VIBRATION CONTROL OF A HIGH RISE REINFORCED CONCRETE FRAMED BUILDING USING ROOF TOP WATER TANKS

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Introduction

Excessive vibration of a high-rise building due to wind effects may lead to a violation of serviceability limit state, with respect to human comfort levels. This paper presents the scenario of forced vibration of a 20 storey high-rise concrete framed building due to three different wind patterns depicting gusts. The resulting vibrations are expected to be controlled by using 3 different configurations of roof top water tanks. The energy transferred to the water will be dissipated by the viscous action of the fluid or by the wave breaking action. The resulting damping action is used to control the vibration of the building. Water tank was simplified into an equivalent mass damper model using two methods: 1- Represent the water tank as an equivalent mass damper with a damping force and stiffness. 2 - Represent the water tank as an equivalent mass damper with lumped masses, damping forces and stiffness in different levels. Analysis was carried out for three different gust patterns (i.e. time history functions with gust die down in a triangular fashion in 3 seconds-Wind Pattern 1, up and down in 6 seconds-Wind Pattern 2 and gradually increase and sharp drop at end in of 3 seconds-Wind Pattern 3) using structural analysis software called SAP2000 (v10).

Methodology

To carry out analysis a reinforced concrete framed building was selected with 20 stories of 3.5 m height and 20 m x 20 m ground plan dimensions with 4 equal bays in each direction, comprising 700 mm × 700 mm columns, 350 mm × 300 mm beams connecting all columns and slab of thickness 150 mm. This 3-D building was lumped into 1-D idealized finite element model with masses lumped in each floor level. The finite element model was formed considering equivalent lateral stiffness of the actual building and an element height equal to the column height (Anil K.Chopra, 2001). Three types of water tanks 10 m × 10 m ×10 m water height 5 m (Tank Type 1), 8 m×8 m×14 m water height 7.8 m (Tank Type 2) and 12.5 m×12.5 m×7.5 m water height 3.2 m (Tank Type 3) of content volume were modelled on top of the existing building model using two methods.

Method 1- Represent the water tank as an equivalent mass damper with a damping force and stiffness (Single Degree of Freedom model) as shown in Fig.1. Parameters such as model mass (m_d), model stiffness (k_d) and model damping coefficient (c_d) were calculated using equations published by Jin-Kyu Yu at el, 1999.

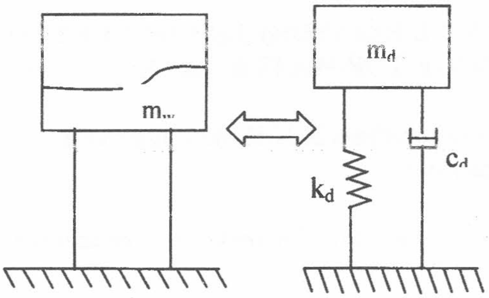

Fig.1. Equivalent mass damper with a damping force and stiffness for water tank

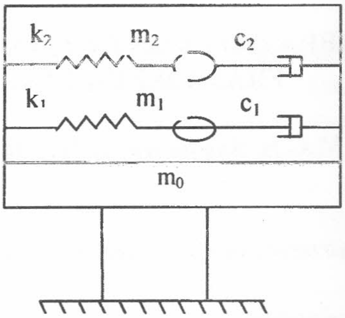

Fig.2. Lumped masses in different levels of water tank

Method 2 - Represent the water tank as an equivalent mass damper with lumped masses, damping forces and stiffness in different levels (Multi Degree of Freedom model) as shown in Fig. 2. In here the water mass was lumped in-to the several equivalent sloshing masses at deferent levels.

Analytical results

First the building was analysed without water tanks and the maximum acceleration was recorded. Subsequently the models were analysed with three different water tanks on the top and percentage reduction of acceleration were calculated. Results after considering two methods of modelling water tanks and 3 gust patterns are summarised in Table 1.

Table 1. Maximum acceleration and percentage reduction of acceleration

Tank types		**Without tank**	**Tank Type 2**		**Tank Type1**		**Tank Type 3**	
Water column depth to tank length ratio			0.975		0.5		0.213	
Modeling Method			1	2	1	2	1	2
Wind pattern 1	Max. acceleration (m/sec^2)	0.569	0.392	0.334	0.364	0.290	0.323	0.223
	Reduction percentage (%)		31.11	41.3	36.03	49.03	43.23	60.81
Wind pattern 2	Max. acceleration (m/sec^2)	0.476	0.233	0.205	0.227	0.193	0.218	0.159
	Reduction percentage (%)		52.31	56.93	51.05	59.45	54.2	66.60
Wind pattern 3	Max. acceleration (m/sec^2)	0.224	0.101	0.094	0.097	0.089	0.095	0.081
	Reduction percentage (%)		54.91	58.04	56.10	60.27	57.59	63.84

Discussion

Damping effects due to roof top water tanks appear to be capable of reducing the acceleration at the top of the building by 31-64%. In case of the building with 10m x 10mx 10m tank, subjected to Wind Pattern 1, the absolute reduction is from 0.569 m/s^2 to 0.334 m/s^2. In other words, by introducing a simple water tank the acceleration of the building can be kept within the human comfort level of 0.5 m/s^2 (Smith and Coull, 1991). When the plan dimensions of the tank is high and the depth of water is low (i.e. water column depth to length ratio 0.213) the damping effect was 60 to 64%. With low plan dimensions and high water depth (i.e. water column depth to length ratio 0.975) the damping effect reduces to 31 to 54%. Variations of maximum and percentage reduction of acceleration with the ratio of depth of water column to length was considered and with increasing this ratio, the effect of Wind Pattern on the maximum acceleration was high as shown in Fig.3. This happened because of shallow tanks were able to dissipate more energy by viscous action of the fluid and the wave breaking action.

Conclusion

Roof top water tanks in high-rise buildings for water storage can be proportioned in such a way to control vibrations in service. Water tanks with large foot print dimensions and low depth of water are more effective in controlling accelerations of buildings to human comfort level.

References

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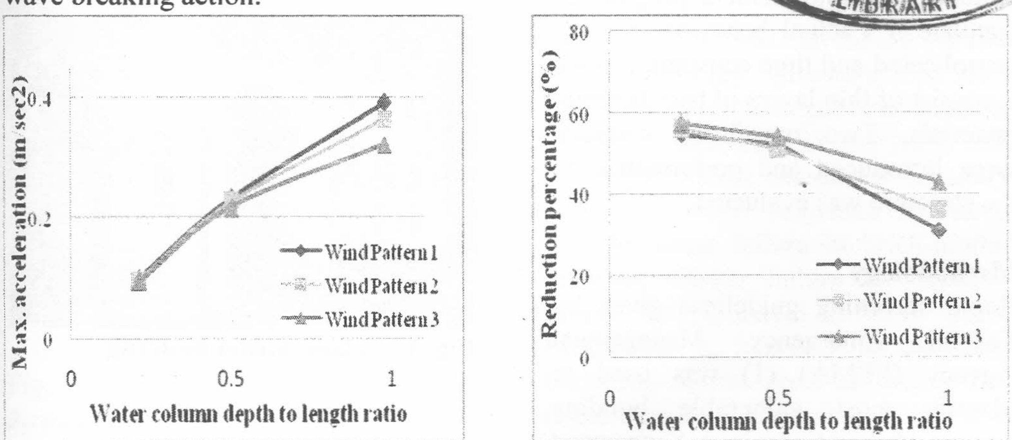

Fig.3. Variation of maximum and percentage reduction of accelerations