



## Effect of Selecting Seismic Coefficients on Performance of Block Gravity Quay Walls

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**ABSTRACT:** In this paper, the effect of selecting the earthquake equivalent acceleration coefficient on the seismic performance of the broken-back quay wall of Pars Petrochemical Port has been studied as a case study. In this regard, the recommendations and relationships presented in the old and new editions of the Japanese Maritime Codes (OCDI, 2002, 2009) are more comprehensive and complete than other codes, especially in the seismic design of quay wall structures. The results illustrated that the proposed relationships of horizontal earthquake acceleration coefficient ( $k_h$ ) based on the new version of the Japanese maritime code are more suitable and help predict the seismic performance of this type of quay walls more accurately and their realistic design. Moreover, based on acceleration time-histories resulting from seismic hazard studies at the site, using FLAC2D software, the values of horizontal displacement of the quay wall have been investigated, and based on that, earthquake coefficient values have been predicted for each relevant time-history.

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### 1- Introduction

The pseudo-static method is the most common design method based on seismic performance due to its simplicity and extensive application in design. In this method, the force caused by the earthquake is taken into account as coefficients of acceleration equivalent horizontally ( $k_h$ ) and vertical ( $k_v$ ) in the effective mass of the structure. In this regard, the Japan Maritime Code (OCDI) is one of the most common seismic design codes for marine structures.

According to the old version (2002), Equations 1 and 2 are proposed to determine the horizontal acceleration coefficient of an earthquake based on the maximum ground earthquake acceleration.

$$k_h = \frac{a_{\max}}{g} \quad a_{\max} \leq 200 \quad (1)$$

$$\left(1Gal = 1 \frac{cm}{s^2}\right)$$

$$k_h = \frac{1}{3} \left(\frac{a_{\max}}{g}\right)^{\frac{1}{3}} \quad a_{\max} > 200 \quad (2)$$

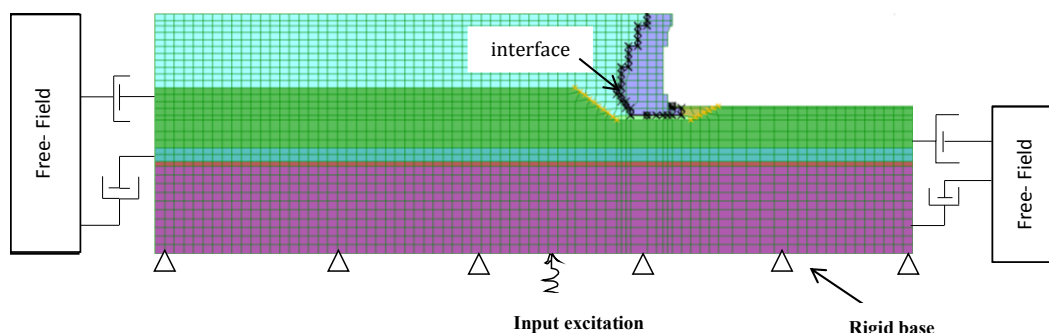
Moreover, the new version of OCDI, 2009 proposes Equation 3:

$$K_h = 1.78 \left( \left( \frac{D_a}{D_r} \right)^{-0.55} \right) \frac{\alpha_c}{g} + 0.04 \quad (3)$$

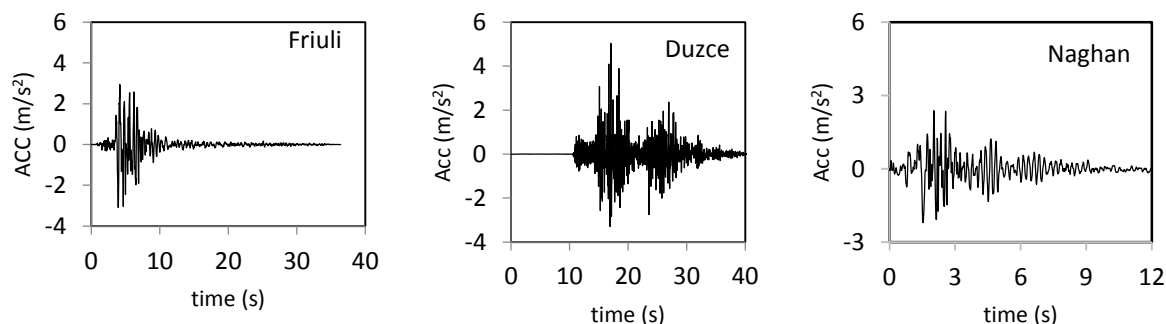
where,  $k_h$  horizontal coefficient acceleration,  $a_{\max}$ : maximum horizontal acceleration of earthquake at the ground level (Gal),  $D_a$ : allowable displacement above the wall in the range of 5 to 20 cm (recommendation equal to 10 cm),  $D_r$ : standard displacement (equal to 10 cm),  $\alpha_c$ : maximum corrected acceleration ( $cm/s^2$ ) and  $g$ : gravitational acceleration ( $980 cm/s^2$ ). It should be noted that the value of  $k_h$  obtained from Eq. 3 should not be less than 0.05. Besides, the above method is specified for the conditions of non-occurrence of liquefaction. Therefore, the purpose of this research is to investigate the effect of selecting the horizontal earthquake coefficient acceleration ( $k_h$ ) for gravity walls according to the approach of the two old and new editions of the Japanese Maritime Code [1, 2] based on a case study the gravity block quay wall with a broken-back cross-section in Pars Petrochemical Port.

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**Fig. 1. Numerical modeling using FLAC2D software**



**Fig. 2. Input motions for seismic level 1 (PGA=0.23g) [3]**

## 2- Numerical modeling

The aim of performing dynamic analysis using FLAC2D finite difference software is to determine the horizontal displacement above the quay wall and its coherence with the relations and allowable value of the new version of the Japanese code [2] to calculate the horizontal acceleration coefficient ( $k_h$ ). The height of the broken-back quay wall is 22 meters, and its bottom block width is 11.25 meters (Figure 1). The concrete blocks based on elastic behavior are modeled. Besides, the Mohr-Columb model with hysteretic damping is taken into account for soil behavior. The interface friction angle between the wall and gravelly bed materials is 40 degrees, and also between the backfill and quay wall is 15 degrees. Moreover, the applied input motions have been illustrated in Figure 2 based on the seismic level 1 (PGA=0.23g) obtained from the seismic hazard study [3].

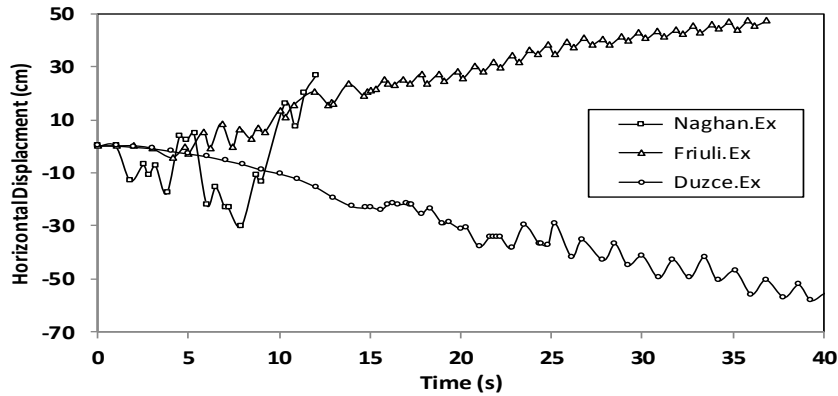
## 3- Results and Discussion

According to the new version of the Japanese Maritime

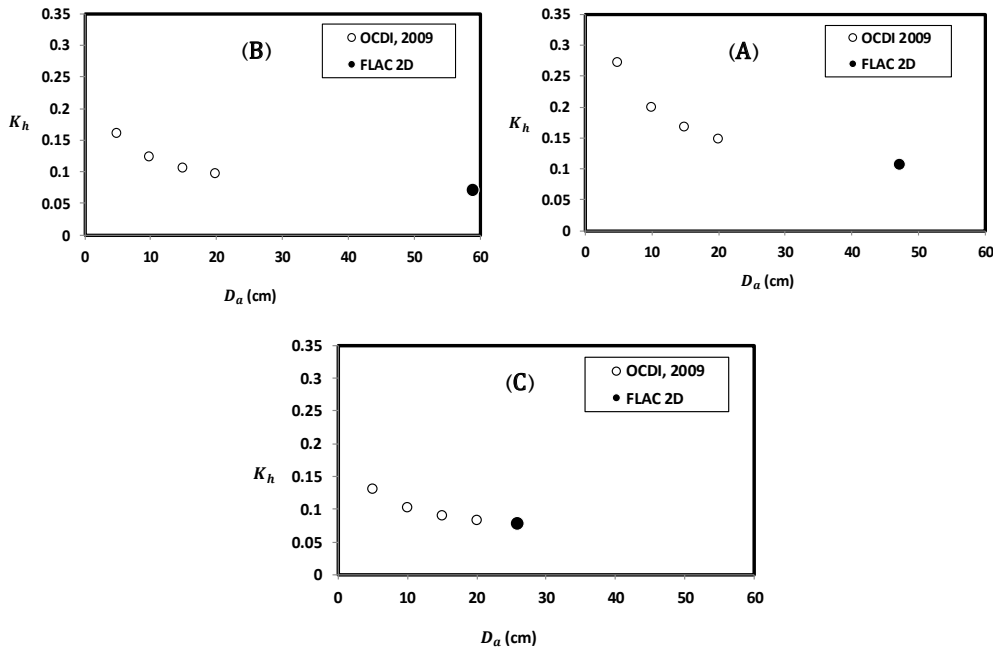
Code, the allowable horizontal displacement above the gravity quay walls is 5 to 20 cm (10 cm is recommended). However, these obtained values based on dynamic analysis results are greater than mentioned recommendation which this matter is shown in Figure 3. Hence, using Eq. 3, the coefficient  $k_h$  is calculated, and the results are provided in Figure 4.

## 4- Conclusion

The obtained results illustrated that values of  $k_h$  coefficient are different from the relations between the old and new editions of the Japanese marine code. The value of  $k_h$  coefficient based on the old edition (Eq. 2) for all three earthquakes (Friuli, Nagan, and Duzce), regardless of their characteristics, were predicted to 0.163. Moreover, this coefficient based on the new edition (Eq. 3) for each ground motion is completely different according to the relevant characteristics and for Friuli, Duzce, and Nagan events were calculated to equal 0.199, 0.123, 0.10, respectively. Besides, the broken-back quay wall was analyzed using FLAC2D finite



**Fig. 3. Horizontal displacement above the quay wall resulting from dynamic analysis based on selected earthquakes**



**Fig. 4. Coefficients of  $k_h$  obtained for the quay wall of the Petrochemical Port based on Eq. 3 and horizontal displacement ( $D_a$ ) (A - Friuli, B - Duzce, C - Nagan)**

difference software, and then the horizontal displacement of the upper level of the wall ( $D_a$ ) based on three ground motions was obtained. The resulting  $k_h$  coefficient for the acceleration time-histories of Friuli, Duzce, and Nagan is 0.108, 0.07, and 0.076, respectively. These results illustrate that the  $k_h$  coefficient obtained from the dynamic analysis is lower than the pseudo-static method according to the new edition of the Japanese code, which indicates that the latest edition of the Japanese Maritime Code [2] is conservative in comparison with its previous edition [1].

**References**

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