Study of Dynamic Behaviour of a Multistoried RCC Structure with Water Tanks as Liquid Dampers

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ABSTRACT:
Sloshing liquid dampers (SLDs), popularly known as tuned liquid dampers (TLDs), are used as passive control devices for reducing structural vibrations resulting from wind and earthquake ex-citations in tall buildings and high-rise structures. In the present investigation, effectiveness of these TLDs has been studied for a building. A twenty-storied building has been considered as a representative of the structure. It is shown that the liquid sloshing is the most important design parameter, rather than, tuning of the fundamental sloshing frequency to the structure frequency for the liquid damper to be effective. Furthermore, the liquid damper design for multistory buildings is different from that for Single Degree Of Freedom (SDOF) structures, where not only the optimal tuning ratio of the liquid damper is different, but multiple dampers located at critical locations are required for effective control of floor accelerations. The investigation is performed using the linear dynamic analysis. Response spectrum method is used for analysis of the structure under dynamic loading. This is very useful tool of earthquake engineering for analyzing the performance of structures and equipment in earth-quakes, since many behave principally as simple oscillators. Thus, if you can find out the natural frequency of the structure, then the peak response of the building can be estimated by reading the value from the ground response spectrum for the appropriate frequency. In most building codes in seismic regions, this value forms the basis for calculating the forces that a structure must be designed to resist. Finally, it is illustrated that TLDs, if appropriately designed, can be very effective in reducing overall forces, moments, base shears, time period and deformation of building structures for earthquake type base excitations.

INTRODUCTION:
Starting from the very beginning of civilization, mankind has faced several threat of extinction due to invasion of severe natural disasters. Earthquake is the most disastrous among them due to its huge power of devastation and total unpredictability. Unlike other natural catastrophes, earthquakes themselves do not kill people, rather the colossal loss of human lives and properties occur due to the destruction of man-made structures. Building structures are one of such creations of mankind, which collapse during severe earthquakes, and cause direct loss of human lives.
Numerous research works have been directed worldwide in last few decades to investigate the cause of failure of different types of buildings under severe seismic excitations. Massive destruction of high-rise as well as low-rise buildings in recent devastating earthquake of Nepal in April, 2015 proves that also in developing counties, such investigation is the need of the hour. Conventionally reinforced concrete tanks have been used extensively in residential and industrial facilities for several decades. The design of these structures is also being given attention considering parameters such as strength requirements and serviceability requirements. Conventional design is followed till date for the design of high rise structures with water tanks. Seismic activity prone countries across the world rely on “codes of practice” to mandate that all the constructions fulfill at least a minimum level of safety requirements against future earthquakes.

The devastation caused by recent earthquakes highlights the necessity of adequate protection in buildings against earthquake damage. One effective way of providing earthquake protection for buildings is the use of external structural control devices. Unfortunately, widespread use of these devices in developing countries is prevented due to the prohibitive additional cost of these devices, relative to the cost of construction of a typical building. Thus, research focus is shifting towards the study of effective and economic control devices for earthquakes.

Seismic Base Isolation:
Seismic base isolation is an old design idea, and has wider applications with mature technology. It is based on the principle of decoupling the structure or part of it, or even of equipment placed in the structure, from the damaging effects of vibrations caused by seismic forces or ground accelerations. Seismic isolation aims: (i) to alter the fundamental frequency of the structure by shifting away from the dominant frequencies of earthquake ground motion (Fig. 1), and (ii) to control the displacement by addition of adequate amount of damping (Fig. 3.2).

Principle underlying seismic isolation may be explained by Figs 1 and 2. Period shift of structure reduces the acceleration transmitted to the isolated structure. In its effective form the structure approaches near stationary state whereas the supporting ground vibrates under excitation (Fig.1). But increase in time period also increases the displacement. The displacement is controlled by inclusion of damping material in isolators such as lead (Fig. 3 & Fig. 4). (iii) The base isolators inserted at founding level or at first floor level filter the horizontal components of the seismic vibrations from soil, which are most dangerous when entering the structure.
Seismic base isolation permits large lateral movement (from 20-40 cm in Italy, even 80 cm in California and Japan) of the structure but quite slowly (typically with periods of 2 s or more), and practically as a rigid body. This makes seismic isolation particularly adequate for the strategic and critically important constructions ensuring their functionality against severe seismic events.

The most commonly used seismic isolation devices are made of rubber called rubber bearings (RBs) as shown in Fig. 3. With, insertion of lead plugs (LRB or PB) or the high damping rubber bearings (HDRB) a damping coefficient more than 10 per cent (Dolce et al. 2005) may be achieved. Thereby the lateral movement is limited to a reasonable value as illustrated in Fig. 4. Important parameter to be considered in the choice of an isolation system, apart from its general ability of shifting the vibration period and adding damping to the structure is its capacity of self-centering, which is accomplished by the RBs and friction pendulums. In the USA a steelteflon recentring sliding system known as Friction Pendulum System (FPS) has been applied alone and performed satisfactorily. The sliding isolation system is based on the concept of sliding friction.

1. The percentage difference in base shear obtained from response spectrum for empty tank and full tank case is 15 percent.

2. The percentage difference in Joint displacements obtained from response spectrum for empty tank and full tank case is 14 percent.

3. The percentage difference in time periods obtained from response spectrum for empty tank and full tank case is 8-9 percent.

4. Based on the results it can be concluded that when water tank sloshing load is analyzed and considered as a TLD in application on the structure against the earthquake load it effectively reduces the overall behavior of the structure resulting in economic and safe design.

5. From this study, it has been found that TLD can successfully be used to control the response of the structure. During the life of the building, if there is no seismic activity, the structure will behave as an elastic system, unaffected by the presence of the dampers.

6. The water tank lies at the roof of the structure, and as they require no extra space they can be used without any problem. Inspection and periodic testing are not required. When there is no seismic activity there is no action in the tank, which can support its design static load indefinitely, so there are no problems of wear or fatigue.
7. Particular water level is to be maintained in the water tank by placing the exit pipe at some elevation which makes sure that required water level for damping is always available.

8. Apparently, TLD is a very attractive proposition for structural response control during a seismic event, but the major limitations hindering the application of TLDs are:

i) The physical phenomenon of water sloshing is not fully understood. Effects of wave breaking in the process of sloshing may be a potential source of analytical and design error; and

ii) Prevalent methods for TLD design involve many approximations, which should be addressed through rigorous analytical and experimental studies.

9)The major advantages which may be attributed to the tuned liquid dampers are:

i) Low initial cost;

ii) Low or no maintenance cost;

iii) Ease of frequency tuning;

iv) No limit for vibration amplitude ;

v) Easy applicability for existing buildings and;

vi) No mass or weight addition to the structure as water required for building purposes may also serve the damping requirement.

REFERENCES:


3. ACI 350 (2001), Seismic Design of Liquid-Containing Concrete Structures (ACI 350.3-01) and Commentary (350.3R-01), ACI, USA.


