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Seismic Analysis of Single Unit Tunnel Form Building Subjected to Out-of-Plane Lateral Cyclic Loading Using Ruaumoko 2D Programme

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Abstract. To date, frequent seismic events are seen to cause major destruction to the countries that are hit by great Earthquake with magnitude greater than 7 Scale Richter. These kinds of disasters are unpredicted and may give negative impacts for structures and human. However, the consequences of seismic can be mitigated by characterizing the hazard that might be affecting the existing structures. Therefore, the performance of tunnel form building (TFB) has been examined under various level of earthquake events. Ten numbers of ground motions are selected based on previous earthquake records to determine the level of safety of single unit tunnel form building (TFB). Four previous earthquake records are selected from countries outside of Malaysia, while the other six previous earthquake records are selected from East and West Malaysia. The prototype building has then been modelled and analysed to obtain the maximum lateral displacement and lateral loading capacity to assess the structural deformation of the TFB at peak ground acceleration for selected past earthquake history. From this analysis, the safety level of TFB under selected ten past earthquake records are investigated. It can be concluded that this type of building survives under local earthquakes but experienced severe damage or collapse under major earthquakes deriving from countries outside of Malaysia.

1. Introduction

Tunnel form building (TFB) system is an industrialized construction technique, in which structural walls and slabs of the building are cast in one operation using steel forms having accurate dimensions and plain surfaces. Tunnel form buildings are built in different way from the other conventional reinforced concrete structures, whereby there are no beams and columns used in this type of building. The minor of non-structural failure of tunnel form buildings were recorded during Izmit Earthquake in 1999 and Bingol Earthquake in 2003 [1]. Meanwhile, 7.4 magnitude of Kocaeli Earthquake and 7.1 Magnitude of Duzce in 1999, indicated similar damage pattern to tunnel form building [2]. Moreover, in Romania similar behaviour seems to be recorded due to 1977, 1986 and 1990 earthquakes [3].

Since 1960, tunnel form building (TFB) have been utilized in multi-story building for residential purposed such as hotel, apartment and condominium. Most of the construction methods utilize BS8110 design standard which does not comply to the seismic load. Normally, high rise buildings in Malaysia were constructed using TFB. Damages of high-rise buildings basically depend on seismic waves period where longer seismic wave will produce large sideway motion which will cause the structure to collapse. Previous studies showed that high-rise buildings in Malaysia experienced sway motion mechanism due to several earthquake from neighbouring countries such as Indonesia with ranging magnitude from 3 to 8 scales Richter. Therefore, the existing buildings in Malaysia are no longer safe from earthquake disaster's consequent if earthquake greater than 5 magnitude of scale



Richter strike in future. Therefore, this study aims to examine and predict the behaviour of TFB under earthquake in Malaysia using past earthquake records.

2. Methodology

The HYSTERES program is used to model the hysteresis loops based on the data obtained from the experimental work. The initial selection shape of the hysteresis rule model in Ruaumoko 2D program depends on the shape of experimental hysteresis loops which had been conducted in the laboratory. Out of 63 numbers of hysteresis loops model, Pampanin Hysteresis with reloading slip factor rule model (IHYST= 44) was selected as the most fitted to represent the experimental hysteresis loops. The hysteresis loops from the model are superimposed to the experimental hysteresis loops in order to compare its behaviour subjected to out-of-plane lateral cyclic loading. Comparison was made in term of seismic parameters such as lateral load, lateral displacement, stiffness, ductility, and equivalent viscous damping (EVD) between experimental and modelling of hysteresis loops which is represented in terms of percentage difference.

In this study, Ruaumoko program has been used to model the seismic behaviour of single unit three-storey tunnel form building which had been constructed in Malaysia. The results obtained from Ruaumoko program can be used to determine the mode shape, hysteresis loops, moment-rotation, damage indices and energy absorption. The Dynaplot Program was also used to generate the hysteresis loops for each node in the prototype building. The output file from Dynaplot contains elastic response spectra for 0.0 %, 2%, 5%, 10% and 20% damping. Dynaplot program is used to obtain the maximum lateral load for pushing and pulling directions for each of the selected past earthquake records in order to assess the structural deformation of the TFB at peak ground acceleration under selected past earthquake records.

3. Results and discussion

3.1. Hysteresis Loops

Hysteresis program is used to model the hysteresis loop based on the data obtained from the experimental work. Pampanin Hysteresis loops with reloading slip factor was selected because it exhibited similar behaviour with the experimental hysteresis loops. Figure 1 shows the comparison between the hysteresis loops and the experimental data. The blue color represents the experiment result while the red colour represents the modelling result. Modelling hysteresis loops seem to have a similar pattern with experimental hysteresis loops. From hysteresis loops, four parameters can be calculated and compared. The lateral strength capacity, stiffness, ductility and equivalent viscous damping of single unit tunnel form buildings can be obtained from hysteresis loops. The experimental drift has the same symmetrical shape and the comparison was made based on the ultimate drift which is obtained at 1.75% drift.

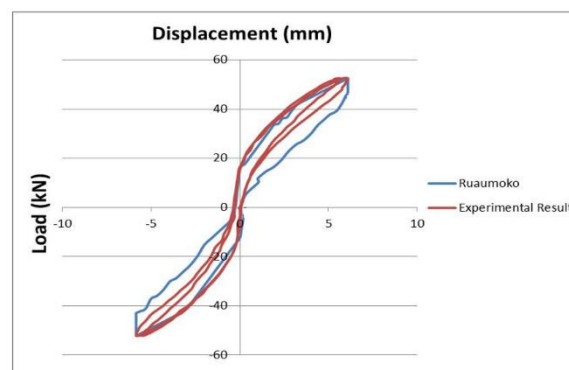


Figure 1. Comparison of hysteresis loops between experimental and modelling

The percentage different of lateral strength obtained from hysteresis loops between experiment and modelling is 1.2%. Meanwhile, the percentage different for lateral displacement is recorded as 0.16%. From experimental data, the highest lateral load and displacement is 6.09 kN and 52.33 mm, respectively. Meanwhile, the highest lateral load and displacement obtained from modelling is 6.10 kN and 51.7 mm, respectively. Meaning that, this model can be utilized to analyse the various stories of tunnel form building.

3.2. Lateral capacity of single unit TFB subjected to multilevel of seismic events

The survivability of tunnel form building under multilevel seismic events can be obtained by applying great, major, strong, moderate, light, minor and very minor past earthquake records using Ruaumoko 2D programme. The survivability of TFB under these ten past earthquakes was investigated as indicated in figure 2. Tunnel form building survive under local earthquakes but experience severe damage or collapse under major earthquakes deriving from countries outside of Malaysia. Local seismic events ranging below 5 Scale Richter classified as moderate, light, minor and very minor known as Tawau, Sebuyau, Kunak, Batu Niah, Kundasang and Bukit Tinggi Earthquake. Meanwhile, another 4 earthquake events known as Mexico, El-Centro and Pacoima Dam Earthquake with magnitude greater than 5 Scale Richter.

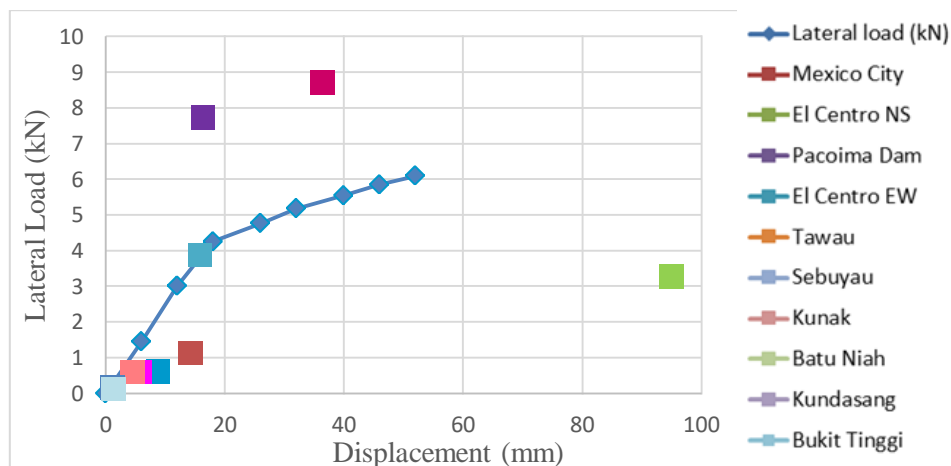


Figure 2. Lateral capacity of single unit tunnel form building subjected to 10 past earthquake records.

3.3. Mode shape of tunnel form building

Mode shape is a specific pattern of vibration executed by a mechanical system at a specific frequency under earthquake excitations. Different frequencies, lateral load and moments will be produced different mode shapes. In this study, there are two mode shapes of the tunnel form building after running Ruaumoko-2D program. Figure 3 (a) shows the first mode shape of the prototype building under Mexico City earthquake records. Mode shape 1 occurs when lateral displacement is sway in one direction either to the left or right of the structure under ground motion. Usually, the maximum lateral deflection occurs at the top of the building for the first mode shape. Figure 3 (b) shows the second mode shape of the tunnel form building under Mexico City earthquake records. Meanwhile, the second mode shape with lateral deflection sways in both directions and the maximum lateral deflection is expected to occur at the second storey of tunnel form building. Mexico City Earthquake was selected because it is classified as the largest magnitude among ten selected past earthquake records.

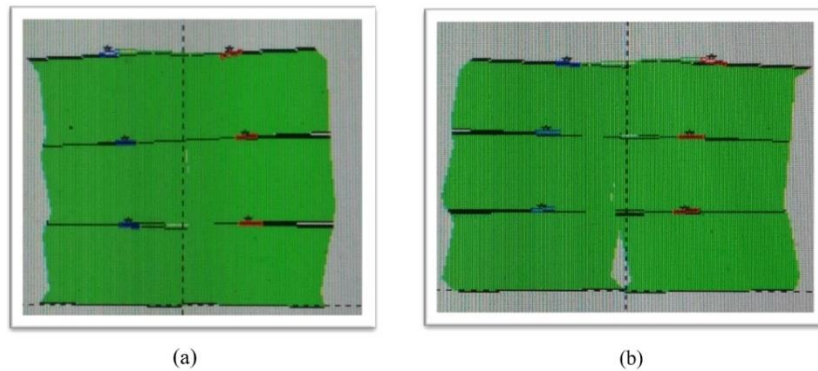


Figure 3. (a) Mode shape 1 and (b) mode shape 2

4. Conclusion

All the input data from the modelling analysis was executed using Ruaumoko 2D under ten actual earthquake records in order to investigate the dynamic behaviour of tunnel form building (TFB). The selected ten past ground motion records are to represent the great, major, strong, moderate, light, minor and very minor earthquake events that occurred around the world and in Malaysia. The applications of these real earthquakes to the tunnel form building gave the actual seismic capacity and dynamic behaviour of the real structure.

Dynaplot program was used in order to detect the yielding point of the prototype specimen subjected to each of these ten past earthquake records. From the dynamic analysis, this specimen seems to survive under local earthquake events with magnitude less than 5 Scale Richter. However, this type of building is not safe under earthquake occurred outside Malaysia with magnitude ranging from 6 to 8 Scale Richter.

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