FRAGILITY CURVES OF THE REGULAR AND IRREGULAR SHAPE OF BUILDINGS BASED ON STATIC PUSHOVER ANALYSIS

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ABSTRACT: This paper studies the development of fragility curves for 12-storey regular and irregular shape building models based on non-linear static pushover analysis (SPA). One regular and two irregular shapes of reinforced concrete building models were considered in this study. H-shape and complex shape were selected as the asymmetric plan for the irregular building models. Each building model was designed based on Eurocode 2 with the aid of Eurocode 8 for seismic loading. Five performance levels, namely operation phase (OP), immediate occupancy (IO), damage control (DC), life safety (LS), and collapse prevention (CP) that were suggested by [1] are adopted in this study. By using SPA, the capacity curves and storey drift were obtained to evaluate the performance of building models. The results showed all the models achieved CP state and the regular building model has the highest base shear force. Complex shape building model experienced largest storey drift at both x- and y-axis. Based on the fragility curves, it indicated that the complex shape of the building model has the highest probability of exceeding the damage state.

Keywords: *High-rise Building, Static Pushover Analysis, Fragility Curve*

1. INTRODUCTION

Owing to the rapid development of urbanization and the growth of the urban population, most buildings around the world are constructed with irregular high-rise buildings. Irregularities can be divided into two types, which are vertical irregularity and horizontal irregularity. Buildings with vertical irregularity are those that have abrupt changes in geometry, strength, mass and stiffness while buildings with horizontal irregularity are those with asymmetrical plan shapes [2]. Buildings are the primary structures that are susceptible to damage during an earthquake, especially irregular buildings. As reported by [3], most of the failures in the Mexico earthquake in 1985 and the Bhuj Earthquake in 2001 were due to structural irregularity, which contributed almost 50%. In Malaysia, the most recent and strongest earthquake was the Ranau Earthquake on 5 June 2015 with a magnitude of 6.0 and lasted for about 30 seconds which caused physical and severe damages to the infrastructures, public and private buildings [4].

Static pushover analysis (SPA) is a technique used to identify the damage state of a structure by monotonically increasing horizontal loads until a target displacement is achieved. It is regarded as a practical approach due to its simplicity and ability to accurately predict component and system deformation requirements without the need for intensive calculation and modelling work for dynamic analysis [5]. Fragility curve is a graphical depiction of the structure's seismic risk and it is useful for evaluating the chance of structures achieving or exceeding structural damage states as a result of earthquakes over a certain range of spectral displacement [6]. There are four methods used to develop the fragility curve, including expert-based or judgmental method, empirical method, analytical method, and hybrid method. This paper addressed the analytical method using the guidelines given by the HAZUS MH MR5 [7] technical manual to develop the fragility curve.

2. METHODOLOGY

Three reinforced concrete building models were considered in this study, which included one regular shape and two irregular shapes. H-shape and complex shape were selected as the asymmetric plan for the irregular building models The regular shape building in this study is designed based on a 12 storey regular reinforced concrete building model from the study by [8]. The structure consisted of 6 bays in both x and y directions with 4m apart and 3 m of story height for each level. The slab thickness was designed as 150 mm and the beam for each level is 400 mm x 600 mm. There are different sizes of columns for each level which are level 1 to 3 (800 mm x 800 mm), level 4 to 6 (700 mm x 700 mm), 7 to 9 (600 mm x 600 mm) and 9 to 12 (500 mm x 500 mm). In this study, guidelines given by HAZUS-MH MR5 [7] was used for the development of fragility curves. A lognormal probability distribution function as shown in Equation 1 was used to generate a fragility curve.

$$P\left[{ds}/{S_d} \right] = \Phi\left[\frac{1}{\beta_{ds}} . \ln\left(\frac{S_d}{\bar{S}_{d,ds}} \right) \right] \quad (1)$$

where Φ is standard normal cumulative distribution function, β_{ds} is the standard deviation of the natural logarithm of spectral displacement for damage state, ds, S_d is spectral displacement, $\bar{S}_{d,ds}$ is the median value of spectral displacement at which the building reaches the damage state, ds, P[•] is the probability of being at or exceeding a particular damage state, ds.

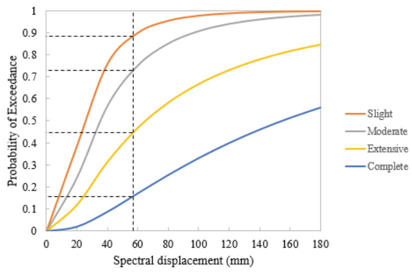
Four damage states, namely slight, moderate, extensive, and complete were used for evaluating the performance of building models based on HAZUS-MH MR5 [7]. The damage-state thresholds proposed by [9] as shown in Table 1 was employed in this study.

Table 1 Damage-state thresholds [9]

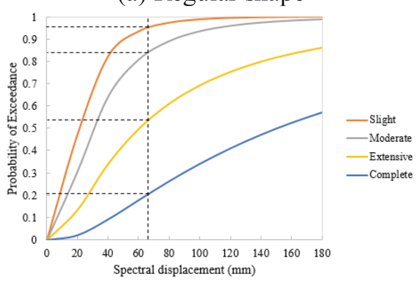
Damage state	Damage-state threshold
Slight	$S_{dS} = 0.7\ S_{dy}$
Moderate	$S_{dM} = S_{dy}$
Extensive	$S_{dE} = S_{dy} + 0.25(S_{du} - S_{dy})$
Complete	$S_{dC} = S_{du}$

3. RESULTS AND DISCUSSION

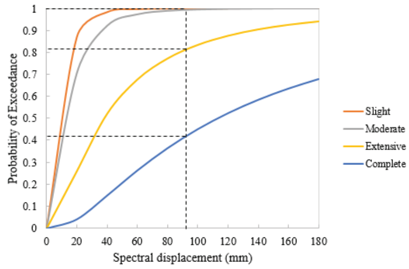
The spectral displacement was used as the damage measure in developing the fragility curve as shown in Figure 1. The spectral displacement was obtained from the performance points that showed in the capacity spectrum after performing SPA. The spectral displacements for regular shape, H-shape and complex shape are 57.76 mm, 66.50 mm and 92.55 mm, respectively. The complete damage is 13% probability for regular shape, meanwhile the H shape 20% and complex shape 42%, respectively. These results show that the complex shape indicates the highest percentage damage and follow by H-shape and regular shape building. However, the slight damage shows a different value which is the probability for H-shape is higher than regular shape with different about 6% meanwhile for the complex shape 100% probability at moderate and slight damage. All building models experienced a high probability of slight and moderate damage states, which is more than 0.5.



(a) Regular shape



(b) H-shape



(c) Complex shape

Figure 1 Fragility curves

4. CONCLUSION

Storey drift results showed that the complex shape of the building model experienced the largest storey drift. In other words, the complex shape of the building model was found to be more vulnerable among these building models. From the result of fragility curves, the complex shape of the building model had the highest probability for all damage states. Thus, the complex shape of a building is more susceptible to severe damage when an earthquake occurred.

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