Seismic response reduction of RC frame staging in elevated water tank

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Abstract

Elevated water tank with frame staging is mostly used in India and due to its requirement after earthquake it is considered as an important structure. Thus, it is required to control seismic response of tank staging to minimise damages. In this work, effectiveness of Lead rubber bearing (LRB) and X – plate damper (XPD) in seismic response control of staging is investigated. Initially two types of frame staging are considered for same capacity of tank and from nonlinear static analysis best suited staging is identified. After this LRB and XPD are installed separately and to check the effectiveness of these devices nonlinear time history analysis has been performed for four different earthquake records. It is observed that, due to these control devices seismic responses are significantly reduced.

Key words: Elevated water tank; Lead rubber bearing; Time history analysis; Pushover analysis; Frame staging.

1 Introduction

Designing structures to respond elastically when they are subjected to earthquakes are uneconomical, especially in high seismic hazard regions. Because of this, seismic design specifications permit structures to yield under the design basis earthquake. As long as adequate detailing is provided, structures can be designed for force levels much lower than would be required for the elastic response.

Conventional earthquake resistant structures rely on inelastic behavior in designated components of the structures. For special moment frames, where high ductility demands are expected, inelastic behavior or damage should be sustained in the beams away from the column faces and in the beam column connections. Energy dissipation (inelastic response) is a result of structural damage (yielding), which is sometimes very difficult and expensive to repair. In addition, if the location of the energy dissipation in the structure isn't predicted accurately, and if the damage occurs in the gravity load system, the structures may collapse

Structures should be able to maintain several cycles of inelastic deformation without significant loss of strength during earthquakes. A reasonable amount of stiffness loss can be accommodated during the inelastic deformation, and the performance of the structure can be evaluated by reviewing the energy dissipation at each cycle of loading.
A variety of methods are available to deal with huge earthquake forces. Among these methods, isolating the structure from the ground, providing passive energy dissipation systems, and controlling the inelastic response of the structure are the most effective and commonly used.

Seismic isolation for tank is effective in reducing seismic response of elevated water tanks [1]. Panchal and Jangid [2] investigated seismic response of liquid tanks with variable friction isolator and results show this isolation is very effective in reducing seismic response. Shekari et al. [3] investigated isolated tank for long period earthquakes which shows significant reduction in response parameters as compared to fixed base tank. Friction pendulum isolator is more efficient for slender tank [4] and isolator parameters also affects the response of tank. Soni et al [5] investigated the behaviour of liquid storage slender and broad tanks isolated by the double variable frequency pendulum isolator. Seleemah and Sharkawy [6] investigated the seismic responses of base-isolated broad and slender cylindrical liquid storage ground tanks by using three types of isolation systems. Panchal and Jangid [7] using Variable Frequency Pendulum Isolator The seismic response of liquid storage steel tanks was studied.

The present study is divided into two phases, in the first phase seismic performance evaluation of two different tank staging is done for same tank capacity and compared the nonlinear static performance. In second phase, the seismic response of staging for nonlinear dynamic analysis is the study. This nonlinear time history analysis is performed for two real ground motions in SAP2000 [8]. From previous study it is observed that passive dampers are not studied for tanks. Thus, base isolation (laminated rubber bearing) and passive device (metallic dampers) are used respectively. These protective systems significantly reduced the seismic response of structure which makes safe response of conditions of staging.

2 X-Plate Damper (XPD)

An XPD is a device that is capable of sustaining many cycles of stable yielding deformation resulting in a high level of energy dissipation or damping. Its energy dissipation depends primarily on relative displacement within the device and not on the relative velocities. It consists of an assembly that holds either single or multiple components of 'X' shape plates, the number of plate depends on the requisite of system to dissipate the external input seismic energy. The use of such device was first proposed by Kelly et al. [9], they performed a series of experimental tests on structures and his work was extended by Skinner et al. [10] and Tyler An X-plate damper device has been studied via experiments by Bergman and Goel [12] and Whittaker [13-14], subsequently employed in seismic retrofitting projects discussed by Matinez-Romero [15] and Perry et al. [16]. A typical XPD with holding device used in the present work as shown in Figure 1

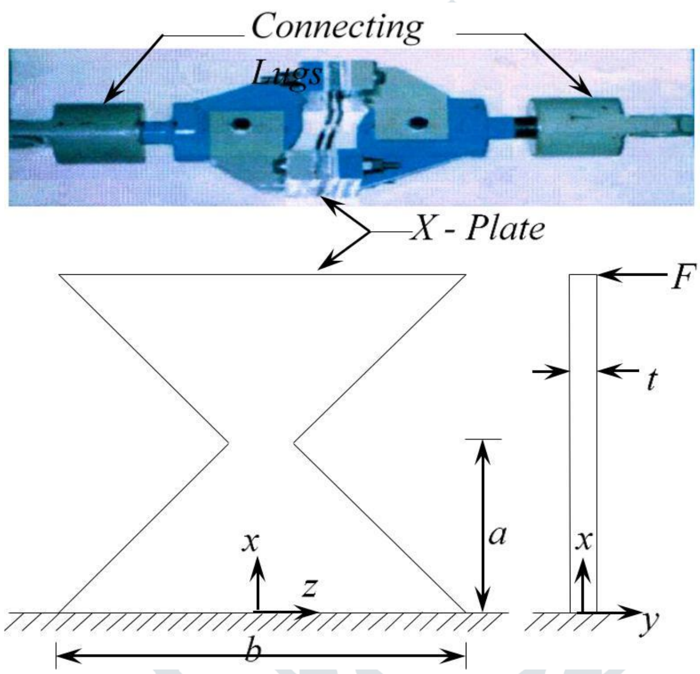

Figure 1 Typical XPD with holding devices [17]

Using beam theory, the properties of XPD are expressed in equation (1) to (3),

□ *bt*
2
y
F □ *n*
y
6*a*

(1)

- □ 2□ *y a* 2 *Et*

(02)

F
y
K □
d
q

(03)

*Ebt*3

K d 12*a*3 *n*

3 Lead Rubber Bearing Isolation

The LRB system was invented in New Zealand in 1975 and developed as an elastomeric-based system. Later, it was widely used in developed countries such as Japan and the USA. The working principle of this system is similar to the laminated rubber bearing system. The systems differ because a cylindrical lead core is placed in the middle of the LRB system to provide additional rigidity to the system (Figure 2). The lead core increases the energy absorption capacity of the system; therefore, the lateral stiffness is potentially increased against strong ground motions. Consequently, the main aim of the lead addition is to increase both the stiffness at relatively low horizontal force levels and the energy dissipation capacity.

The characteristics of the lead material have been considered in the production of LRB systems. In general, lead has a low yield point when its shear stress reaches 10 Mpa, and it exhibits elasto-plastic behavior. Lead is also resistant to repeated loads and can renew itself over time following deformation, Komur [18].

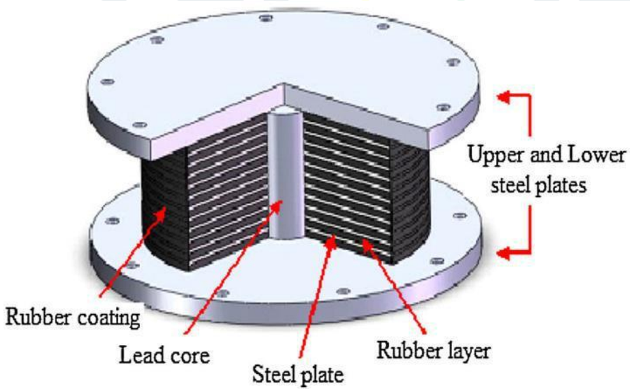

Figure 2. Lead rubber bearing isolator

4 Details of tank model

In this work elevated tank of capacity 250 m3 with two different staging is considered. The configuration of frame staging is shown in Figure 3. The tank frame staging is considered as special moment resistance frame with response reduction factor R = 4. Seismic forces are calculated according to IS 1893 Part 2 (2014) [19] and designed. Concrete grade of M30 and steel grade of Fe415 are used in design. Initially the sizes of column, top beam and brace based on IS 1893 Part 2 (2014) 450 x 450 mm, 300 x 600 mm and 300 x 450 mm is used respectively. All the sections are designed as per IS 456 (2000)