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STUDY ON SEISMIC PERFORMANCE OF VERTICAL IRREGULAR RC STRUCTURES WITH CANTILEVERED OFFSET

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ABSTRACT

The behaviour of a building relies upon the association of structural elements present in it. The crucial aspects on which the structural configuration depends are the length, shape and geometry of the buildings. And studies on the type of irregularity i.e. cantilevered offset as per the IS 1892 (Part 2) 2016 are very limited and have not been done extensively in the past literature. Hence, in the present investigation the above-said type of irregularity i.e. buildings with cantilevered offsets has been considered. In the current work, response characteristics of this type of vertical irregularity have been investigated and an attempt has been made to full fill the following objectives: To evaluate seismic demands of vertical irregular structures with the building having cantilevered i.e. offsets dimensions larger than that of the story below as per the latest code IS 1893-2016, to analyze the frames under evaluation, contain vertical irregularities for earthquake loads using equivalent static method and time history method for various offset dimensions (A > 0.1 L) and to arrive at the particular correlation for critical results like story drifts, displacements, member forces.

Keywords: Vertical Geometric Irregularities, Cantilevered Offset, Regression Analysis.

I. INTRODUCTION

The behaviour of any building relies upon the overall association of structural elements present in it. The crucial aspects on which the structural configuration depends are the shape, length, and geometry of the building. In the modern era, construction of an irregular building is increasing rapidly. The group of people involved in the construction of the building consists of the owner, structural engineer, architect, contractor, and local authorities who make contributions to the overall making plans, selection of structural machine, and its configuration. This may lead to the construction of buildings with irregular distribution of the strength, stiffness, and mass along with the height of the building. The performance of these irregular buildings will not be the same as that of the regular buildings. Buildings having simple geometry and uniformly distributed stiffness and mass in elevation and the plan will suffer from fewer damages than buildings with irregular configurations in their life span.

According to IS 1893 : 2016 irregularities in the buildings are categorized into two groups as follows,

1. Plan irregularities
2. Vertical irregularities

The greatest challenge for any structural engineer in today's scenario is to design seismic-resistant structures. A regular building behaves normally when subjected to seismic forces because its mass and stiffness are uniformly distributed throughout its height, vertically irregular structure subjected to earthquake forces is a matter of concern. Points of a sudden change in stiffness, mass, and strength in buildings are known as weak points. For the design of safe irregular buildings, it is necessary to study the effect of irregularity on the response of buildings to lateral loads.

II. METHODOLOGY

The following methodologies have been adopted to quantify the responses of cantilevered offset type vertical irregular RC building and arrive at response indices. Initially, gravity load analysis is performed for the considered case of vertical irregularity. And critical results are evaluated. Next, modal analysis has been conducted to understand the vibrational characteristics like mode shapes, time-period, frequencies, and mass participation at various modes. Further, equivalent static and dynamic time history analysis will be performed

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and key responses as mentioned above are recorded. Based on the key responses, particular response indices are evaluated and presented.

III. MODELING AND ANALYSIS

Initially, a reference RC structure has been modeled using ETABS software without any irregularity. This model is considered as a base model where the deviation of all responses from the vertical irregular structure is quantified for the base model. Similar constituent properties for both regular and irregular structures are considered. Height is constant for all the buildings. The variation in the A/L ratio which is greater than 0.1 is incorporated into the irregular models (Fig. 1). The following Table 1 will give model information regarding the number of models considered in the present work. The total number of models considered is 60 including 6 base models without any irregularity which are considered as based models. The models are categorized into 6 types (Type A to Type F). Each type consists of 10 models.

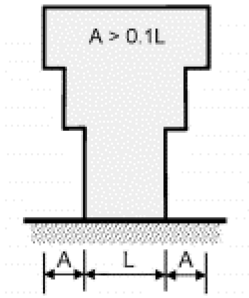

Fig. 1: Vertical Geometric Irregularity with Cantilevered offset

Table. 1: Number of Models for Analysis

Case	No. of Models	Remarks
$A < 0.1\ L_1$	6	Base model without vertical irregularity
$A = 0.10\ L_1$ to $A = 0.5\ L_1$	27	L = 9 m, 12 m and 15 m (For constant H = 15 m)
$A = 0.10\ L_2$ to $A = 0.5\ L_2$	27	L = 12 m, 16 m and 20 m (For constant H = 15 m)
Total No. of Models	60	

Model Description - Typical Plan and elevation of types of models considered for the our study is shown below

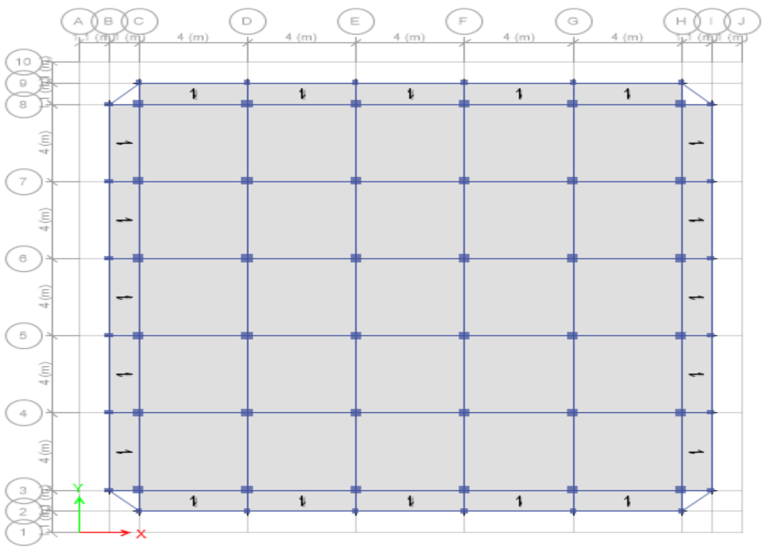

Fig. 2: Typical Plan at Storey 8 with Cantilevered offset - Type F Model

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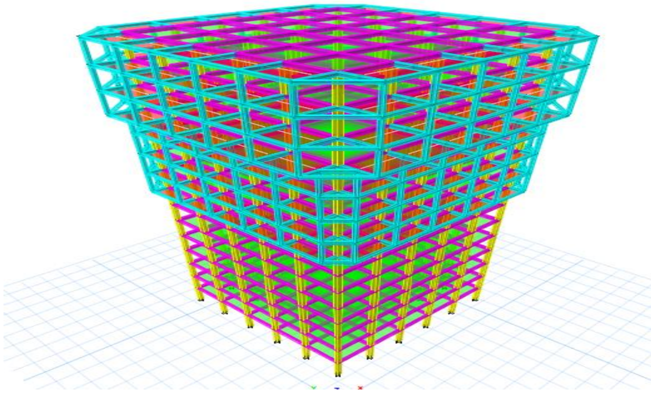

Fig. 3: 3D- Render view with Cantilevered offset - Type F Model

IV. RESULTS AND DISCUSSION

The results extracted from the gravity and lateral analysis of all the sixty models are presented in the form of tables and graphs. The results are interpreted, and technical discussions are made. Further an attempt has been made to generalize the response for other building configurations in the form of rations/indices or general forms of equations. Results are presented and interpreted separately for different types categorized as Type A to Type F, where each type contains a set of ten models.

Gravity Load Analysis Results: Type A-Type C (3 m - Bay)

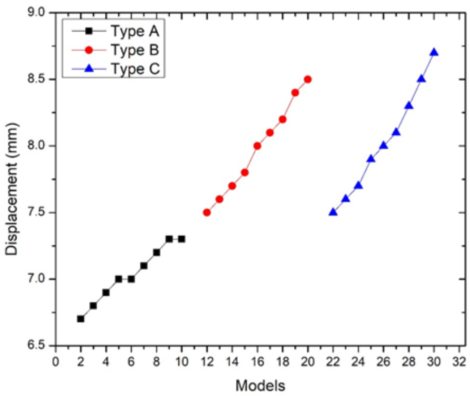

Fig. 4 : Displacements of Type A, Type B and Type C Models

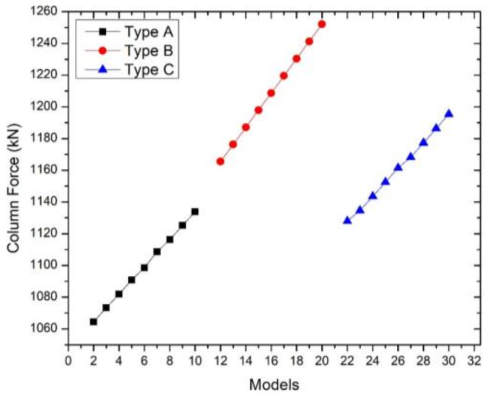

Fig. 5: Column Forces of Type A, Type B and Type C Models

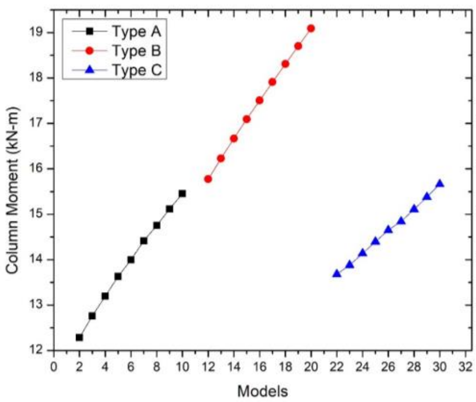

Fig. 6: Column Moments of Type A, Type B and Type C Models

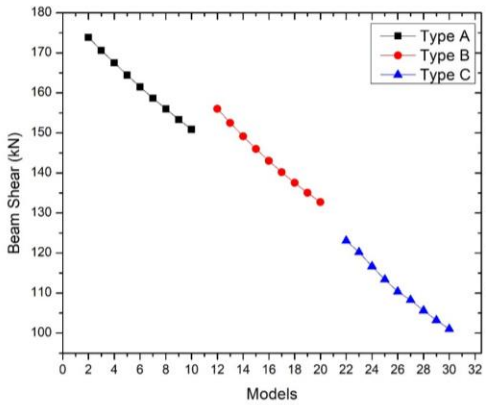

Fig. 7: Beam Shear of Type A, Type B and Type C Models

There is a 40% increase in deflection, 53% increase in column force, 38% in beam moment. On the contrary column moments and beam shear decreases with the increase in cantilevered offset of 16.75% and 13% respectively (Fig. 4-3 and Fig. 4.4). Similar observations have been made in Type B and Type C models which can be observed from Fig. 4 to Fig. 7

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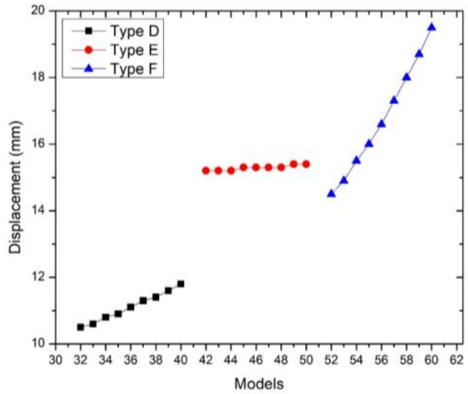
Gravity Load Analysis Results: Type D-Type F (4 m - Bay)



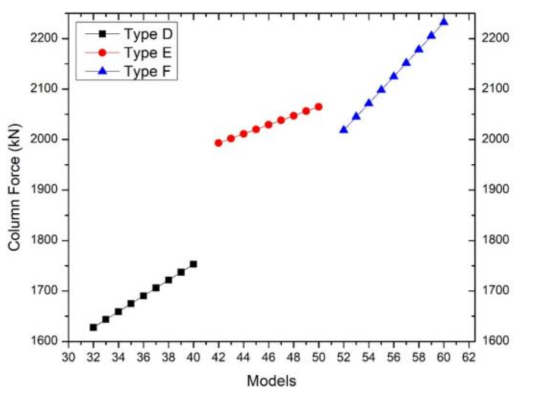
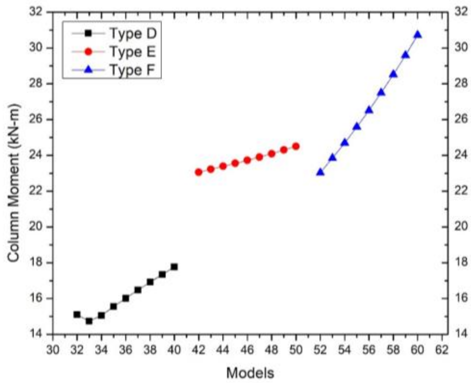


Fig. 8 : Displacements of Type D, Type E and Type F Models **Fig. 9:** Column Forces of Type D, Type E and Type F Models



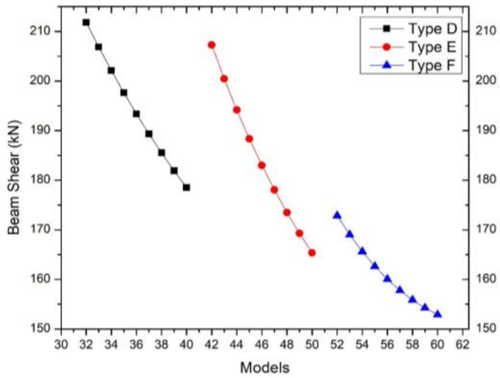
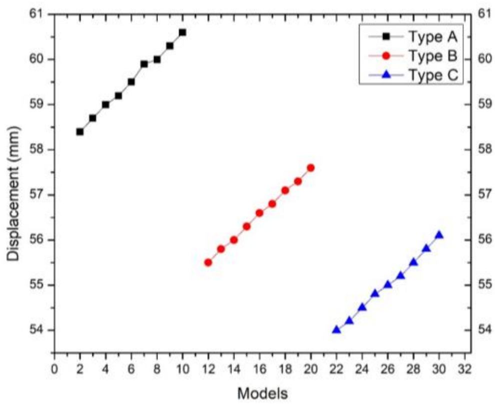


Fig. 10 : Displacements of Type D, Type E and Type F Models **Fig. 11:** Column Forces of Type D, Type E and Type F Models

With the increase in bay size from 3 m to 4 m, and responses from Model 30 and Model 60, an increase in 124%, 86%, 96% 104% and 51% in displacements, column forces, column moments, beam moments and beam shear respectively has been observed. From Fig. 8 to Fig. 11, it has been observed that, all the forces in Type F models are more in comparison with the Type D and Type E models.

Earthquake Load Analysis Results: Type A-Type C (3 m - Bay)



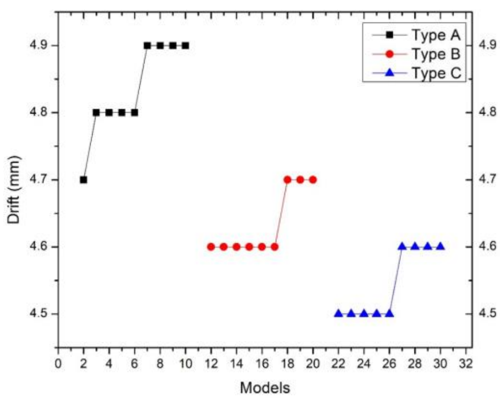
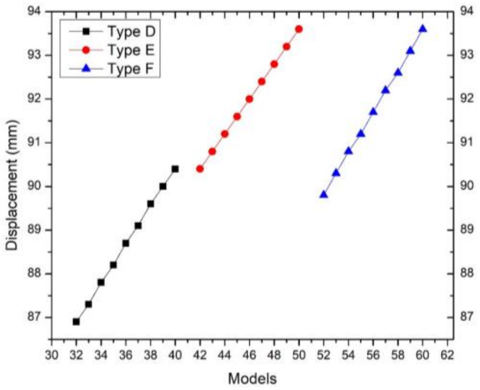


Fig. 12 : Displacements of Type A, Type B and Type C Models **Fig. 13:** Drifts of Type A, Type B and Type C Models

From lateral load analysis, it is found that maximum displacement & drift is found in Type-A i.e 60.6 mm and 4.9 mm and minimum is in Type C model 56.1 mm and 4.6 mm which is about a decrease of 7.5% and 6.1% in lateral displacement and drift respectively. A decrease in trend of displacement and drift can be observed in Fig. 12 and Fig. 13

Earthquake Load Analysis Results: Type D-Type F (4 m - Bay)



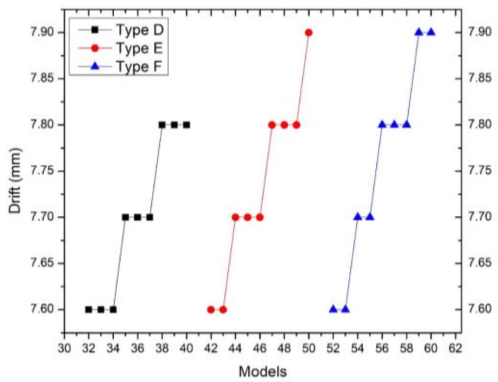


Fig 14 : Displacements of Type D, Type E and Type F Models **Fig. 15:** Drifts of Type D, Type E and Type F Models

It can be observed that, by comparing Type A (Model 1) and Type F (Model 6) models, there is a significant increase in lateral displacement and drift of about 59.4% and 61.2% respectively. Variation in displacement and drifts can be quantified and observed in Fig. 14 to Fig, 15

Generalization of Response Characteristics of the Present Study

The present study focuses on finding the effect of cantilevered offset due to gravity and lateral loads for total lateral dimension of the building 12 m with bay width of 3 m each and 20 m with 4 m bay width. In this portion a generalized response equations are given in order to find the response characteristics of buildings with overall dimension other than the 12 m and 20 m.

Generalization of Equations for Gravity Load Responses

Using regression analysis, a linear relationship between cantilevered offset and various response quantities has been formulated and presented in this section. Here, cantilevered offset is taken as an independent variable, deflection and member forces are considered as dependent variables.

Table 2: Generalised Expression for gravity loads – Type A to Type C (3 m Bay)

Responses	Generalized Expressions
Displacements	$y = -0.1881x + 4.9305$
Drifts	$y = -0.1881x + 4.9305$

Table 3: Generalised Expression for gravity loads – Type D to Type F (4 m Bay)

Responses	Generalized Expressions
Displacements	$y = 3.3841x + 83.75$
Drifts	$y = 0.1279x + 7.4636$

V. CONCLUSION

Maximum Cantilever offset depends on bay width and overall dimension of the building as per IS 1893 (Part – 2) 2016. From the gravity analysis of our study, it can be concluded that there is a significant effect of member forces and deflection on cantilever offset building. A reduction in column moment has been observed with the increase in cantilevered offset. This is due to the increase in beam moments and the transfer of these moments to columns in the form of axial loads to columns. There is a significant effect of cantilevered offset in response to lateral load analysis since a maximum increase in lateral displacement and drift of about 59.4% and 61.2% respectively. From the regression analysis and linear expressions, having an R2 value close to 1.0 can be used as a general expression to find out the deflection, later sway, and various member forces for various cantilever projection within the range considered and for various lateral dimensions of the buildings with 9 m to 20 m.

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