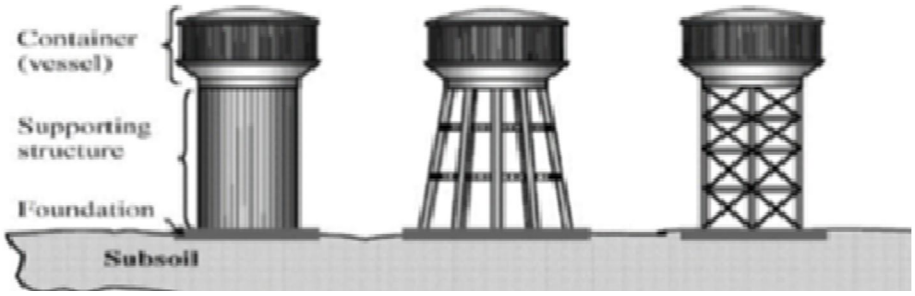

Fig 1: Overhead Service Reservoir

Overhead tanks are generally reinforced concrete tanks rested on staging. The base of the tanks is subjected to weight of water and the pressure of soil. Overhead reservoirs are highly earthquake prone structure to be effected by earthquake as large mass is concentrated at the top of structure which is supported by staging system. Due to slender staging, it is most critical part of tank leading to sudden damage to the structure and can induce large horizontal force and overturning forces in overhead tank during earthquake. Staging is the most vulnerable part of overhead tanks so that the main focus is given to the support system i.e. staging. The analysis and design of the structure is made using software SAP2000, STAAD. Pro and ETAB. Various results can be obtained from these softwares such as loads, moments and shear forces.

STAAD. Pro (Structural Aided Analysis and Design) is a design software licensed by Bentley. It is most popular software for 3D modeling of structure for their analysis and design.

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It is user friendly which allow user to work extremely easily and analysis complex structure with ease and with less time. It has been the choice of design professional for static or dynamic analysis of bridge, tunnels, pipe racks, steel, concrete, aluminum buildings and many more simple and complex structure. There are two methods of modeling in it. One is using the command files and other is using graphical user interface (GUI). It uses finite element method for analysis.

SAP2000 (Structural Analysis Program) is latest version of SAP series of analysis program. It is more sophisticated. It allows to creating complex model that can be generated and meshed with templates built into the interface. In SAP 2000, the model templates allow quick and easy generation of various numbers of model using parametric generation techniques. Modeling is initiated using grid generation. Geometry defining, proper defining of major geometric aspect of structure is important while laying out of grid. It also uses finite element method for analysis.

ETABS (Extended three Dimensional Analysis of Building System) is easy to use especially for analysis and design of building system. It is mostly utilized for handling large scale seismic projects and highly acclaimed for static and dynamic analysis of buildings. It is well equipped to handle simplified lateral procedures, pushover analysis, response spectrum analysis and time history analysis. The data output options are much conductive to lateral design.

In STAAD Pro., Y-axis is taken in vertically upward and X-axis & Z-axis are taken in plan (fig.2) whereas in SAP 2000 and ETABS, Z-axis is taken in vertical direction (fig.3 and fig.4). STAAD software makes it more convenient to use as the directions used by this software are adopted globally.

Fig 2: Cartesian coordinate in STAAD. Pro

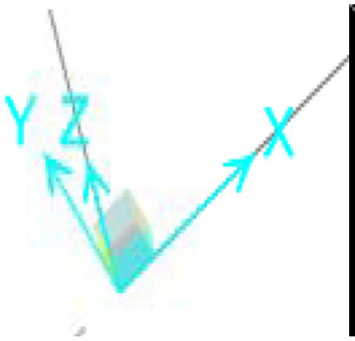

Fig 3: Cartesian coordinate in SAP2000

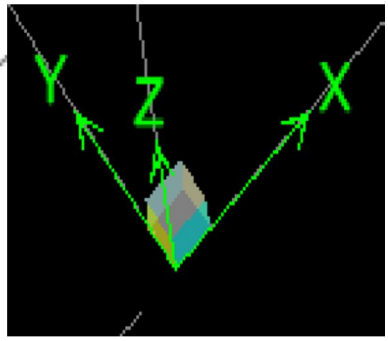

Fig 4: Cartesian coordinate in ETABS

II. METHODOLOGY

Reinforced concrete OHSR supporting on the circular framed staging of 10m diameter is analyzed. In practical scenario, frame type staging are used generally. Columns are arranged at the periphery and bracing are used to connect the columns. In this paper, 8 circular column of 0.45m diameter are taken. Rectangular bracing rings are provided at different levels of 0.3m×0.6m. Top bracing member was 0.45m×1m. Density of concrete is taken as 23.56 kN/m$^{3.}$ OHRS are analyzed for different height of staging such as 20m, 25m and 30m on different softwares and the stiffness are compared. Models were prepared on STAAD. Pro, SAP2000 and ETAB for all the different height. Lateral stiffness of staging is the force required to be applied at the center of gravity (C.G) of tank to get corresponding unit displacement. Stiffness of staging can be calculated from the displacement of C.G of tank due to an arbitrary lateral force. Stiffness is defined as load divided by lateral displacement. In the models, arbitrary load of 10kN were applied at the C.G of tank. Dome like structure (fig. 6) is prepared at the top so that a single member did not deflect. Density of inclined members and rigid link was kept as 0 so that they act as a mass-less member and did not conclude to the dead load. Self-weight is applied at whole structure except the inclined members and rigid link making dome like structure on top. Since, the container of tank is designed by excel sheet or by IS 3370(part 4). Only staging is analyzed by software.

Table 1: Size of various components

Component	Description
Height of staging	20m, 25m, 30m
No. of column	8
Size of column	450mm Diameter
Bracing	600mmD×300mmB
Top bracing	1000mmD×450mmB
Rigid link and inclined member	1000mm dia (circular)

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III. DISCUSSION

Models of 25m height of staging are shown below. Fig. 5 shows the 3D view of 25m staging without inclined member in STAAD. Pro. Fig. 6 shows the 3D view of 25m staging with all staging member and massless member in SAP 2000. Fig. 7 shows the 3D view of 25m height of staging without inclined member at top in ETABS.

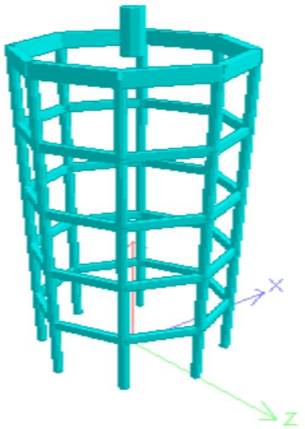

Fig 5: 3D view without inclined member in STAAD. Pro

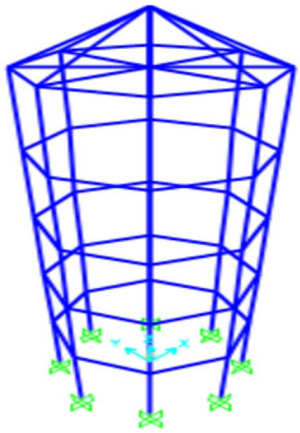

Fig 6: 3D view with inclined member in SAP 2000

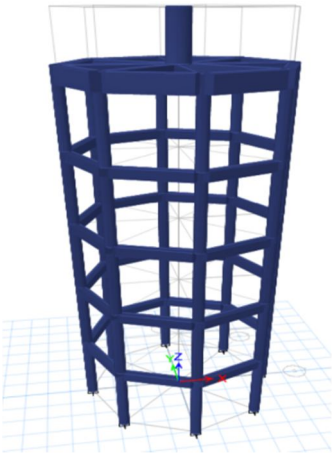

Fig 7: 3D view without inclined member in ETABS.

From the analysis done on the staging of 20m, 25m and 30m with different software, following values shown in graph and table are obtained.

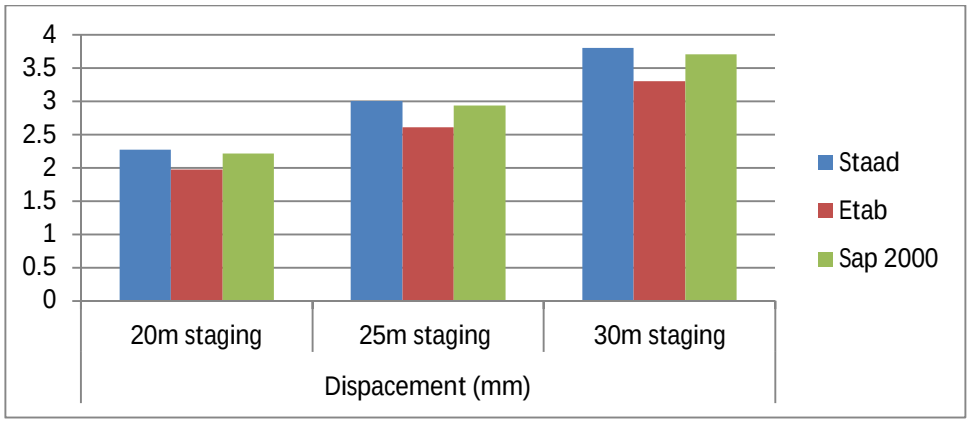

Fig 8: Comparison of displacement obtained by different software

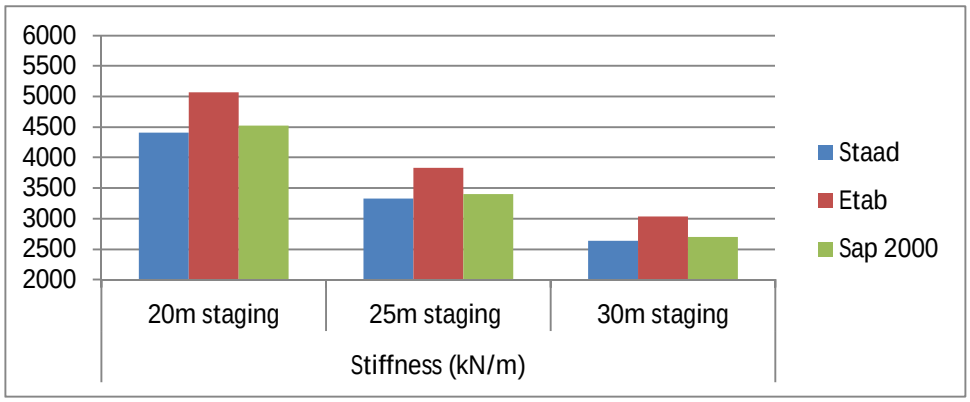

Fig 9: Comparison of lateral stiffness obtained by different software

Fig. 9 shows variation of stiffness with increase in height of staging. The stiffness of 25m and 30m staging is decreased by 24% and 40% respectively when compared to 20m staging for all three softwares. Stiffness obtained by ETABS for 20m height of staging is 14.8% to 15% and 11.21% to 12.45% more than the stiffness obtained by STAAS. Pro and SAP2000.

Table 2: Dead load of the staging structure

Software	Height of staging (m)		
	20m	25m	30m
STAAD Pro.	1313.7 kN	1593.419 kN	1873.151 kN
SAP 2000	1229.80 kN	1494 kN	1758.72 kN
ETABS	1313.687 kN	1593.419 kN	1873.151 kN

Table 2 shows the dead load of staging which include 8 columns and bracing only. The load obtained by ETAB is approximately 6% less than SAP200 and STAAD. Pro for all the height of staging.

IV. CONCLUSION

After analyzing the staging of different heights with all the three software packages, following conclusions can be withdrawn for the some salient features of design of overhead water tanks:-

A. STAAD Pro. and SAP 2000 provide higher self-weights of staging members than ETABS. Self-weight of staging members were checked manually by calculating volume of concrete used. ETABS automatically deduct overlapped common portion of framing beams into column and results in lower dead weight.

B. Stiffness of staging shown by ETABS was more than shown by both STAAD and SAP 2000. Lesser the stiffness, lesser the time period of oscillations and this will give additional safety proportionate to system.

C. STAAD Pro. and SAP 2000 give almost same results for stiffness and lower stiffness can be selected as better option.

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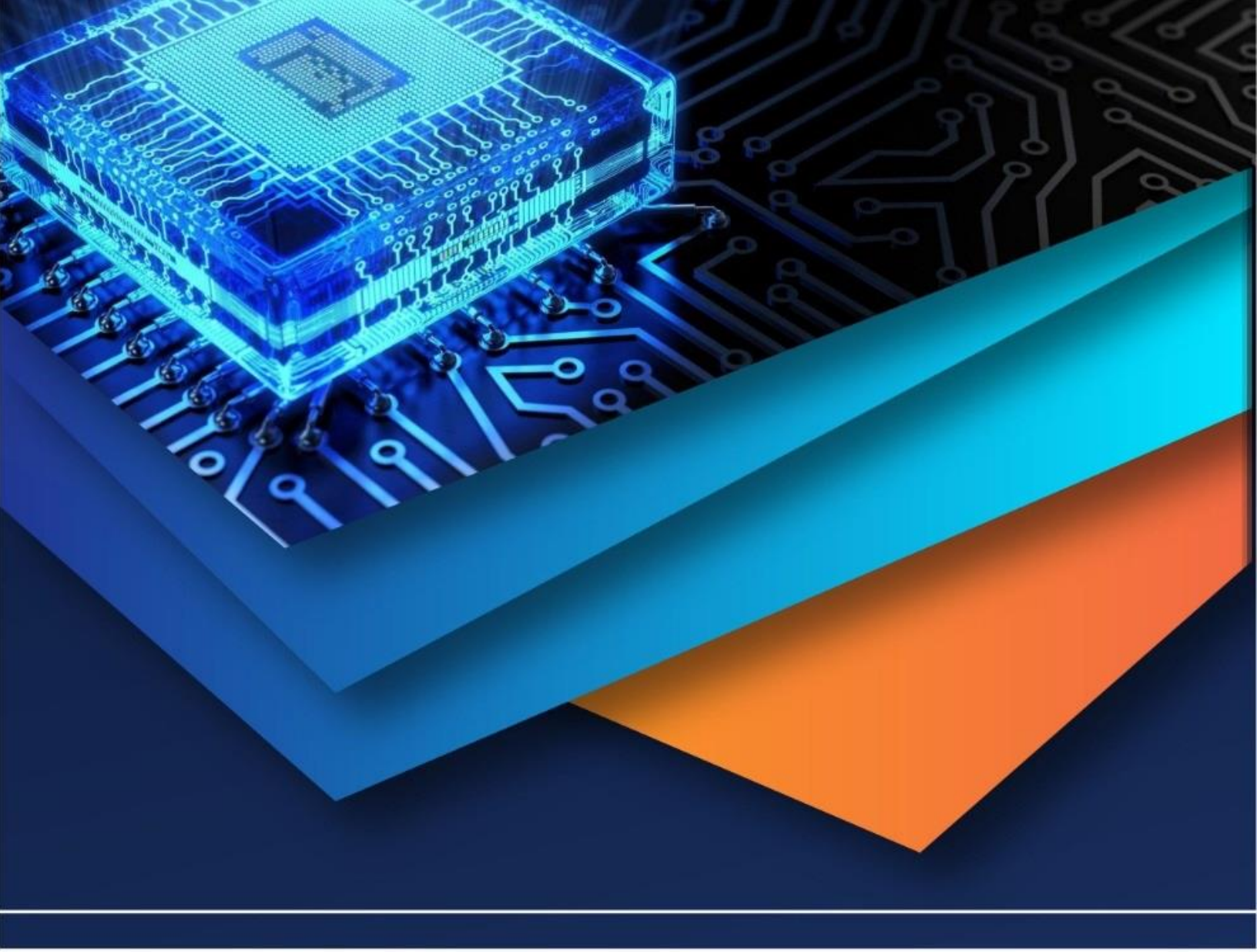

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