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Analytical Investigation on the Seismic Response of Reinforced Concrete Frame Using Midasgen

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Abstract:
The recent Nepal earthquakes in 2015 have raised the questions about the adequacy of frame structures to resist strong motions since many buildings suffered great damages and collapse. Effective mitigation of structures against seismic load is of paramount importance when considering structural resistance and physical integrity. In this paper, the nonlinear static (pushover) analysis of a seven storey building has been conducted using MIDASGEN with the aim of studying the seismic response of the RC frame and to determine the displacement capacity of the structure. The pushover analysis shows the pushover curve, capacity spectrum, and performance level of the existing building. Since the demand spectrum was found to intersect the capacity spectrum near the elastic range, it then means that the structure has a good resistance to the design earthquake load of magnitude 5.2 (Mw) and would not necessarily require retrofitting. Pushover analysis gives an insight and crucial information about the seismic performance of structures as the failure progression of members can be easily monitored.

Keywords: *Nonlinear static, Seismic load, Seismic performance, Displacement capacity, Pushover curve, Demand spectrum, Capacity spectrum.*

1. Introduction

Seismic hazard can be defined as the predicted level of ground motion with the exceedance probability of a certain seismologic parameter (for instance the peak ground acceleration, velocity or displacement) at the site under consideration due to the occurrence of earthquake anywhere in the region, in a given time interval, say fifty years [1]. Seismic occurrence can result in high consequences in terms of permanent damages or failures of buildings and structures.

Effective mitigation of structures is of paramount importance in terms of structural resistance and physical integrity. This can be achieved by designing the structures to be earthquake-resistant. Structural engineers can observe and predict the expected performance of any structure under large forces and modify the design with the application of finite element software packages. A properly engineered structure does not necessarily have to be extremely strong or expensive. It has to be well designed to withstand the effects of seismic loads while sustaining an acceptable level of damage. Nonlinear response history analysis is a possible means of predicting structural response under severe seismic action. This approach is not considered practical due to large amount of data generated in the analysis. Pushover analysis has been the preferred method for seismic performance evaluation of structures by the major rehabilitation guidelines and codes because it is conceptually and computationally simple. Pushover analysis allows tracing the sequence of yielding and failure on members as well as the progress of global capacity curve of the structure [2]. Nonlinear static analysis or pushover analysis is a practical and effective seismic assessment tool, which gives a good understanding of the performance of a structural frame under strong seismic actions.

2. Methodology

2.1. Preamble

The pushover analysis is performed by subjecting the structure to a monotonically increasing pattern of loads representing the inertia forces which would be experienced by the structure when subjected to lateral loading. Under increasing loads, various structural elements may yield sequentially. Using the pushover analysis, the characteristic nonlinear force-displacement relationship is determined.

The non-linear analysis involves three main steps:

1. Pre Procession (Modelling)

2. Elasto-Plastic Analysis
3. Post Procession (Access to the output)

2.2. Description of Case Study Frame

The case study frame is a seven storey building. It was designed using the British Standard Code 8110-1 1997. Three dimensional model of the frame was generated using MIDASGEN. The necessary geometric and strength characteristics of all members were taken into consideration. The plan layout is shown in Figure 3. The typical floor height is 3.0m.

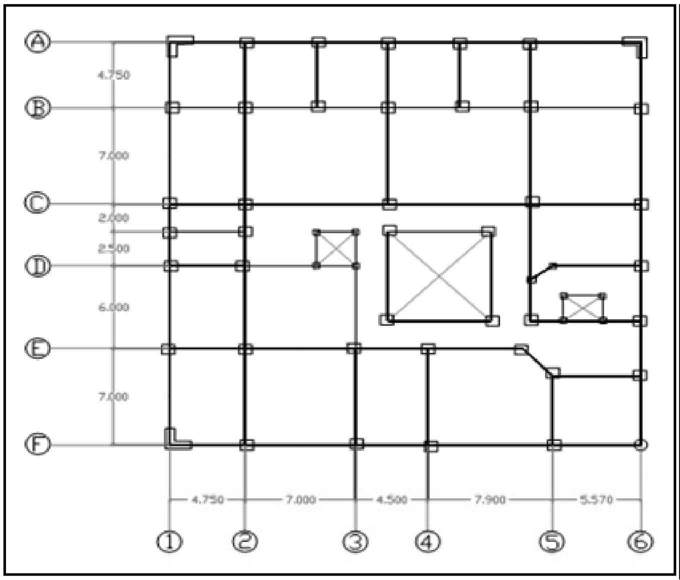

Figure 1: Plan of the structural frame

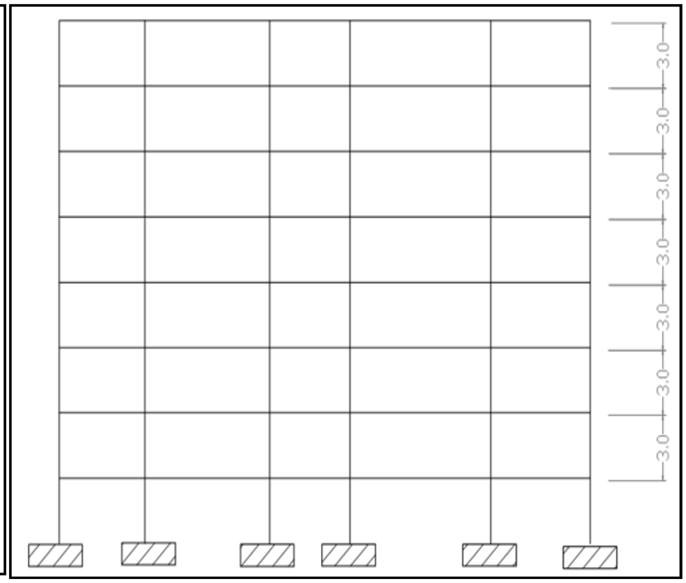

Figure 2: Elevation of the structural frame

Members	Dimension
Column 1	650mm x 250mm
Column 2	450mm x 250mm
Column 3	230mm x 250mm
Column 4(circular)	Diameter is 300mm
Beam 1	250mm x 650mm
Beam 2	250mm x 500mm
Beam 3	250mm x 450mm
Slab	150mm thickness

Table 1: Members dimension of the structural frame

Beam and column members have been defined as frame elements with the appropriate dimensions and reinforcements.

3. Results and Discussion

3.1. General

A seven storey reinforced concrete frame was taken for the investigation. The frame was subjected to design earthquake forces as specified in the EC8: 2004. The responses of the frames are discussed below.

3.2. Pushover Curve

The graphical representation of the base shear and displacement is called pushover curve. The resulting pushover curve (MDOF) for the seven building is shown in fig. 5. This curve depicts the global behavior of the structural frame in terms of its stiffness and ductility. The global plastic mechanism is formed at the base shear of 6050kN and roof displacement of 0.194mm.

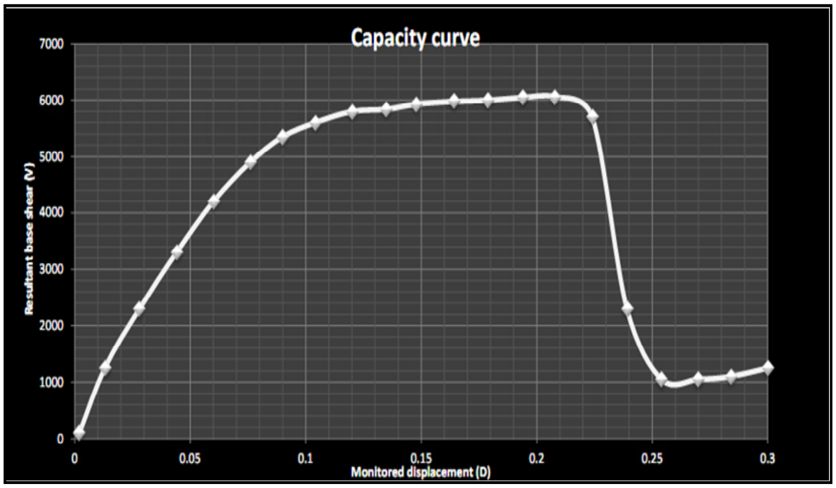

Figure 3: Pushover Curve.

3.3. Capacity Spectrum

Capacity spectrum is obtained from the pushover curve when it is transformed from base shear (V) versus monitored displacement (D) co-ordinates into spectral acceleration (Sa) versus spectral displacement (Sd) co-ordinates. That is, the pushover curve (MDOF) is simplified to an idealized SDOF form and then used together with the design response spectrum to determine the performance point or target displacement. The performance point is obtained at point A in figure 6 at a spectral acceleration of 0.108 and spectral displacement of 0.035m. The non-linear static analysis is then revisited to determine the member forces and deformations at this point.

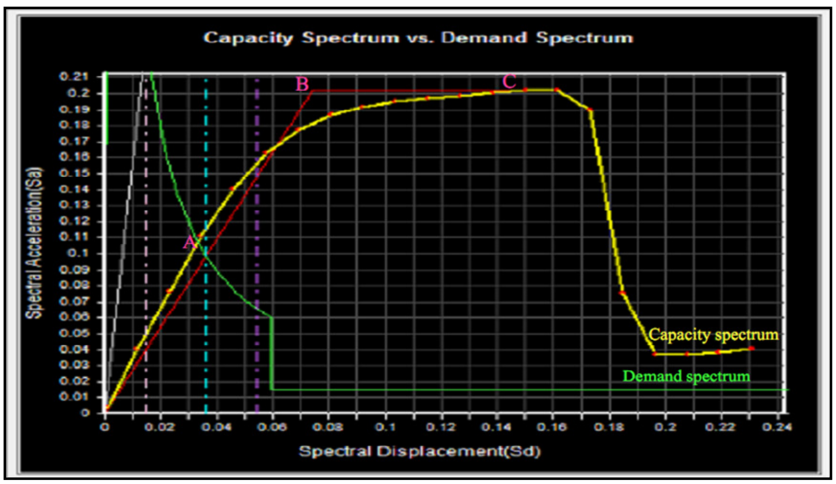

Figure 4: Capacity-Demand Spectrum Curve

3.4. Plastic Hinges

The plastic hinges formation of the building mechanisms on a step by step basis was obtained at different displacements levels as shown in figures 7 and 8. Plastic hinge formations begins with beam ends and proceeds to base columns of lower stories, which then propagates to upper stories and continue with the yielding of interior intermediate beams.

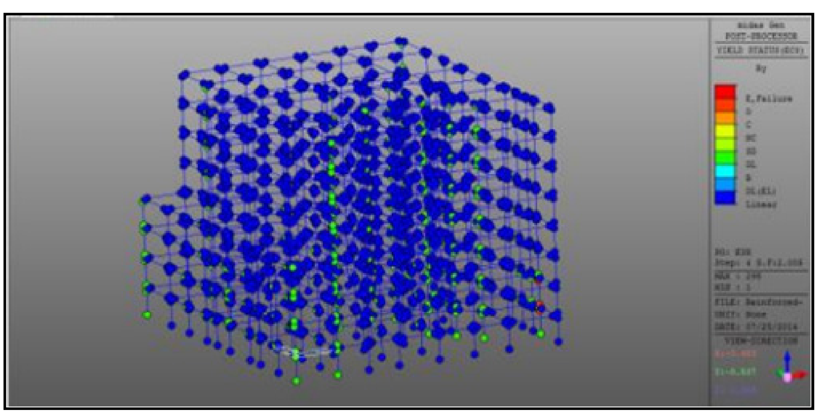

Figure 5: Plastic hinge status at performance point. (Source: Alomajaet al., 2015)

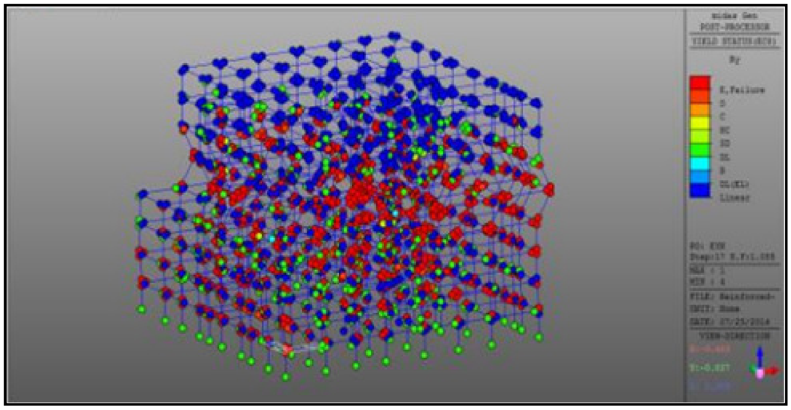

Figure 6: Plastic hinge status at failure point. (Source: Alomajaet al., 2015)

4. Conclusion

Based on the capacity curve, a target displacement which is an estimate of the displacement that the design earthquake will produce on the building is determined. The extent of damage experienced by the structure at this target displacement is considered representative of the damage experienced by the building when subjected to design level ground shaking.

The demand spectrum intersects the capacity spectrum near the elastic range then, the structure has a good resistance to the design earthquake load of magnitude 5.2 (Mw). On the other hand, if the demand spectrum intersects the capacity spectrum with little reserve of strength and deformation capacity then, it can be stated that the structure will behave poorly during the imposed seismic excitation and need to be retrofitted to avoid future major damage or collapse.

The results obtained in terms of demand, capacity and plastic hinges gave an insight into the real behaviour of the structures.

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