Modeling of Single Bay Precast Residential House Using Ruaumoko 2D Program

N. H. Hamid, N. M. Mohamed, S. A. Anuar

***Abstract*—**Precast residential houses are normally constructed in Malaysia using precast shear-key wall panel and this panel is designed using BS8110 where there is no provision for earthquake. However, the safety of this house under moderate and strong earthquake is still questionable. Consequently, the full-scale of residential house are designed, constructed, tested and analyzed under in-plane lateral quasi-static cyclic loading. Hysteresis loops are plotted based on the experimental work and compared with modeling of hysteresis loops using HYSTERES in RUAUMOKO 2D program. Modified Takeda hysteresis model is chosen to behave a similar pattern with experimental work. This program will display the earthquake excitations, spectral displacements, pseudo spectral acceleration, mode shape and deformation of the structure. It can be concluded that this building is suffering severe cracks and damage under moderate and severe earthquake**.**

***Keywords*—**Deformation shape, hysteresis loops, precast shear-key, spectral displacement.

I. Introduction

MALAYSIA is located close to the two most seismically active plate boundaries known as the inter-plate boundaries between the Indo-Australian and Eurasian plate on the west. Most of the buildings in Malaysia were designed according to BS 8110 where there is no provision for earthquakes. The safety of the precast building is still questionable until research is conducted to verify their safety. Poor performance of precast shear-key wall was observed during experimental work with ductility less than 3 [1]. Further analysis on seismic assessment of this building using fragility curve showed that it cannot survive under moderate or severe earthquake [2]. Moreover, the overall seismic performance of full-scale single bay precast residential were designed, constructed and tested under in-plane lateral cyclic loading is with low lateral strength, stiffness and ductility [3].In order to get the global behavior of actual full scale of structures such as precast hollow core wall for warehouse [4], beam-column joint [5], tunnel form building [6] and turbine-generator [7] using Ruaumoko 2D program can be obtained under several selected earthquake records. Therefore, the intention of this paper is to model the hysteresis loops of two-storey residential house using HYSTERES program and compare with the experimental results. After that, the modeling of two-storey precast residential house using Ruaumoko 2D is fully utilized for determination of overall global behavior.

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II. Takeda with Slip Hysteresis Model

HYSTERES program is used to model the hysteresis loop based on the data obtained from the experimental work. The Modified Takeda with Slip Hysteresis Model is chosen to behave a similar pattern with the experimental hysteresis loops as shown in Fig. 1. The recommended values for two parameters are $\beta = 3.706$ and $\alpha = 2.34$.

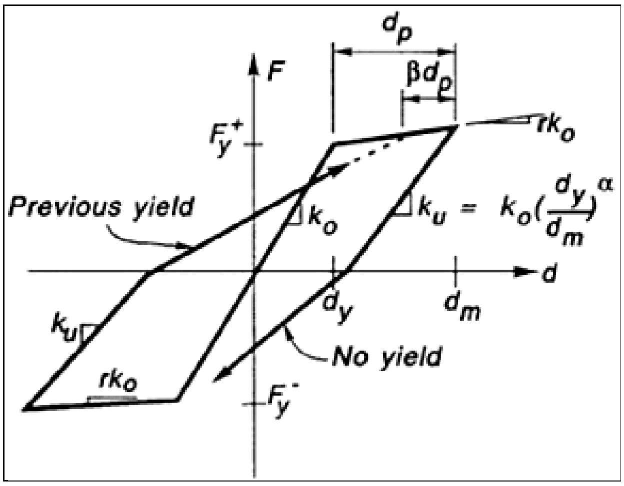


Fig. 1 Modified Takeda Hysteresis Model [8]

The prototype of a full-scale double storey precast single bay building is modeled using the RUAUMOKO 2D program and run under three different earthquake records. The structure is assumed to act as a rigid-moment resisting RC-frame with a monolithic connections system. Beam-column connections are assumed to be rigid at beam-column interface and column-foundation interface. The connection between the beam-column and column-foundation is represented by the nodes and the beam, the column, and wall are assigned as elements.

Fig. 2 shows the numbering system used for two-storey precast building structure for nodes and elements. A total number of six nodes and six elements were identified under finite element method. The loading induced by an earthquake propagated at ground level has caused the structure to experience the highest deformation/deflection shape at the top of the structure. Nodes 1 and 2 are represented as fix-end moment with restrain in x and y direction. The analysis and deformation shape of the double storey house under three selected earthquakes are discussed in the following section.

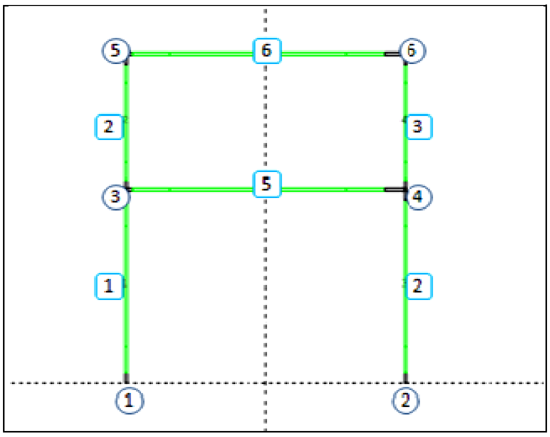


Fig. 2 There is 6 nodes and 6 elements for the building

III. Analysis of Results

A. Validation of Hysteresis Loops between the Experimental and the Model Results

It is important to validate the behaviour of hysteresis loops between the experimental work and the Takeda with Slip Model before running the two storey precast building under three different earthquakes excitations. Fig. 3 shows the comparison between the experimental hysteresis loops and the modeling hysteresis loops. The modeling hysteresis loops show a similar pattern to the experimental hysteresis loops. The parameters of hysteresis modeling will be used to model the overall global behaviour precast shear-key precast two-storey residential house. Table I shows the percentage differences between the experimental results and the modeling for maximum lateral strength, stiffness and ductility of the two-storey precast building. The percentage difference of the maximum lateral strength between the modeling and the experiment is 9.98%, the stiffness is 61% and the ductility is 21.6%.

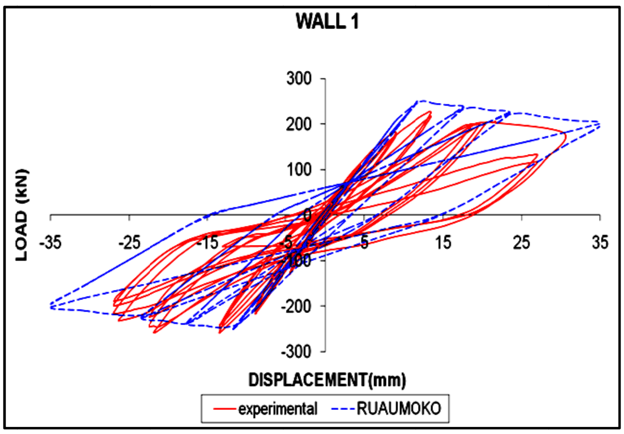


Fig. 3 Comparison of Hysteresis Loops between Experimental and Modeling Results

TABLE I
COMPARISON OF LATERAL STRENGTH, STIFFNESS AND DUCTILITY BETWEEN THE EXPERIMENT AND MODELING

	Experiment	Modeling	Percentage Difference
Lateral Strength	274.96kN	250kN	9.98%
Stiffness	5.19kN/mm	13.31kN/mm	61%
Ductility	1.67%	2.13%	21.6%

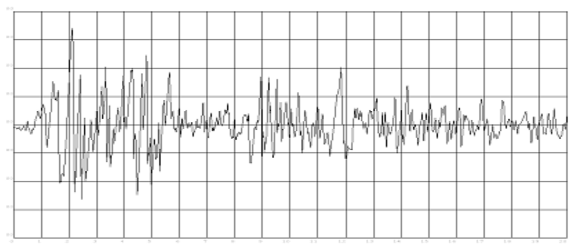
B. Three Selected Past Earthquake Records

The control parameters for earthquake accelerograms, displacement time-history or loading time-history in the RUAUMOKO 2D program were based on excitation in BERG Format and NCEER Format database. Three earthquake excitation records were chosen to run the modeling of the two-storey precast shear key residential house. These three earthquakes data are chosen because Malaysia does not have any established database on recent earthquakes in Malaysia or the local effects of earthquakes in the surrounding regions. With regard to this matter, three past earthquakes time-history records have been selected for the purpose of this modeling. The characteristics of the selected three past earthquake records are presented in Table II.

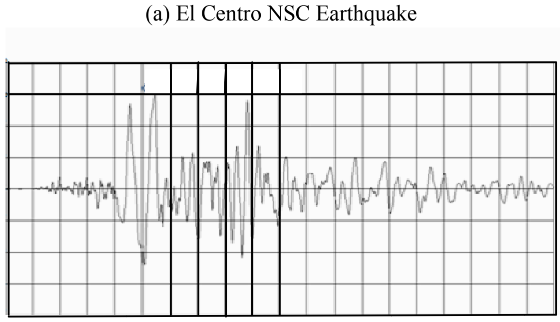
TABLE II
CHARACTERISTICS OF THREE PAST EARTHQUAKE RECORDS

Magnitude	PGA	Duration	Depth	Location
7.1	0.348g	32 sec	6 km	El Centro NSC
6.9	0.8g	20 sec	16km	South Coast Western Honshu
6.6	1.170g	60 sec	8.4km	Pacoima Dam

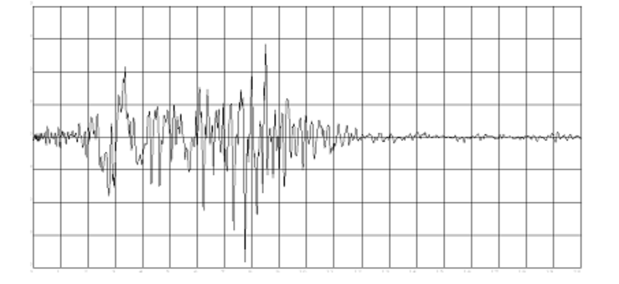
Earthquake Excitation



(a) El Centro NSC Earthquake



(b) Kobe Earthquake

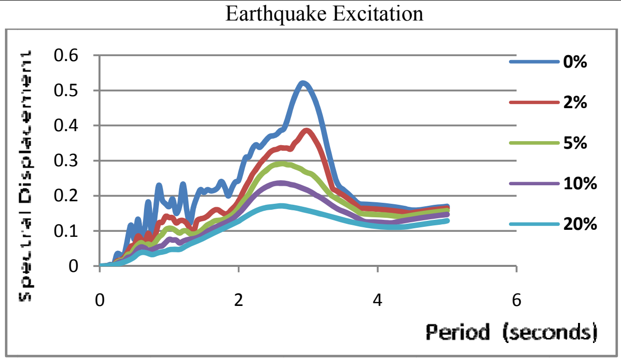


(c) Pacoima Dam Earthquake

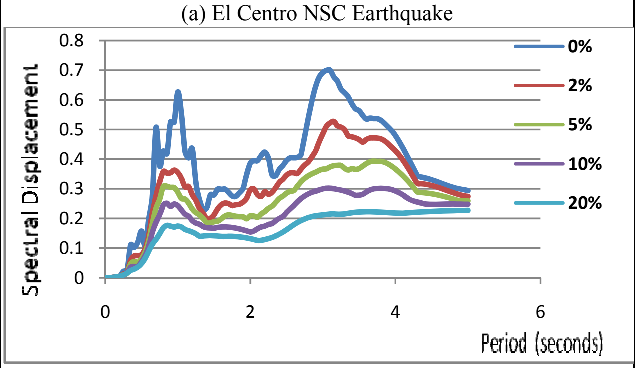
Fig. 4 Three selected earthquakes excitations

After running the RUAUMOKO 2D program, the output data file appears as a file with an extension of the .RES. This output data file can only be plotted using the DYNAPLOT program in the RUAUMOKO 2D folder. The graphs such as earthquake excitation, spectral displacement, pseudo spectral acceleration, mode shapes and others can be plotted using the DYNAPLOT program. Fig. 4 shows the three output of DYNAPLOT for the three selected earthquakes excitations. Maximum excitation within a period of 20 seconds for each of the chosen earthquake events, ranked from highest to lowest value is PACMSW 11.70 m/s^2 or 1.17g, KOBE95EW 6.19 m/s^2 or 0.619g and EL40EWS 2.14 m/s^2 or 0.214g. Fig. 5 shows the spectral displacement of a structure with various percentages of damping starting from 0% until 20% damping. Fig. 6 shows the pseudo spectral acceleration of the precast wall panel starting from 0% damping until 20% damping.

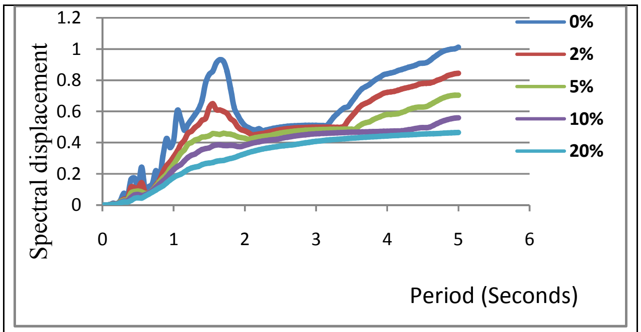
Earthquake Excitation



(a) El Centro NSC Earthquake



(b) Kobe Earthquake



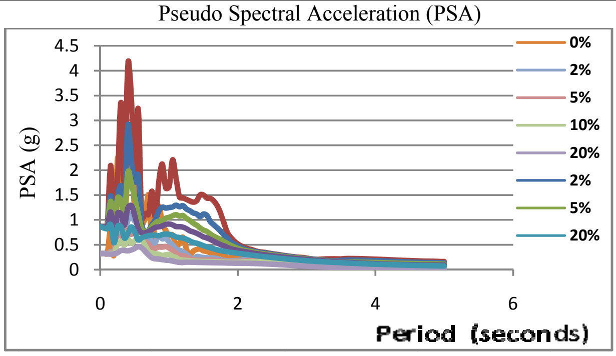
(c) Pacoima Dam Earthquake

Fig. 5 Spectral displacement for three selected earthquakes

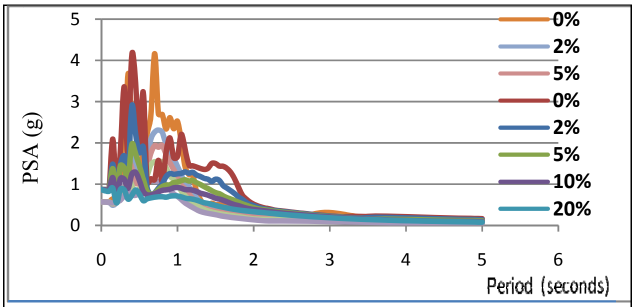
IV. Deformed Shape of the Structure

The two-storey precast building has two types of mode shapes which deformed in the x-direction, either left or right with maximum displacement at the top of the structure known as mode shape one and maximum displacement occurred at the first floor, which is known as mode shape two. The deformed shape of the double storey house under the three chosen earthquake excitations is discussed under dynamic solutions. For mode shape under dynamic solution, maximum movement of the frame happens at the period of 20 seconds under EL40NSC, KOBE95EW and PACMSW accelerograms. Natural frequency for mode shape under dynamic solution for the three chosen earthquake accelerograms is 2.94 Hz with a damping factor of 5%. During earthquake excitations, the moment-rigid frame sways repeatedly to the left and to the right of the turbine foundation in opposition to the ground motion. Within each sway cycle, the condition of the concrete (especially in columns) will change from compression to tension. This repetitive change will definitely affect the strength and durability of the columns. It is well known that concrete is strong in compression and weak in tension. Table III shows the maximum deformation of this structure under the mode shape 1 and mode shape 2 at Node 6. The maximum deformation located at the top right of the structure is similar for the three earthquake accelerograms. The red colour of the building frame indicates the failure point of this building.

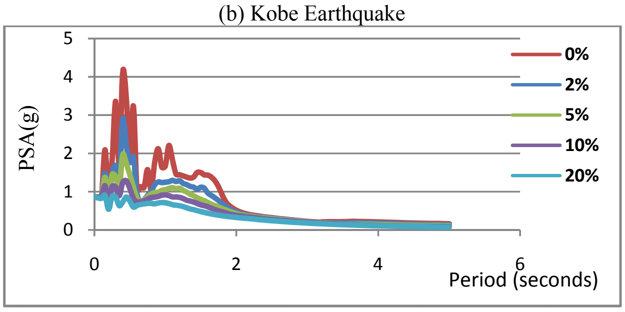
Pseudo Spectral Acceleration (PSA)



(a) El Centro NSC Earthquake



(b) Kobe Earthquake



(c) Pacoima Dam Earthquake

Fig. 6 Pseudo spectral acceleration with various damping ratio starting from 0% to 20%

Table IV shows the forces in each structural member due to earthquake excitation. The forces consist of axial forces, moments and shear forces for these three earthquakes. All of the earthquakes have a similar value of force and the maximum values of these forces are axial forces = 440.70kN, moment=478.40 kNm and shear force = 349.40 kN. These values represent the real or actual values of force, moments and shears of the members in the buildings.

After running the Ruaumoko programming for these three earthquakes it is found that this building cannot survive under these three earthquakes. The connection between wall and beam has to be improved by providing more reinforcement, while the construction of the wall must be improved in order to maintain the quality of the wall.

V. Conclusion

From modeling of a single bay of precast residential house using RUAUMOKO 2D program, the conclusions are as follows:

1. The pattern of hysteresis loops are similar and good agreement between experimental results and modeling results.
2. From Ruaumoko 2D program, Paicoma Dam Earthquake (PACMSW) has the worst impact as compared to the other two past earthquake records on the global behaviour of the prototype building.
3. Base on both of mode shape, damages are occurred at joint between wall-beam interface and ground level of the structures.
4. Member 1 has the greatest axial force and member 5 has the highest moment and shear.

TABLE III
Mode Shape under Dynamic Solution

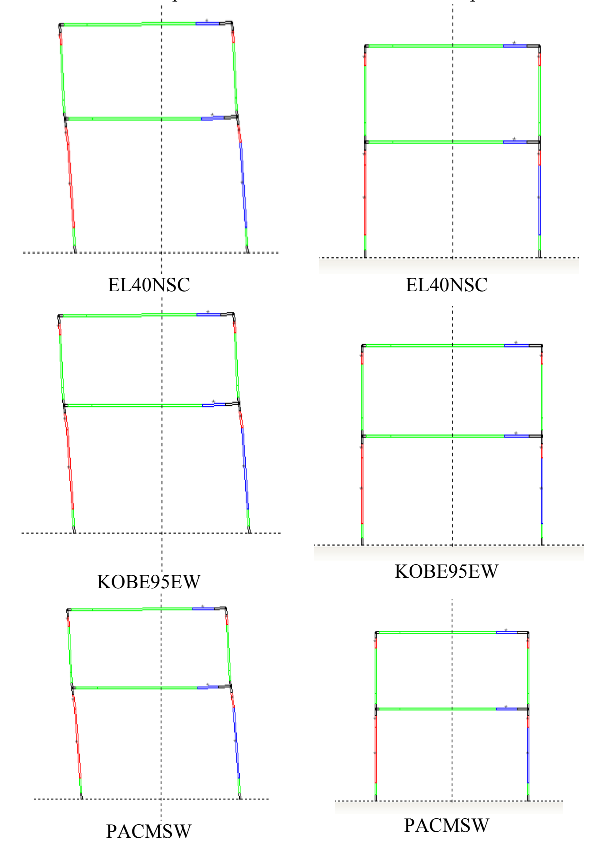


TABLE IV
Member Forces

Member	Force-Ax (kN)	Moment-1 (kNm)	Moment-2 (kNm)	Shear-1 (kN)	Shear-2 (kN)
		Earthquake : EL40NSC			
1	440.70	-450.10	242.40	-274.30	-274.30
2	157.90	-175.70	246.20	-251.90	-251.90
3	-440.70	-447.80	229.70	-268.30	-268.30
4	-157.90	-80.56	167.60	-148.10	-148.10
5	0.00	465.10	-478.40	349.40	349.40
6	0.00	272.10	-334.30	224.60	224.60
		Earthquake : KOBE95EW			
1	440.70	-450.10	242.40	-274.30	-274.30
2	157.90	-175.70	246.20	-251.90	-251.90
3	-440.70	-447.80	229.70	-268.30	-268.30
4	-157.90	-80.56	167.60	-148.10	-148.10
5	0.00	465.10	-478.40	349.40	349.40
6	0.00	272.10	-334.30	224.60	224.60
		Earthquake : PACMSW			
1	440.70	-450.10	242.40	-274.30	-274.30
2	157.90	-175.70	246.20	-251.90	-251.90
3	-440.70	-447.80	229.70	-268.30	-268.30
4	-157.90	-80.56	167.60	-148.10	-148.10
5	0.00	465.10	-478.40	349.40	349.40
6	0.00	272.10	-334.30	224.60	224.60

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