Earthquake Vibration Control by using Tapered Shear Wall

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Abstract— In India the enormous loss of life and property perceived in the last couple of decades, attributable to failure of structures instigated by earthquakes. Responsiveness is now being given to the assessment of the sufficiency of strength in framed RCC structures to resist solid ground motions. The seismic reaction of RCC building frame in terms of performance point and the earthquake forces on Reinforced building frame with the help of pushover analysis is carried out in this project. In this method of analysis a model of the building is exposed to a lateral load. Pushover analysis can afford a substantial insight into the weak links in seismic concert of a structure and we can know the weak zones in the structure. In this project effort has been made to investigate the effect of Shear Wall and Structural Wall on lateral displacement and Base Shear in RCC Frames. RCC Frames with G+15 are considered, one with only shear wall and other with only structural walls. The pushover analysis of the RCC building frame is carried out by structural analysis and design software ETABS.

Keywords: Earthquake, Vibration, Tapered Shear Wall

I. Introduction

The term earthquake can be used to describe any kind of seismic event which may be either natural or initiated by humans, which generates seismic waves. Earthquakes are caused commonly by rupture of geological faults; but they can also be triggered by other events like volcanic activity, mine blasts, landslides and nuclear tests. There are many buildings that have primary structural system, which do not meet the current seismic requirements and suffer extensive damage during the earthquake. According to the Seismic zoning Map of IS: 1893-2002, India is divided into four zones on the basis of seismic activities. They are zone II, zone III, zone IV and zone V. Some industries usually make full-scale models and execute wide testing, before manufacturing thousands of identical structures that have been analyzed and designed with consideration of test results. Unluckily, this choice isn't available to building industry so that economy of huge scale creation is unfeasible. In India many existing structure design as per Indian standard code 456:2000 but to make building earthquake resistant IS 1893-2002 should be used to avoid future building vulnerable in earthquake.

Generally, loads on these structures are only gravity loads and result in elastic structural behavior. However, under a Strong seismic event, a structure may actually be subjected to forces beyond its elastic limit. Since. The recent earthquake in last 4 decayed in which many concrete structure have been harshly damaged or collapsed, it have indicated the need for evaluating the seismic suitability of present building or purposed building. Therefore structure vulnerable to damage must be determined. To make or attain this objective, simplified linear elastic methods are not suitable. Thus the structural designer has developed a new method of design and seismic procedure that include performance based structure towards nonlinear technique.

A. Objectives

- To study the performance of RC plane frames under lateral loads (Earthquake loads).
- To perform Linear Analysis and Non-Linear Analysis.
- To study the performance of R.C.C structure with or without structural wall w.r.t. Different parameters such as story drift, story displacement, base shear, etc.
- To study the inelastic response of RC plane frames using Earthquake Vibration analysis.

B. Shear Wall

Shear walls are vertically oriented members in addition to slabs, beams and columns, capable of resisting the lateral loads. They start at the foundation and run throughout the height of the building. The thickness of the shear walls vary from 150mm to 400mm depending on the height of the building. RCC shear wall has high in plane stiffness, at the same time resist massive horizontal masses and support gravity masses in the direction of orientation of the walls, thereby serving advantageous in many Structural Engineering applications and reducing the risk of damage in structure. Shear walls additionally give lateral stiffness to prevent the roof or floor on top of from excessive side-sway. Shear walls are of varied cross sections such as rectangular shaped, irregular cores like channel, T, L, barbell shape, box etc. are being used. Usually they form the core for elevator or used as reinforced walls with openings in it. Positioning of shear wall in a building influences the behavior of the building. For effective and economic performance of building it is essential to position shear walls in a proper location so that they are symmetrical and torsional effect on the building is avoided. In this study, a reinforced concrete structure with shear walls at various locations is analyzed and the optimum position of the shear walls has been studied

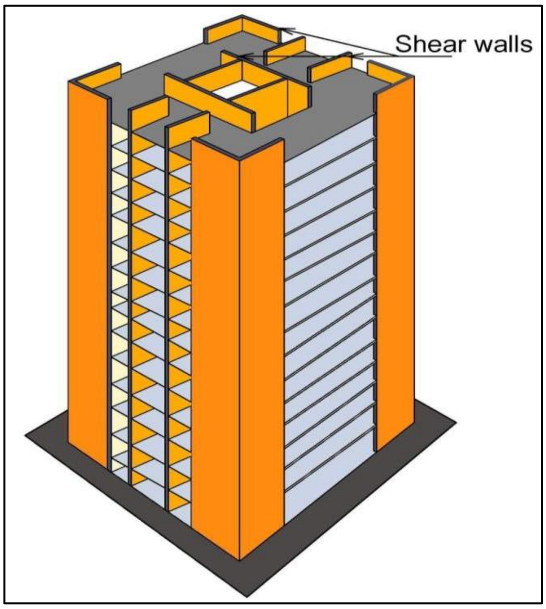


Fig. 1: Building with Shear Wall

II. STATE OF DEVELOPMENT

ParmodSharan1, Balwan2 In earthquake regions major problem is rehabilitation of vulnerable buildings. In recent past a number of techniques have been developed to strengthened and rehabilitation the buildings in these regions. However, occupants are disturbed following these strengthening and rehabilitation techniques because vacation of buildings. In present study, a new strengthening technique for exterior shear walls has been discussed under reversed cyclic loading. In past earthquakes, many buildings (Reinforced Concrete) have experienced either different types of damage or collapsed. On buildings which were collapsed by earthquakes various investigations have been carried out. Week column – strong beam behavior, poor quality concrete, poor bond of the end regions, inadequate splice lengths, short column behavior and incomplete design consideration were some of structural deficiencies. Modern building codes are introduced after the construction of most of these buildings. Required ductility, lateral stiffness and strength are much less than those imposed by modern building codes. As they have low ductility these buildings are prone to large displacement demand due to deficient lateral stiffness and strength.

Yoshio SAWAKI1, Rajesh RUPAKHETY2, Símon ÓLAFSSON System identification was conducted to estimate the fundamental vibration period and damping ratio of a residential building in Kathmandu. Ground motion and structural response due to aftershocks of the 2015 Gorkha Earthquake, as well as noise data triggered by ambient vibration were used to identify the dynamic properties of the structure. The identification is based on non-parametric spectral methods as well as parametric methods. Using aftershocks and triggered noise, the fundamental period of the building was found to be in the range of 0.23-0.3s. An empirical relation available in the literature predicts a fundamental period of 0.25s for the building being studied. It can be thus concluded that the fundamental period can be estimated with confidence. The damping ratio, however, showed greater variation. Statistical analysis by using auto-regressive with exogenous input (ARX) gave similar results as the non-parametric methods. The damping ratio estimated by ARX models was found to be closer to a generally expected value of 3-5%. In addition, a finite element model consisting of three dimensional beam column elements and compression diagonal struts was created. The finite element model had a fundamental period of 0.26s, which is close to the value predicted by system identification.

Putul Haldar, Yogendra Singh and D.K. Paul Unreinforced Masonry (URM) is the most common partitioning material in framed buildings in India and many other countries. Although it is well-known that under lateral loading the behavior and modes of failure of the frame buildings change significantly due to infill-frame interaction, the general design practice is to treat infills as nonstructural elements and their stiffness, strength and interaction with the frame is often ignored, primarily because of difficulties in simulation and lack of modeling guidelines in design codes. The Indian Standard, like many other national codes, does not provide explicit insight into the anticipated performance and associated vulnerability of infilled frames. This paper presents an analytical study on the seismic performance and fragility analysis of Indian code-designed RC frame buildings with and without URM infills. Infills are modeled as diagonal struts as per ASCE 41 guidelines and various modes of failure are considered. HAZUS methodology along with nonlinear static analysis is used to compare the seismic vulnerability of bare and infill frames. The comparative study suggests that URM infills result in a significant increase in the seismic vulnerability of RC frames and their effect needs to be properly incorporated in design codes

III. METHODOLOGY

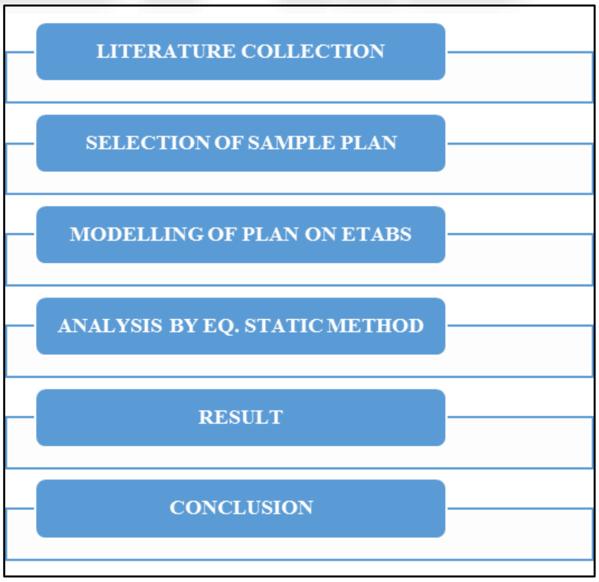


Fig. 2:

A. *Problem Statement*

The main aim of project is evaluate the seismic behavior of RCC building having structural walls. For this purpose equivalent static method of analysis is used to evaluate behavior of the building. Analysis by response spectrum method is also carried out, to study the dynamic behavior. The modeling and analysis is carried using ETAB software

1) Description of Structure

- Type of frame: Special RC moment resisting frame fixed at the base.
- Spacing between frames: 4m along x and 5m along y-directions
- Number of story: 15
- Floor height: 3 m
- Depth of slab: 0.15m
- Size of beam: 0.23m x 0.45m
- Plinth beam at 2m from footing
- Size of column: 0.3m x 0.6m
- Thickness of shear wall : 0.15m
- Masonry wall: 0.2m thick External and 0.15m thick. Internal.
- Live load on floor: 3 kN/m2
- Grade of concrete : M30
- Grade of steel : Fe 415
- Density of concrete: 25 kN/m3
- Density of infill: 20 kN/m3
- Seismic zone: IV
- Type of soil: Medium
- Damping of structure: 5 %

2) Assumption

1) The material is homogeneous and isotropic.
2) All columns supports are considered as fixed at the foundation.
3) Tensile strength of concrete is ignored in sections subjected to bending.
4) The maximum target displacement of the structure is calculated in accordance with the guidelines given by IS Code for maximum roof level lateral drift and displacement.
5) The building is designed by according to I.S. 456:2000 for Dead Load and Live load.

IV. SYSTEM DEVELOPMENT

In the Present work three building models of G+15 has been developed for RCC, for different position of shear wall situated in zone V with subsoil Type medium -II were analyzed in ETAB software. All the buildings are subjected to same earthquake loading to check their seismic behavior for same storey and storey height. For the analysis of these models various methods of seismic analysis are available but for present work both linear static and non-linear static method is used.

A. Method of Analysis

1) Equivalent Static Method

The design lateral force due to earthquake is calculated as follow

a) Design horizontal seismic coefficient:

The design horizontal seismic coefficient Ah for a structure shall be determined by the following expressions:-

$$Ah = (Z/2) X (I/R) X (Sa/g)$$

Provided that for any structure with $T \leq 0.1$ s, the value of Ah will not be less than Z/2 whatever the value of I/R.

Where,

- Z= Zone factor
- I = Importance factor depending upon the functional use of the structure.
- R=Response reduction factor, depending upon the perceived seismic damage performance of the structure.
- Sa /g = Average response acceleration coefficient

b) Design Seismic Base Shear

The total design lateral force or seismic base shear (Vh) along any principal direction is determined by the following expression:

$$Vb = Ah .W$$

Where, W is the seismic weight of the building.

Distribution of design force:

The design base shear (Vb) computed is distributed along the height of the building as below:

$$Qi=Vb\ (wihi2 / \sum wihi2)$$

Where,

- Qi = Design lateral force at each floor level i
- Wi = Seismic weight of floor i.
- hi = Height of floor i measured from the base.

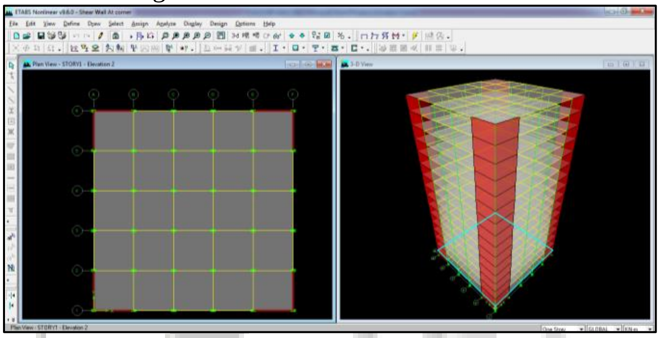
B. Software Information (ETABS)

ETABS is a sophisticated, yet easy to use, special purpose analysis and design program developed specifically for building systems. ETABS 2016 features an intuitive and powerful graphical interface coupled with unmatched modeling, analytical, design, and detailing procedures, all integrated using a common database. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of nonlinear behaviors necessary for performance based design, making it the tool of choice for structural engineers in the building industry.

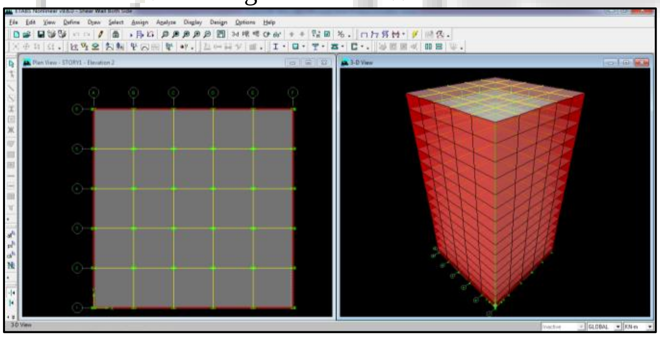
Dating back more than 40 years to the original development of TABS, the predecessor of ETABS, it was clearly recognized that buildings constituted a very special class of structures. Early releases of ETABS provided input, output and numerical solution techniques that took into consideration the characteristics unique to building type structures, providing a tool that offered significant savings in time and increased accuracy over general-purpose programs. As computers and computer interfaces evolved, ETABS added computationally complex analytical options such as dynamic nonlinear behavior, and powerful CAD-like drawing tools in a graphical and object-based interface. Although ETABS 2016 looks radically different from its predecessors of 40 years ago, its mission remains the same: to provide the profession with the most efficient and comprehensive software for the analysis and design of buildings. To that end, the current release follows the same philosophical approach put forward by the original programs, namely most buildings are of straightforward geometry with horizontal beams and vertical columns. Although any building configuration is possible with ETABS, in most cases, a simple grid system defined by horizontal floors and vertical column lines can establish building geometry with minimal effort.

- Many of the floor levels in buildings are similar. This commonality can be used to dramatically reduce modeling and design time.
- The input and output conventions used correspond to common building terminology. With ETABS, the models are defined logically floor-by-floor, column-by-column, bay-by-bay and wall by-wall and not as a stream of non-descript nodes and elements as in general purpose programs. Thus the structural definition is simple, concise and meaningful.
- In most buildings, the dimensions of the members are large in relation to the bay widths and story heights. Those dimensions have a significant effect on the stiffness of the frame. ETABS corrects for such effects in the formulation of the member stiffness, unlike most general-purpose programs that work on centerline-to-centerline dimensions.

The results produced by the programs should be in a form directly usable by the engineer. General-purpose computer programs produce results in a general form that may need additional processing before they are usable in structural design.



Model 1: Building with Shear Walls of RC Frame



Model 2: Building with Structural Wall along Perimeter of RC Frame

V. THEORETICAL CONTAIN

A. Base Shear

Base shear is an estimate of the maximum expected lateral force that will occur due to seismic ground motion at the base of a structure. Calculations of base shear (V) depend on:

- Soil conditions at the site
- Proximity to potential sources of seismic activity (such as geological faults)
- Probability of significant seismic ground motion
- The level of ductility and over strength associated with various structural configurations and the total weight of the structure
- The fundamental (natural) period of vibration of the structure when subjected to dynamic loading

B. Drift in High Rise Building

Drift of a building in simple terms can be defined as the horizontal displacement undergone by the building with respect to its base when subjected to horizontal forces such as wind and earthquake loads. Thus story drift can be defined as the displacement of one floor level of the building with respect to its adjacent level above or below the considered floor level. The above figure (Fig 1) shows the displacement undergone by the structure with respect to its base due to the horizontal load ex. In Fig 2, drifts at each floor level such as ground, first, second and third floor are denoted as D1, D2, D3 and D4 respectively and d1, d2, d3, d4 are the story drifts of each floor of the building.

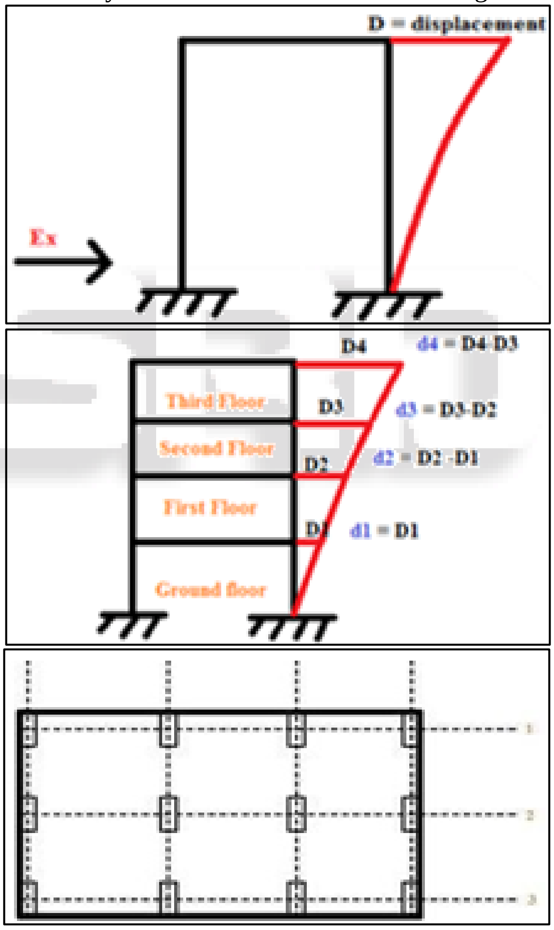


Fig. 3: Displacement

In Fig 2, plan of the building is shown where the columns with same sizes are aligned in same direction and the spacing between them is equal in both x and y directions. So here the lateral stiffness on grids A, B, C, D, 1, 2 and 3 are same. So when Base shear or seismic load is applied to the building as Ex or Ey in x and y directions, load is distributed equally along the grid lines, thus resulting in equal drift values along each grid line. For Example, if the base shear (Ey, i.e along y direction) calculated is 1000 KN, the load carried by columns along each grid line will be 250 KN as the lateral stiffness along each grid line are equal. But this scenario is quite rare or can be referred to as an "ideal condition". In most of the cases, buildings are designed with different column sizes and with irregular column spacing which results in variation in lateral stiffness along each column line as shown in Fig 3.2.

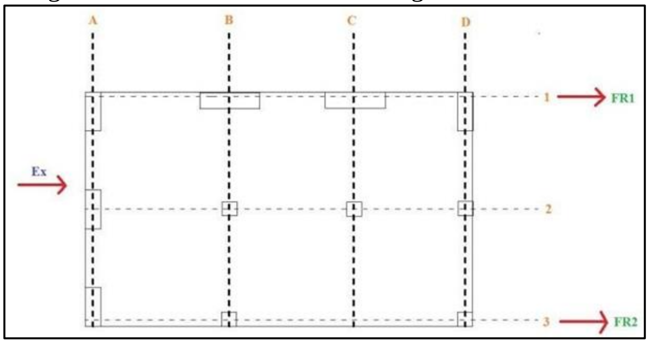


Fig. 4: Lateral Stiffness along Each Column

Since the number of columns and its size are less along the grid line 3, it is quite evident that lateral stiffness along grid line 3 is quite less compared to grid line 1.This difference in lateral stiffness will give rise to twisting or torsion in building when subjected to horizontal loads. The drift along a column grid line can be calculated by

Drift = Lateral Load/Lateral stiffness

C. Demand of Displacement in High Rise Buildings

A change of frame of reference of deformation facilitates converting the moving base problem of earthquake shaking of buildings into a fixed base problem. The latter is easy to handle, since design practice is conversant with analysis and design of structures subjected to forces, and not subjected to displacements or accelerations. Therefore, now the acceleration response spectrum allows quick, back- of-the-envelope type calculations by senior engineers to check the ball park values of force generated in a building during earthquake shaking. In early days of designing buildings to resist earthquakes, an earthquake-induced lateral force was thought to be the root cause of the earthquake problem. Designers observed that buildings performed well, if they were designed for lateral forces; mostly, this lateral force was due to wind effects. Hence, as a first measure of consciously designing for earthquake effects, designers took 10% of the weight of the building and applied it as a lateral force on the building (distributed along the height). But, the 10% force was too penalizing for taller buildings. Around that time, understanding grew on the ground motions, and it was learnt that different buildings respond differently to the same ground shaking. Thus, the design lateral force was now taken as a function of the fundamental natural period of the building. This was not sufficient either. Many buildings showed brittle performance, i.e., collapsed suddenly in low seismic regions. This was the beginning of understanding the importance of introducing ductility in buildings. But, the method of introducing ductility was prescriptive; it was based on limited laboratory tests performed on structural elements and sub-assemblages. The above also was found insufficient, when buildings did not collapse, but were rendered not-usable after many strong earthquakes.

Performance of buildings during and after the earthquake came into focus. And, this was the beginning of a new direction of designing buildings to resist earthquake effects. Fresh thinking began towards displacement-based design of buildings. Then, it was clear that imposed lateral displacement was the root cause of the earthquake problem and not any lateral force. Thus, the present effort in the research community is to arrive at a displacement based design with capability to quantitatively assess the ultimate deformation capacity of buildings at the design stage itself. In the following chapters, earthquake DEMAND on the building and earthquake CAPACITY of the building are discussed. While doing so, the associated basic concepts are elaborated and demonstrated with appropriate numerical work. Acceleration time history at the base of a building: Converted to a force time history at the mass of the building with the base fixed … ag (t) Mass m – mag

D. Deflection in High Rise Buildings

Serviceability criteria in the form of lateral deflection and acceleration limits under wind loading are often the governing structural issues for tall buildings. Whilst the basis for acceleration criteria has been the subject of research, rational refinement and consensus over recent years, deflection limits are still rather arbitrary. Current guidance on deflection limits in international design codes is very limited and is based primarily on experience with typical low and medium -rise buildings. The issues with lateral deflection in very tall buildings are different to those of low-rise buildings, and depend on structural form. Rational choice of deflection criteria for tall buildings therefore requires further consideration of the nature of the deformations and the effects they have on the functional aspects of the building.

Lateral loading effects from wind and seismic sources usually dominates the structural design of tall buildings. As well as strength considerations, stiffness and its' effect on deflection is usually the governing criteria which determines structural element size and cost. Structural design codes are generally written with conventional types of low-rise and medium-rise buildings in mind. High-rise buildings often have different structural forms such as outrigger systems, bundled tubes, mega bracing etc. The nature of the deflection with these structural types often differs to that in low-rise buildings. At the time of writing there are a large number of buildings around the world being designed above 300m in height, with a few significantly higher than that. In order to justify the performance of these buildings, it is essential to understand the nature of lateral deflections.

VI. CONCLUSION

In India many existing structure design as per Indian standard code 456:2000 but to make building earthquake resistant IS 1893-2002 should be used to avoid future building vulnerable in earthquake. Although quick and easy for simple structures, ETABS can also handle the largest and most complex building models, including a wide range of nonlinear behaviors necessary for performance based design, making it the tool of choice for structural engineers in the building industry. Hence, as a first measure of consciously designing for earthquake effects, designers took

10% of the weight of the building and applied it as a lateral force on the building (distributed along the height).

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