Study of the Vertical Irregularities in Tall RC Structures under Lateral Load

Sawsan Yaseen Khudhair¹, D. Chandra Mouli²
M.Tech Student¹, Assistant Professor²
Department of Civil Engineering
A.N.U. College of engineering and technology, Guntur, Andhra Pradesh, India

Abstract:
Nowadays, in the urban areas the space required for the construction of buildings is limited. To fulfil this demand, tall buildings becoming more popular. In these modern days, most of the structures are involved with architectural importance and it is highly impossible to plan with regular shapes. These irregularities are responsible for structural collapse of buildings under the action of dynamic loads like wind or earthquake, stability of these irregular structures is important topic of present study. Stability weakness arises due to discontinuity in mass, stiffness and geometry of structure. A vertical irregularity is one of the major reasons of damage or failures of structures during past earthquakes. In this work, the performances of tall RC structure with irregularities are studied. The modelling and analysis of the structures is carried out using the software ETABS and dynamic analysis is carried out using response spectrum method.

Keywords: Shear Wall, Response spectrum

I. INTRODUCTION

Nowadays, due to rapid growth in the urban areas, the space available for the construction of buildings is very limited and expensive. So in this limited space we have to construct such type of buildings which have can be used for multiple purposes such as lobbies, car parking etc. To fulfill this demand, buildings with irregularities is the only option available. During large lateral load due an earthquake or wind, these building will undergo severe damage or sometimes lead to failure of structure. The main reason for this weakness arises due to discontinuity in mass, stiffness and geometry of structure. Vertical irregularities are one of the major reasons for failures of structures during earthquakes.Earthquakes have become a cause of great devastation for mankind. Study of history and latest earthquake damage illustrates that the structures are susceptible to rigorous damage or fails when subjected to strong ground motion. Severe damages of engineered buildings, bridges, industries and airport cause’s great economic losses to the country. Numerous harmful earthquakes have stroked our world in both past and modern times from distant and near earthquakes.

II. SIGNIFICANCE OF STUDY

Vertical irregularities are characterized by vertical discontinuities in the geometry, distribution of mass, rigidity and strength. Setback buildings are a subset of vertically irregular buildings where there are discontinuities with respect to geometry. However, geometric irregularity also introduces discontinuity in the distribution of mass, stiffness and strength along the vertical direction. Majority of the studies on setback buildings have focused on the elastic response. The behavior of these types of building is something different. The component of the building, which resists the seismic forces, is known as lateral force resisting system (L.F.R.S). The L.F.R.S of the building may be of different types. The most common forms of these systems in a structure are special moment resisting frames, shear walls and frame-shear wall dual systems

As per IS Code 1893 (Part 1):2002, irregularities are classified as

- Plan Irregularities and
- Vertical Irregularities.

Figure 1. Buildings with Plan irregularities

Figure 2. Buildings with vertical irregularities
III. EARTHQUAKE VS. WIND-DYNAMIC ACTION ON STRUCTURES

Dynamic actions are caused on buildings by both wind and earthquakes. But, design for wind forces and for earthquake effects are distinctly different. The intuitive philosophy of structural design uses force as the basis, which is consistent in wind design, wherein the building is subjected to a pressure on its exposed surface area; this is force-type loading. However, in earthquake design, the building is subjected to random motion of the ground at its base (Figure-4), which induces inertia forces in the building that in turn cause stresses; this is displacement-type loading. Another way of expressing this difference is through the load-deformation curve of the building – the demand on the building is force (i.e., vertical axis) in force-type loading imposed by wind pressure, and displacement (i.e., horizontal axis) in displacement-type loading imposed by earthquake shaking.

Effect of setback irregularities:

The setback irregularity is one of the most common types of irregularity in the modern buildings. The functional and aesthetic requirements are the main reasons for preference of these structures. The setback buildings are quite useful in urban areas where there is a space constraint and closer proximity of buildings is required. In such areas, these buildings provide adequate sunlight and ventilation for the bottom storeys.

In addition, these buildings comply with the building byelaw restrictions of “Floor area ratio” as pre-building code of India. The presence of setbacks in a building results in abrupt reductions of the floor area which in turn results in change of mass, stiffness and strength along the building height. This results in variation of dynamic characteristics of these buildings as compared to the regular buildings. This aspect has been ignored by the seismic design codes in formulating the seismic design methodologies.

This is reflected in poor seismic performance of setback structures during the past earthquakes. Figure-5 shows failures of a 21 storeyed building at its 12 storey (due to presence of setback) during Chile 2010 earthquake. Moreover, projections in form of balconies have also experienced severe failures during past earthquakes. Therefore, storeys adjacent to setback should be given a special design consideration due to avoid failure.

Effect of stiffness and strength irregularity on deformation demands:

The stiffness and strength variation are very commonly encountered in the modern buildings due to functional and aesthetic considerations e.g. reduction of beam-column sizes (for economy) and increase in height of a particular storey (especially to create basements, car-parking etc.). Likewise, variation of reinforcement and concrete grade also results in stiffness and strength irregularities.
IV. EFFECTS OF SEISMIC FORCES ON STRUCTURES

The under horizontal shaking of the ground i.e. the movement of the ground, more inertia forces are developed at the mass of the structure which are commonly located at floor levels. As the inertia forces develop, they are then carried to the walls or columns from the floor slab, and from columns they are then carried to the foundation and from there to the soil underneath. Hence, all the structural elements i.e. the floor slabs, walls, columns, and foundation must be safely designed so as to allow the transfer of inertia forces through them. Walls and columns are the most important elements in transferring the inertia. The behavior of a building during earthquakes is largely dependent on the structure of the building. It’s shape, size and span plans an important role in the transfer of the inertia forces.

Buildings with different vertical layout:

The forces developed by earthquake should be brought from the top of the building to the ground. This force is brought down by the simplest route or path in a building and if there is any hindrance in the transfer of load then it will affect the overall performance of a building. Some buildings with vertical Setbacks like that seen for few star buildings that had got vertical discontinuity along the height which results in an increase in the earthquake force at the point of discontinuity. A particular collapse in a storey can happen when fewer columns are present in that particular floor or storey (Figure 8-b). What happened in Gujarat earthquake was that many buildings which had soft storey at ground floor collapsed and were severely damaged. The structures that as seen on unveled grounds will have an equal length in the column and thus it will result in damage in the shorter column and will result in the collapse of the structure. (Figure 8-c).

Buildings with have columns which hang/float on beams at a specified storey and does not reach the ground, will have discontinuities in the load transfer mechanism (Figure 8-d). Some buildings have RC walls designed to carry the earthquake loads to the foundation. Buildings, in which these walls do not go all the way to the foundation but stop at an upper level, are prone to get severely damaged during earthquakes.
wise reduction of floor height considered for different models. The following points are studied in this work.

- Study the behavior of the structure due to set back irregularity at different levels are studied as shown in model description.
- Study is carried out for both lateral load like wind load and earthquake load. Results are compared with help various parameters.

VI. MODEL SPECIFICATION

An RCC building plan of 30mX30m with 6 bays of 5m each in both direction is considered. The building is having a special moment resisting frame of 30 storeys. Set back vertical irregularity considered reducing floors step wise as shown in the model details.

Table 1. Member sizes of building model

<table>
<thead>
<tr>
<th>Member</th>
<th>Size(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Column</td>
<td>500x500 (BASE TO Story 10) 400X400 (Story 11 TO Story 20) 300x300 (Story 21 TO Story 30)</td>
</tr>
<tr>
<td>Beam</td>
<td>300x400 (BASE TO Story 10) 250X300 (Story 11 TO Story 20) 200x300 (Story 21 TO Story 30)</td>
</tr>
<tr>
<td>Slab</td>
<td>125</td>
</tr>
</tbody>
</table>

Table 2. Load data

<table>
<thead>
<tr>
<th>Type of Loads</th>
<th>Floor</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live Load</td>
<td>Typical floor</td>
<td>3 kN/m²</td>
</tr>
<tr>
<td></td>
<td>Terrace Floor</td>
<td>1.2 kN/m²</td>
</tr>
<tr>
<td>Super Dead Load (SDL)</td>
<td>Typical floor</td>
<td>1.2 kN/m²</td>
</tr>
<tr>
<td></td>
<td>Terrace Floor</td>
<td>0.8 kN/m²</td>
</tr>
</tbody>
</table>

Table 3. Earthquake & Wind Load Details

<table>
<thead>
<tr>
<th>Earthquake Load</th>
<th>Wind Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone factor (Zone V)</td>
<td>0.36</td>
</tr>
<tr>
<td>Importance factor</td>
<td>1</td>
</tr>
<tr>
<td>Response reduction</td>
<td>5</td>
</tr>
<tr>
<td>Soil type</td>
<td>III</td>
</tr>
<tr>
<td>Topography</td>
<td></td>
</tr>
</tbody>
</table>

Regular model without any vertical irregularity-RM

Vertical geometric irregularity with side offset –VGSM1

Vertical geometric irregularity with side offset –VGSM2
Vertical geometric irregularity with side offset – VGSM3

Vertical geometric irregularity with side offset both direction – VGSM6

Vertical geometric irregularity with side offset both direction – VGSM7

Vertical geometric irregularity with side offset both direction – VGSM8
VII. RESULT DISCUSSIONS & CONCLUSIONS

From above results following observations are made during study.
The displacement value is maximum for model RM for RSX case.

The storey drift value is maximum for model VGSM5 for RSX case between 20th and 30th floor whereas RM having maximum values between 20th and 30th floor.

Storey stiffness value is maximum for RM model compared to all other models.

Storey shear value is least for model VGSM5 whereas RM are having maximum value.

The displacement value is maximum for model VGSM8 and the model VGSM7 having least value.

The storey drift value is maximum for model VGSM8 between 10th and 20th floor whereas VGSM6 having maximum values between 20th and 30th floor.

Storey stiffness value is maximum for VGSM7 model between 10th and 20th floor whereas in other floors, all the models show almost same values.

Storey shear value is least for model VGSM8 whereas VGSM7 & VGSM6 are having almost same values.

Following are the conclusions:

In this study, it is observed that the models are more vulnerable to higher lateral load due to earthquake in comparison to the wind load.

The wind loads are less vulnerable compared to seismic load for considered study, but as the vertical irregularity level increases, the lateral load for both the cases is almost same.

Structure which is located in seismic zone with vertical irregular configuration needs be analysed not only by response spectrum method but also time history analysis.

In case of building with vertical irregularities is unavoidable then structure should be provided with sufficient lateral strength by providing shear wall or stiffer columns to increase the stiffness of structure.

VIII. REFERENCES


[9]. Ankesh Sharma and Biswobhanu Bharda (2013) executed the seismic analysis as well as design of vertically irregular RC building frames, National Institute of Technology Rourkela


[14]. V. Indumathy and DR.B.P. Annapurna. (2012)”Investigating a four storied one bay infilled frame with soft storey at ground floor’. International journal of research technology and engineering. ISSN: 22777-3878, volume 3 issue 4, September 201 2


IX. BIOGRAPHY

SAWSANYASEEN KHUDAIR, M. Tech Student, Department of Civil Engineering, A.N.U. College of engineering and technology, GUNTUR 522510, ANDHRA PRADESH, INDIA

Mr. D.CHANDRA MOULI, Assistant Professor, Department of Civil Engineering, A.N.U. College of engineering and technology, GUNTUR 522510, ANDHRA PRADESH, INDIA