DEVELOPMENT OF FRAGILITY CURVES OF ENGINEERED CEMENTITIOUS COMPOSITES

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A lot of earthquakes occur each year throughout the world, causing death of people, extreme damage to buildings and financial loss, especially in developing countries. Experiences of earthquakes have shown that masonry elements used as infill walls in steel/concrete frames are one of the most vulnerable elements and a vast source of damage. They are traditionally made with brick or adobe and mortar, with low strength materials. However, Infill walls affect the lateral stiffness and strength of the structure dependent on the mechanical properties of the materials used for making infills as well as the interaction between the infill walls and frame.

It has been generally recognized that infill walls enhance the response of the frame buildings in low to moderate seismic regions, yet they exhibit poor seismic performance under high seismic demand due to the degradation of stiffness, strength, and energy dissipation capacity. Their degradation results from the progressive damage of the masonry wall and the deterioration of the panel-frame interfaces (El-Dakhakhni et al., 2004).

Although there are numerous experimental and analytical studies on RC buildings, few have aimed on these buildings to simulate and predict their seismic performance and establish an effective strengthening procedure by considering the effects of infill walls. Therefore, the seismic performance evaluation of these buildings against seismic forces is an essential step toward hazard mitigation and risk assessment. Fragility curves are powerful tools which can be utilized for the structural performance and vulnerability assessment.

Developing fragility curves for a specific type of building is a probabilistic method to estimate the probability that the building will exceed a specific state of damage for a definite value of the seismic intensity parameter. This parameter can be taken as PGA (Peak Ground Acceleration), Ia (Arias Intensity), CAV (Cumulative Absolute Velocity), etc. PGA is often used as the seismic intensity parameter in developing fragility curves.

In this paper, the hysteretic behaviour of reinforced concrete (RC) infilled frame has been simulated under in-plane loading condition using OPENSEES 2.4 (Mazzoni et al., 2007) software before and after retrofitting by Engineered Cementitious Composites (ECC). The nonlinear analysis program, OPENSEES 2.4, is used for structural modelling and calculating the damage indices. RC and steel structure can be modelled using the program. However, the models for masonry buildings cannot be generated directly.

Nonlinear beam column elements were used to model beams and columns. With respect to shear dominated damage of masonry wall, the simple single-strut (compression-only) element model was utilized for considering the behaviour of masonry wall in in-plane direction. Furthermore, fiber section has been used to show the plasticity properties of the sections for all elements. To consider axial, flexural and shear behaviour of columns, Elwood model were adopted and assigned to model by using series springs (Elwood, 2004). Figure 1 shows a schematic view of masonry infill wall and column modelling.

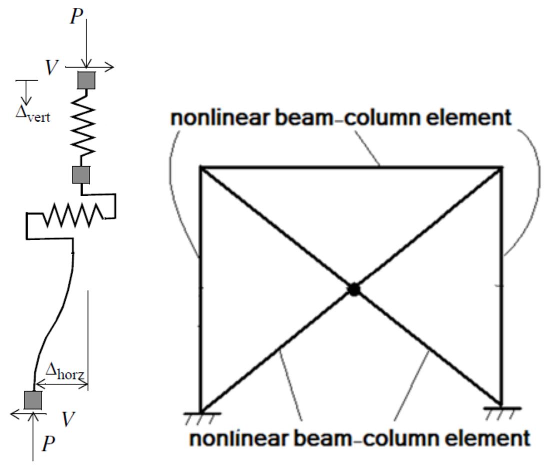

Figure 1. Model of Column and RC infilled frame

The models have been calibrated under in-plane condition based on an experimental study conducted by authors (Dehghani et al., 2013) study. In this paper, five damage states are considered nonstructural damage, slight structural damage, moderate structural damage, severe structural damage and Collapse. These damage states are defined, using the damage index proposed by Park-Ang. The Park and Ang damage index for a structural element is defined as follows (Rubinstein, 1989):

$$DI_{PA} = \frac{u_{max}}{u_{mon}} + \frac{\beta}{F_y u_{mon}} \int dE \qquad (1)$$

Park has proposed β = 0.15 for concrete structures. Park-Ang damage index was selected for obtaining fragility curves and assessing vulnerability. Furthermore, ; seismic parameters of selected records including PGA, CAV, EPA and duration are calculated and compared to find the best correlation between them and damage index. Lognormal distribution was used to calculate the probability of exceedance of damage as follows:

$$F_i(im) = P\left(DI > d_i \mid IM = im\right) = 1 - P\left(DI \le d_i \mid IM = im\right) = 1 - \Phi\left(\frac{\ln(DI_i) - \ln(\overline{DI})}{\sigma_{\ln(DI)}}\right) \qquad (2)$$

The obtained results can show the probable damage to those types of RC infilled frames chosen in this research for different earthquake intensities. Furthermore, the results can utilized to prove efficiency of the ECC retrofitting method to reduce the probability of exceedance under seismic loads. Also by comparison of damage index in elements, it will be show the propagation of damage in frame.

REFERENCES

Dehghani A, Fischer G and Nateghi-Alahi F (2013) Strengthening masonry infill panels using engineered cementitious composites, *Materials and Structures*

Elwood KJ (2004) Modelling failures in existing reinforced concrete columns, NRC Research Press Web site, 31, 846–859

El-Dakhakhni WW, Hamid AA and Elgaaly M (2004) Seismic retrofit of masonry infill walls using advanced composites, *13th World Conference on Earthquake Engineering,* Vancouver, B.C., Canada, P. 3093

Mazzoni S, McKenna F, Scott MH and Fenves GL (2007) OpenSees Command Language Manual

Rubinstein RY (1989) Simulation and the Monte Carlo Method, John Wiley & Sons, New York, NY