Seismic Analysis of Interlocking Blocks in Walls

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Abstract— Generally RC framed structures are designed without regards to structural action of masonry infill walls present. Masonry infill walls are widely used as partitions. These buildings are generally designed as framed structures without regard to structural action of masonry infill walls. They are considered as non- structural elements. RC frame building with open first storey is known as soft storey, which performs poorly during strong earthquake shaking. Past earthquakes are evident that collapses due to soft storeys are most often in RC buildings. In the soft storey, columns are severely stressed and unable to provide adequate shear resistance during the earthquake. Hence a combination of two structural system components i.e. Rigid frames and RC shear walls or Rigid frames and Bracings leads to a highly efficient system in which shear wall and bracings resist the majority of the lateral loads and the frame supports majority of the gravity loads. From the above studies it has been observed that non-linear pushover analysis provide good estimate of global as well as local inelastic deformation demands and also reveals design weakness that may remain hidden in an elastic analysis and also the performance level of the structure. Storey drifts are found within the limit as specified by code (IS: 1893-2002 part-1) in both linear static, linear dynamic and non-linear static analysis.

Key words: Pushover Analysis

I. INTRODUCTION

The capacity of structural members to undergo inelastic deformations governs the structural behaviour and damageability of multi-storey buildings during earthquake ground motions. From this point of view, the evaluation and design of buildings should be based on the inelastic deformations demanded by earthquakes, besides the stresses induced by the equivalent static forces as specified in several seismic regulations and codes. Although, the current practice for earthquake-resistant design is mainly governed by the principles of force-based seismic design, there have been significant attempts to incorporate the concepts of deformation-based seismic design and evaluation into the earthquake engineering practice. In general, the study of the inelastic seismic responses of buildings is not only useful to improve the guidelines and code provisions for minimizing the potential damage of buildings, but also important to provide economical design by making use of the reserved strength of the building as it experiences inelastic deformations. In recent seismic guidelines and codes in Europe and USA, the inelastic responses of the building are determined using nonlinear static methods of analysis known as the pushover methods.

Thus the impact of wind and seismic forces acting on them becomes an important aspect of the design. Improving the structural systems of Multi-Storeyed buildings can control their dynamic response. With more appropriate structural forms such as shear walls, tube structures and braced structures, and improved material properties, the maximum height of concrete buildings has soared in recent decades. Therefore; the time dependency of concrete has become another important factor that should be considered in analyses to have a more reasonable and economical design.

A large portion of India is susceptible to damaging levels of seismic hazards. Hence, it is necessary to take in to account the seismic load for the design of Multi-Storeyed Structures. The different lateral load resisting systems used in Multi-Storeyed building are: 1.Bare frame 2.Brace frame 3.Shear wall frame. Due to Industrial revolution, availability of jobs and facilities, population from rural area is migrating towards cities. Because of this metro cities are very thickly populated. Availability of land goes on decreasing and land cost also increases. To overcome this problem the use of multi-storeyed buildings is must. But such provisions increases self-weight and live load along with earthquake forces. With in-crease in height stress, strain, deformation and displacement in the structure increases; which ultimately increases the cost of construction due to increased cross-sections of the elements. Bracing systems provide lateral stability to the overall frame-work. The bracing members of such braced frame act as truss system to resist lateral forces and are subjected primarily to axial stress in the elastic range. It is but obvious that bare frames are found to be more flexible and have large section requirement to with stand forces induced. The same can be minimizing by making structure more rigid but it seems to be not feasible and uneconomical.

Nonlinear static (pushover) analysis can provide an insight into the structural aspects, which control performance during severe earthquakes. The analysis provides data on the strength and ductility of the structure. Which cannot to be obtained by elastic analysis. By pushover analysis, the base shear versus top displacement curve of the structure, usually called capacity curve, is obtained. To evaluate whether a structure is adequate to sustain a certain level of seismic loads, its capacity has to be compared with the requirements corresponding to scenario event.

Two key elements of performance based design procedure are demand and capacity. Demand is a representation of the earthquake ground motion. Capacity is a representation the structure’s ability to resist the seismic demand. The performance is dependent on manner that the capacity is able to handle the demand. In other words, the structure must have the capacity to resist the demands of the earthquake such that the performance of the structure is compatible with the objectives of the design.

Simplified nonlinear analysis procedures using pushover methods, such as the capacity spectrum method and the displacement coefficient method, require determination of three primary elements: Capacity, Demand (displacement) and Performance .Each of these elements is briefly discussed below.

A. Capacity

The overall capacity of a structure depends on the strength and deformation capacities of the individual components of the structure. In order to determine capacities beyond the elastic limits, some form of nonlinear analysis, such as pushover procedure is required .This procedure uses a series of sequential elastic analyses, superimposed to approximate a force-displacement capacity diagram of the overall structure. The mathematical model of structure is modified to account for reduced resistance of yielding components. A lateral force distribution is again applied until additional components yield. This process is continued until the structure becomes unstable or until a predetermined limit is reached.

B. Demand (Displacement)

Ground motions during an earthquake produce complex horizontal displacement pattern in structures that may vary with time. Tracking this motion at every time-step to determine structural design requirements is judged impractical .Traditional linear analysis methods use lateral forces to represent a design condition. For nonlinear methods it's easier and more direct to use a set of lateral displacement as a design condition. For a given structure and ground motion, the displacement demand is an estimate of the maximum expected response of the building during the ground motion.

C. Performance

Once capacity curve and demand displacement are defined, a performance check can done. A performance check verifies that structural and nonstructural components are not damaged beyond the acceptable limits of the performance objective for the forces and displacement implied by displacement demand.

D. Nonlinear Static Pushover Analysis

The recent advent of performance based design has brought the nonlinear static pushover analysis procedure to the forefront. Pushover analysis is a static, nonlinear procedure in which the magnitude of the structural loading is incrementally increased in accordance with a certain predefined pattern. With the increase in the magnitude of the loading, weak links and failure modes of the structure are found. The loading is monotonic with the effects of the cyclic behaviour and load reversals being estimated by using a modified monotonic force-deformation criteria and with damping approximations. Static pushover analysis is an attempt by the structural engineering profession to evaluate the real strength of the structure and it promises to be a useful and effective tool for performance based design.

Pushover analysis is a nonlinear static method of analysis. This analysis technique, also known as sequential yield analysis or simply "Pushover" analysis has gained significant popularity during past few years. It is one of the three analysis techniques recommended by FEMA 273/274 and a main component of Capacity Spectrum Analysis method (ATC-40). The static pushover analysis is becoming a popular tool for seismic performance evaluation of existing and new structures. The expectation is that the pushover analysis will provide adequate information on seismic demands imposed by the design ground motion on the structural system and its components.

II. DESCRIPTION OF THE SAMPLE BUILDING

The description of each building model is given below as fallows.

1) Model 1: Building modeled as bare frame. However, masses of the walls are included.
2) Model 2: Full infill masonry model, building has one full brick masonry wall of 230mm thick in all the storey including the ground storey.

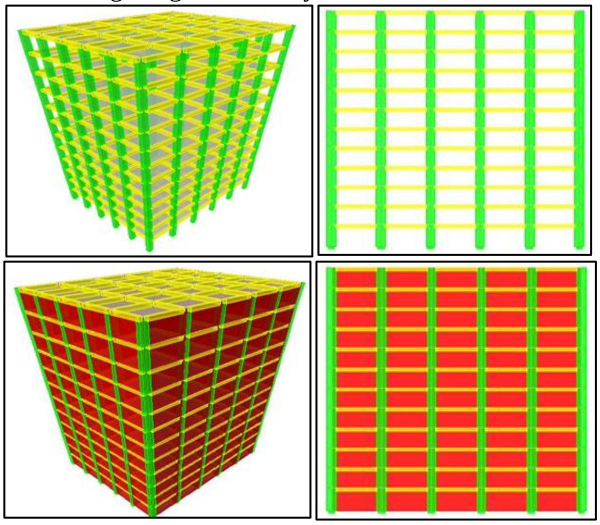

Fig. 1: 3D View of Models

III. EXAMPLE BUILDING MODELS STUDIED

The plan layout of the reinforced concrete moment revisiting frame building is shown in figure 5.1. The elevation and 3D views of different building models are also shown above. For the study, the plan layout is kept the same for all the models. Each building model is of 21 storeys. The height of each storey is 3.5m except 11^{th} storey, height of 11^{th} storey is 2m for all the different building models. The building is considered to be located in seismic zone V .In seismic weight calculations, 50% of floor live load is considered. The input data given for all the different building models is listed below.

A. Design Data

1) Material Properties

- Young's modulus of (M30) concrete, E = 27.386×10^6 kN/m²
- Density of Reinforced Concrete = 25kN/m³
- Modulus of elasticity of brick masonry = 3500×10^3kN/m²
- Density of brick masonry = 20kN/m³

2) Assumed Dead Load Intensities

- Floor finishes = 1.5kN/m²

3) Live load intensities

- Imposed loads = 3.5KN/ m²

4) Member properties

- Thickness of Slab = 0.125m
- Column size = (0.5m x 0.9m)
- Beam size = (0.4m x 0.6m)
- Thickness of wall = 0.23m
- Thickness of concrete wall = 0.20m

5) Load Calculations

- Wall load on roof =1x0.23x20 = 4.6 KN/m
- Wall load on each storey =2.9x0.23x20 = 13.34KN/m
- Earthquake Live Load on Slab as per clause 7.3.1 and 7.3.2 of IS 1893 (Part-I) - 2002 is calculated as:
- Roof (clause 7.3.2) = 0

- Floor (clause 7.3.1) = 0.5x3.5 = 1.75kN/m^2
- IS: 1893-2002 Equivalent Static method

B. Seismic Data

- Zone factor as per (table 2 of IS 1893-2002)= 0.36(Zone –V)
- Importance factor I from (Table 6 of IS 1893-2002) = 1.5(Important office building)
- Response reduction factor R from (Table 7 of IS1893-2002 =5.00(SMRF)
- Soil type (Figure 2 of IS1893-2002) =Type II (Medium soil)

1) Equivalent Static Analysis Procedure based on IS1893-2002

a) Fundamental Time Period (T)

Fundamental natural time period in seconds for moment resisting frame building without brick panels:

$$T = 0.075\ h^{0.75}$$

Fundamental natural time period in seconds for moment resisting frame building with brick infill panels:

$$T = \frac{0.09\ h}{\sqrt{d}}$$

For 21 storeyed frame building:

Time period in both longitudinal and transverse directions:

$$T = 0.075 \times 42.5^{0.75} = 1.248 \text{ sec}$$

For 21 storeyed brick infill building:

Time period in longitudinal directions:

$$T = \frac{0.09\ \times 42.5}{\sqrt{25}} = 0.765 \text{ se}$$

Time period in longitudinal directions:

$$T = \frac{0.09\ \times 42.5}{\sqrt{20}} = 0.855 \text{ sec}$$

2) Spectral acceleration co-efficient (Sa/g)

For medium soil sites

$$\frac{sa}{g} = \begin{matrix} 1 + 15\,T \\ 2.5 \\ 1.00/T \end{matrix}$$

For 12 storeyed frame building:

$$\frac{sa}{g} = \frac{1.36}{T} = \frac{1.36}{1.248} = 1.089$$

For 12 storeyed brick infill frame building:

In longitudinal direction

$$\frac{sa}{g} = \frac{1.36}{T} = \frac{1.36}{0.765} = 1.777$$

In transverse direction

$$\frac{sa}{g} = \frac{1.36}{T} = \frac{1.36}{0.855} = 1.590$$

3) Design horizontal seismic coefficient (A_h)

$$A_h = \frac{Z}{2} * \frac{I}{R} * \frac{Sa}{g}$$

For 21 storeyed frame building:

$$A_h = \frac{0.36}{2} * \frac{1.5}{5} * 1.089 = 0.058$$

For 21 storeyed brick infill frame building:

In longitudinal direction

$$A_h = \frac{0.36}{2} * \frac{1.5}{5} * 1.777 = 0.096$$

In transverse direction

$$A_h = \frac{0.36}{2} * \frac{1.5}{5} * 1.590 = 0.058$$

Model No	Seismic Weight in KN	Design Seismic Base shear in KN(longitudinal dir.)	Design Seismic Base shear in KN(transverse dir.)
1	116237.7	6823.153	6823.153
2	116237.7	11158.82	9996.442
3	114126.3	10956.12	9814.862
4	113408.5	10887.21	9753.128
5	113236.2	10870.68	9738.313
6	111553.7	10709.16	9593.622
7	110865.3	10643.07	9534.417
8	111561.5	10709.9	9594.286

Table 5.1: Design Seismic Base Shear for Various Models in Longitudinal & Transverse Directions

IV. CONCLUSIONS

- Fundamental natural period decreases when effect of infill wall, concrete shear wall and concrete bracings are considered.
- As the soft stories Exist at Ground storey, the fundamental time period of the structure is increases; hence existence soft storey can make the structure to be flexible in nature.
- The seismic base shear obtained by IS Code is not in a good agreement with the values obtained from Equivalent static and Response spectrum analysis using ETABS.
- Seismic base shear considerably more for masonry infill, shear wall and Concrete bracings models as compared with bare frame model. Hence consideration of masonry infill stiffness, shear wall and Concrete bracings increases Strength of the structure.
- Storey drifts are found within the limit as specified by code (IS 1893-2002 Part-1).
- The presence of masonry infill influences the overall behaviour of structures when subjected to lateral forces. Joint.

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