00674-EM
7th International Conference on Seismology & Earthquake Engineering
18-21 May 2015

EXPERIMENTAL EVALUATION OF CODE PROVISIONS FOR HYDRODYNAMIC WALL PRESSURE OF A RECTANGULAR STORAGE TANK

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Keywords: Liquid Storage Tanks, Wall Pressure, Experimental Results, ACI-350 Code Results

One of the most important key factors in designing liquid storage tanks is the design of wall thickness to provide sufficient resistance and rigidity against critical loads. The hydrodynamic pressure on tank wall shells is the key factor in determination of a tank wall thickness.

In this paper, a wall pressure comparison has been carried out between experimental tests results and values suggested by the ACI-350 code. This comparison could lead to a better understanding of ACI code provisions in this regard.

In order to compare the seismic wall pressure obtained from tests results and ACI-350 code, a series of shaking table tests have been conducted at International Institute of Earthquake Engineering and Seismology. The chosen records are Tabas (PGA=0.66g), Chichi (PGA=0.34g) and Kobe (PGA=0.6g). The dimensions of rectangular tank are $100\times100\times30$ (height $\times$ length $\times$ width). The tank comprises of plexiglass with a thickness of 1cm. The pressure transducer is placed at 13 cm from the base. Figure 1 shows the tank where it is excited by Kobe earthquake.

Figure 1. Rectangular storage tank under seismic excitation

In order to calculate hydrodynamic pressures, ACI code generally divides the contained liquid in to two separate parts: a) Hydrodynamic impulsive pressure P_i from the contained liquid and b) Hydrodynamic convective pressure P_c from the contained liquid. The dynamic lateral forces above the base shall be determined as follows:

$$P_i = ZSIC_i \times \frac{W_i}{R_{wi}} \quad (1) \quad , \quad P_c = ZSIC_c \times \frac{W_c}{R_{wc}} \quad (2)$$

W_i and W_c are the impulsive and convective component of the liquid mass, respectively. Factor Z represents the maximum effective peak ground acceleration for the site, while C is a period-dependant spectral-amplification factor. In equation 1 and 2 factor C is represented by C_i and C_c , corresponding to the responses of the impulsive and convective, respectively. R_{wi} and R_{wc} are response modification factors which reduce the elastic response spectrum to account for the structure's ductility, energy-dissipating properties and redundancy.

P_{iy} is the lateral impulsive force due to equivalent mass of the impulsive component and P_{cy} is lateral convective force due to equivalent mass of the convective componant of the stored liquid, which are represented as follows:

$$P_{iy} = \frac{\frac{P_i}{2}(4H_L - 6h_i - (6H_L - 12h_i) \times (\frac{y}{H_L}))}{H_L^2} \quad (3), \qquad P_{cy} = \frac{\frac{P_c}{2}(4H_L - 6h_c - (6H_L - 12h_c) \times (\frac{y}{H_L}))}{H_L^2} \quad (4)$$

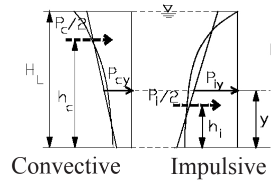

Figure 2. Vertical force distribution in a rectangular tank suggested by ACI code

The factor H_L is design depth of stored liquid. H_i and h_c are heights above the base of the wall to the center of gravity of the impulsive and convective lateral force, respectively (Figure 2) which are calculated from the Equations 5 and 6:

$$\text{For tanks with } \frac{L}{H_L} \prec 1.333 \rightarrow h_i = (0.5 - 0.09375(\frac{L}{H_L})) \times H_L \quad (5\text{-}1)$$

$$\text{For tanks with } \frac{L}{H_L} \succ 1.333 \rightarrow h_i = 0.375 \times H_L \quad (5\text{-}2)$$

$$\text{For all tanks} \quad h_c = (1 - \frac{\cosh(3.16(H_L/L)) - 1}{3.16(H_L/L)\sinh(3.16(H_L/L))}) \times H_L \quad (6)$$

Therefore, the horizontal distribution of the dynamic pressures across the wall width B is:

$$p_{iy} = \frac{P_{iy}}{B} \quad \text{and} \quad p_{cy} = \frac{P_{cy}}{B} \quad (7)$$

The hydrodynamic pressure at any given heights y from the base shall be determined by the following equation:

$$p_y = \sqrt{p_{iy}^2 + p_{cy}^2} \quad (8)$$

As it's shown in Figure 3, we could deduce the ACI code in case of lesser h/a (a=Length/2) have closer wall pressure response versus the experimental results, but according to the fact that higher liquid level leads to more pressure in convective part, pressure distribution will vary and deviate from the code values. It also has to be noticed that if the earthquakes have been set due to ACI code spectrum, the response will probably have more equality to ones in experimental results.

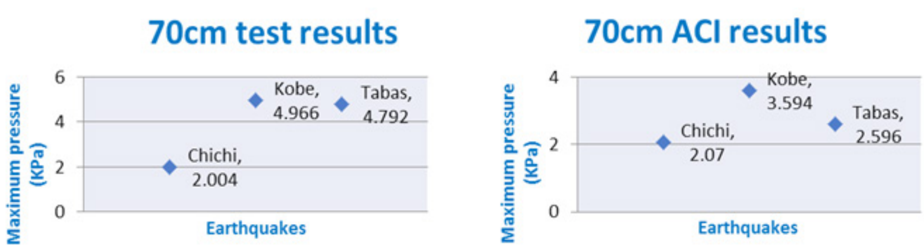

Figure 3. Comparison of maximum wall pressure between tests results and ACI code for H_w= 70cm

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