Effect of Design Parameters on Performance Evaluation of a RCC Building

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***Abstract*—** Performance based seismic design allows to design the building with a realistic understanding of risk of life, occupancy and economic losses that may occur from future seismic activities. New building having expected performance level can be constructed using this concept. The non-linear performance level of a RCC building is affected by its design parameters one of which major contributor is the longitudinal and transverse reinforcement present in the columns and the beams of a structure. The present study includes analyzing and designing a 10 storey RCC building using response spectrum method for building located in zone-III. The performance level of the building is evaluated depending on drift values and yielding of hinges as per ATC 40 in SAP 2000. The effect of various design parameters on the performance level of a building is found out. Results are presented in terms of static pushover curve, displacements and hinge status. Later for changing the performance level of building to all the possible performance levels like IO, LS, CP and other levels, their respective change in design parameters will be evaluated.

Keywords— performance based seismic design, pushover curve, yielding of hinges, ATC 40, and design parameters.

INTRODUCTION

The primary objective of performance based seismic design is to know the actual performance reliability of the design. Performance based seismic design refers to the methodology in which the structural design criteria are expressed in terms of achieving the performance objectives when subjected to stated seismic activity. The performance objectives may be a level of stress, a load, a displacement, a limit state or a target damage state that is not to be exceeded. Target damage state is commonly used criteria of performance objective for performance based seismic design.

ATC 40 is limited to concrete buildings and recommends the use of capacity spectrum method. Capacity spectrum is the force versus displacement curve obtained in pushover analysis. Force and displacement are converted into spectral accelerations and spectral displacements using an equivalent SDOF system. Demand curves are the response spectrum curves for specified damping value and they are also converted into spectral acceleration versus spectral displacement curves. Superposition of capacity curve and demand curve gives the performance point which is then evaluated with the trial performance point previously set.

As pushover analysis continues the damage in the building is evaluated in terms of hinges modelled in the beams and columns in a structure.

Fig. 1 shows the relation between force and displacement for a standard hinge. Hinge is in elastic state until a certain limit after which it changes itself from an elastic to an inelastic stage i.e. from point A to B.

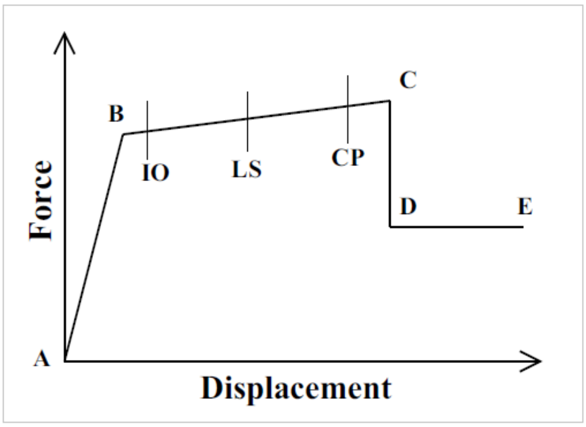

Figure 1: Hinge Behaviour (CSI Knowlegde Base)

Further the nonlinear portion B to C is divided into 4 zones B- IO which is approximately 10% value of the total zone B to C, IO-LS which is approximately 10 - 60% value of the total zone B to C, LS - CP which is approximately 60 – 90 % value of the total zone B to C and the remaining portion is termed as CP – C. Beyond point C the hinge suddenly drops its load carrying capacity and after which large amount of deflections are observed till point E. Beyond point E the hinge is considered failed which means the moment carried by the member is beyond the maximum plastic moment the member can resist and the member is considered failed.

REVIEW OF LITERATURE

Yamawaki *et al.* (2000) proposed a study on general information of performance based seismic design as per Japanese codes and the evaluation of performance point of a building models of three different heights was carried out. The study concluded that criteria established for obtaining the building performance for concrete and steel structures are storey drift, storey height, ductility and design storey shear.

Ghobarah (2001) had completed a case study on general information of three basic documents for performance based seismic design which were ATC 40, SEAOC Vision 2000, and FEMA 273. It was seen that advantage of performance-based design is the possibility of achieving predictable seismic performance with uniform risk. It was seen that the reliability of the approach may ultimately depend on the development of explicit and quantifiable performance criteria that can be related to the response parameters such asstresses, strains, displacements, accelerations and their derivatives.

Inel *et al.* (2006) studied the difference between the use of auto defined hinge and the manually defined hinge in software for pushover analysis. It was seen that the base shear for both is hinges is almost similar with marginal difference of 5%. Plastic hinge length has about 30% effects on the displacement capacity of the frames. Amount of transverse reinforcement has a large effect on displacement. Both the hinges have a similar yielding pattern. If modelled correctly the auto hinges results are over safe. Auto hinges can give higher deformation capacity than expected if modelled incorrectly.

Khan (2014) found out the performance point of a 5 storey RCC building symmetrical in plan and lying in zone-IV with variable sizes of beams and columns and varying the reinforcement in beams and columns. Pushover analysis was carried out using the N2 method of analysis. It was noticed that in pushover analysis higher modes are neglected, roof displacement increases as peak ground acceleration increases and performance point is slightly affected by variation of response reduction factor.

Shinde *et al.* (2014) studied the capacity based design to find the maximum load carrying capacity of members for three buildings with soft storey G+3, G+8, and G+15 and compared the load carrying capacities with the limit state design. Study proposed that collapse due to sway mechanism can cause failure of a storey or whole frame. Capacity based design method eliminate sway mechanism by making columns stronger than beams. This method also eliminates the possibility of shear mode of failure by making shear capacity of elements more than their moment capacity. Reserve strength beyond elastic limit is dependent on the provided reinforcement.

Akhare *et al.* (2015) carried analysis for Performance Point of a RCC building for three shapes; T shape, L shape and C shape considering the Torsional effect. Two methods of pushover analysis was used namely standard pushover analysis and modal pushover analysis. Torsional forces effect on behavior of irregular shaped building. Performance point evaluated and seen that it lies between immediate occupancy and life safety for all the three shapes of building.

Zameeruddin *et al.* (2016) evaluated the information on reviewing the recent developments in performance based seismic design; compared ATC 40 CSM (Capacity spectrum method), N2 Method, FEMA 273 CSM (Capacity spectrum method), FEMA 440 DCM (Displacement control method) and ASCE 41 DCM (Displacement control method) to find the similarities and the dissimilarities between all the methods.

Karkhanis *et al.* (2016) found out the performance point of a RCC building for three different shapes; T shape, L shape and C shape. Study used the 2 methods of pushover analysis one of which was the standard pushover analysis and the other one was the modal pushover analysis. The modal pushover analysis estimated seismic demand due to an intense ground motion has been more accurate for irregular buildings if compare with the regular building. Performance point was lying between immediate occupancy and life safety for all the three shapes.

Ingale *et al.* (2017) found out the Performance Point of a six storey RCC building for three different seismic zones viz. Zone-III, Zone-IV and Zone-V. They concluded that base shear increases and displacement decreases as the zone increases and thus the load carrying capacity increases as the zone decreases. Also the storey displacement and storey drift both increases with increase of zone and are greater in MCE than DBE. Plastic hinges formed in columns and beams are within immediate occupancy and life safety, as they are designed with strong column and weak beam concept.

Javiya *et al.* (2017) found out the performance point of a 10 storey RCC building symmetrical in plan using ATC 40. Three sets of structures were prepared which named as low sized and reinforced, moderately sized and reinforced and highly sized and reinforced. It was found that lower most sized and reinforced building resulted hinges in all zones causing collapse, moderate sized and reinforced building limited the hinges in collapse prevention zone and the highly sized and reinforced building was found to lie in life safety mode. Highly sized and reinforced building was termed to be repairable.

METHODOLOGY

The building data used for analysis and design is as follows.
Building Plan Dimension: 15m x 15m
No. of bays in X direction: 3 Bays, @5m c/c.
No. of bays in Y direction: 3 Bays, @5m c/c.
No. of storey: 10
Floor to floor height: 3m
Sizes of columns below 3rd storey: 600mm x 600mm
Sizes of columns above 3rd storey: 500mm x 500mm
Size of beams: 230mm x 400mm

The building is analysed by response spectrum analysis and then designed in SAP 2000 with the following reinforcement data.

Top reinforcement in beams: 2 Bars - 16mm ϕ
Bottom reinforcement in beams: 2 Bars - 25mm ϕ
Reinforcement in Columns:
Below 3rd storey: 24 Bars - 20mm ϕ

Above 3rd storey: 16 Bars - 20mm ϕ

The building is analysed by pushover analysis in SAP 2000 considering soil type II which is dense soil and soft rock and seismic source A which is a fault capable of producing large magnitude events and which have a high rate of seismic activity. The data is used for the calculation of demand spectrum.

RESULTS AND DISCUSSION

Results are obtained by using pushover analysis are presented in graphical and tabular formPushover curve

Fig. 2 shows pushover curve obtained in terms of base shear and roof displacement. The curve is a nonlinear curve which is flattening as the structure is being pushed.

Performance Point

Fig. 3 shows the capacity curve in green color which is obtained when the pushover curve is plotted in spectral coordinates. The red color curve shows the reduced response spectrum called as the demand curve. The point of intersection of the two curves gives the performance point of the structure.

Interstorey Drift

Table-I shows the interstorey drift of the structure at performance point step i.e. where the capacity spectrum intersects the demand spectrum. The maximum obtained drift is 0.0075 which is less than 0.01 as specified by ATC 40 for global performance of the structure.

Hinge Results

Fig. 4 shows the location of hinges all over the structure on the performance point step. Pink color hinges indicate that the hinges are yielded to a maximum of B – IO stage which is a permissible as per ATC 40. There are a total of 800 hinges modelled in the structure out of which 116 hinges are yielded on performance point step. For complete pushover analysis results the Hinges are located in all possible states throughout the structure.

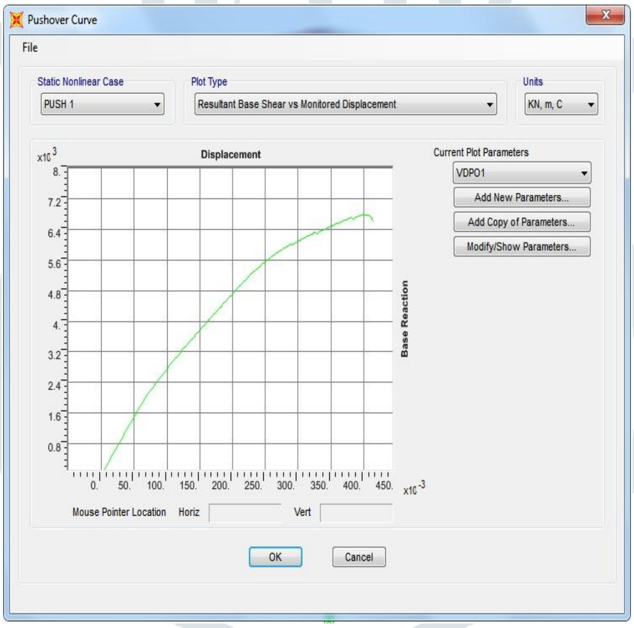

Figure 2: Pushover Curve

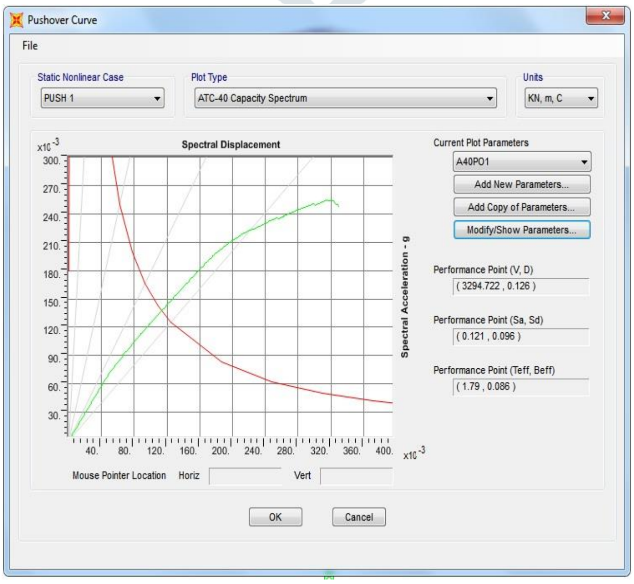

Figure 3: Performance Point

Table I: Interstorey Drift at Performance Point

Storey	Interstorey Drift at Performance Point
10	0.0017
9	0.0028
8	0.0042
7	0.0056
6	0.0069
5	0.0075
4	0.0067
3	0.0037
2	0.0020
1	0.0012
F	0.0000

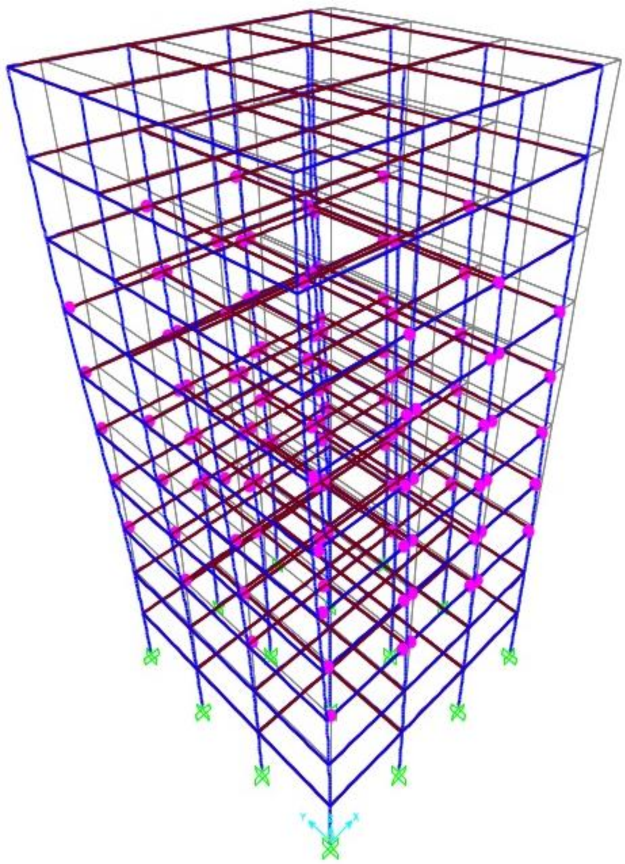

Figure 4: Hinge Location at Performance Point

CONCLUSIONS

Following conclusions are drawn based on results obtained by using pushover analysis are:

1. Overall generalized performance point of the structure is found out which lies in Immediate Occupancy level.
2. First yielding of hinge is observed in beams which indicates strong column and weak beam structure.
3. Last step of pushover analysis shows yielding of 2 hinges beyond point E.
4.

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