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Comparative study on Plan Irregular RC Frame Building with Force Based Design and Direct Displacement Based seismic Design

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Abstract: Earthquakes are one of the most disastrous forces which cannot be prevented but their effects can be minimized with minimal causalities of lives and structural damages. Over the past decade, analysis of the seismic site response has gone from a topic of controversy to the mainstream issue addressed in most building codes, research and practice. Structural design has headed a path from Conventional method Seismic Design i.e., Force Based Design (FBD) towards Performance-based Design. Performance levels, indeed, are described in terms of displacements, as damage is better correlated to displacements rather than forces. As a consequence, new design approaches, based on displacements, have been recently implemented. One of such approach is the Direct Displacement-Based Design (DDBD), proposed by Priestley (1993). This paper presents a comparative study on RC frame buildings with plan irregularity using Force based design (FBD) and Displacement based design (DDBD). Here the building is analyzed and designed with linear static and non linear static or push over analysis. And the results are compared in terms of Percentage of reinforcement (P_t), Base shear (V_B) and Response Reduction Factor (R).

Keywords-Force Based Design (FBD), Direct Displacement-Based Design (DDBD), Percentage of reinforcement (P_t), Base shear (V_B) and Response Reduction Factor (R)

I. INTRODUCTION

Over the past decade, analysis and determination of the seismic site response has gone from a topic of controversy to the mainstream issue addressed in most building codes, research and practice. Only the right estimate of the earthquake force and reliable seismic analysis finds the way to minimize the damage in casualties and structures. Conventional force based seismic design (FBD) uses empirical approach without giving due considerations to the displacements which accounts for actual earthquake excitation. Although the structure is designed to yield during the design earthquake, only the elastic part of the response, up to yield, is examined. After the elastic limit, strength plays lesser role while the displacement leads to the failure depending on ductile feature of the building. Therefore, ductility demand on structural elements is the major criteria to prevent collapse of the building. And the overall deformation of the structure needs to be controlled. Hence Structural design has headed a path from Working Stress Design towards Performance-based Design. As design criteria are expressed in terms of achieving stated performance objectives when the structure is subjected to stated levels of seismic hazard. Performance levels, indeed, are described in terms of displacements, as damage is better correlated to displacements rather than forces. As a consequence, new design approaches, based on displacements, have been recently implemented. One of such approach is the Direct Displacement-Based Design (DDBD), firstly proposed by Priestley (1993). The fundamental principle of DDBD is to obtain a structure which will reach a target displacement profile when subjected to earthquake forces. As per IS 1893 during earthquake, irregular buildings having different type of irregularity shows more complex behavior than regular shaped buildings. So a detailed investigation of irregular type of building is needed.

Present work involves a comparison of a plan irregular RC frame building with FBD and DDBD using linear static and non linear static analysis using SAP 2000.

II. STRUCTURAL MODELLING AND ANALYSIS

The irregularity is given as per IS 1893 Cl.7.1. i.e., Plan configurations of a structure and its lateral force resisting system contain re-entrant corners, where both projections of the structure beyond the re-entrant corner are greater than 15 percent of its plan dimension in the given direction. Re-entrant corners are provided to the regular structure to analyze the behavior of an irregular building under seismic designs. The building dimensions and loading data and also the seismic parameters are provided in Table 1, Table 2 and Table 3 respectiely.Figure1:, shows the plan view of the model. After modeling the building is analyzed with linear static analysis and non linear static analysis. The load combinations for linear static analysis as per IS 1893 are as follows.

1. 1.5(DL+LL)
2. 1.2(DL+LL±EQL)
3. 1.5(DL±EQL)
4. 0.9(DL±1.5EQL)

Non linear static or push over analysis is performed in the building assuming maximum displacement occurs in between ground and first floor levels.

Table 1: Model Dimensions

Type of frame	Special Moment Resisting RC Frame
Grade of concrete	M 25(f_{ck}= 25 N/mm^2)
Grade of reinforcing steel	Fe 415 (f_y = 415 N/mm^2)
Density of concrete	25 kN/m^3
Bay size	4m x 4m
Number of stories	G + 9
Floor height	3.5m
Beam size	350mm x 650 mm
Column size	700 mm × 700 mm
Slab thickness	150 mm
Wall thickness @ exterior portion	230mm
Wall thickness @ interior portion & parapet	115mm
Foundation	Isolated footing

Table 2: Loading data

Live load at typical floor	2kN/m^2
Live load at roof	2kN/m^2
Floor finish at typical floor	1kN/m^2
Floor finish at terrace floor	1kN/m^2
Self weight of slab(150mm thick)	3.75kN/m^2
Wall load at typical floor(230 mm thick)	13.11kN/m^2
Wall load at typical floor (115 mm thick)	6.55kN/m^2
Parapet wall load at terrace(115 mm thick)	2.3kN/m^2

Table 2: Seismic Parameters

Seismic Zone	Zone 3
Seismic zone factor z	0.16
Soil Type	Type 2 (Medium soil type)

Importance factor	1
Response Reduction factor	5

The equivalent displacement is calculated using the expression $\Delta_d = \frac{\sum_{i=1}^{n}(m_i \Delta_i^2)}{\sum_{i=1}^{n}(m_i \Delta_i)}$. And it is found out to be 0.3m. Where m_i is the mass at each floor and Δ_i is the design displacement at each floor of the building assuming the critical displacement is 2% of height of first storey from ground storey.

III. RESULTS AND DISCUSSIONS

After the analysis the reinforcement details of a beam at supports in each floor is found out and compared. Figure 2 shows the reinforcement detail of the beam at support using FBD and DDBD. From Figure 2 it is clear that that P_t values decreases from GF to top floor. FBD requires more percentage of reinforcement compared to DDBD from GF to terrace floor. Figure 3 represents the percentage reinforcement of column at each storey; in this we can see a constant variation of reinforcement between FBD and DDBD from GF to the top floor. It is clear from the graph that FBD requires more reinforcement than DDBD. Fig.4 shows a comparison between FBD and DDBD in terms of base shear. It is nothing but the capacity of the building or the total force acting at the base of the building. It is clear from the graph that the base shear force in x and y direction using FBD is less than DDBD. Which shows that the building designed using DDBD has more capacity compared to those with FBD.And also here included the comparison of FBD and DDBD in terms of Response Reduction Factor (R) it reflects the capacity of structure to dissipate energy through inelastic behavior. It is calculated by R= R_S*R_R*R_μWhere R is the Strength level response modification coefficient & R_S is the Period dependent strength factor, R_R is the Redundancy factor and R_μ is the Period dependent ductility factor. R_x is found out to be 5.61 and R_y is found to be5.11.Figure 5:, shows a comparison of response reduction factor between FBD and DDBD. It is clear from the graph that the R value in x and y direction is constant in FBD and it get increased in DDBD in both x and y direction.

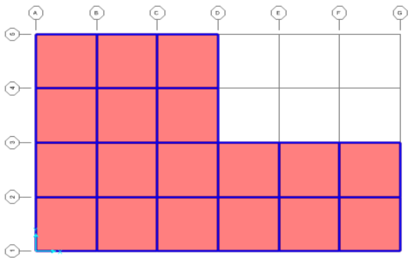

Figure 1:, Plan view of the building

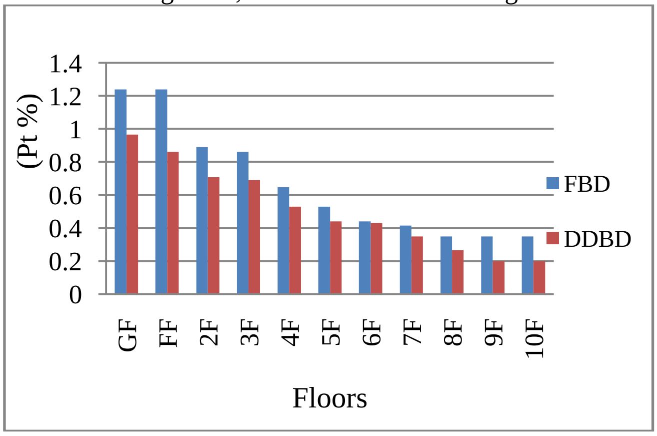

Figure 2:, Percentage reinforcement of a beam

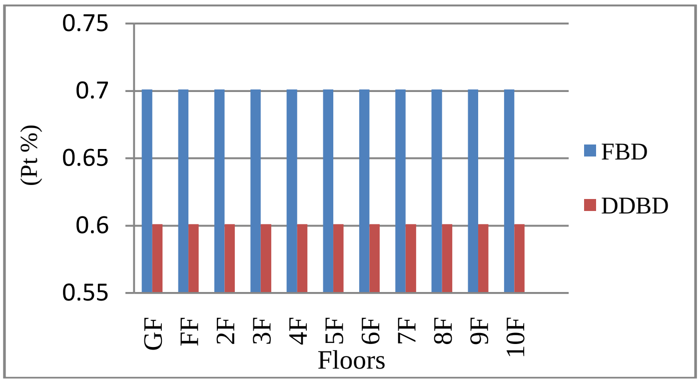

Figure 3:, Percentage reinforcement of a column

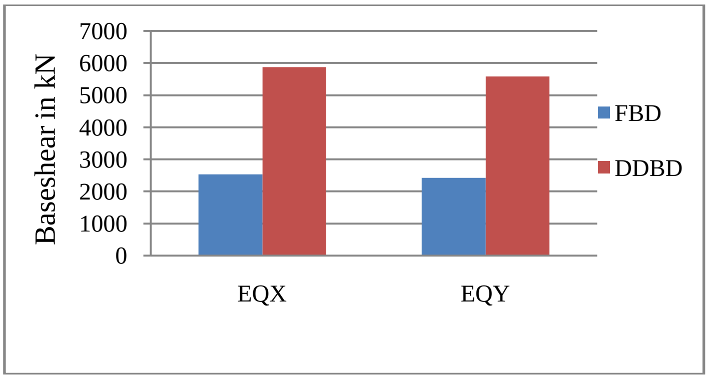

Figure 4:, Base shear values in X and Y direction

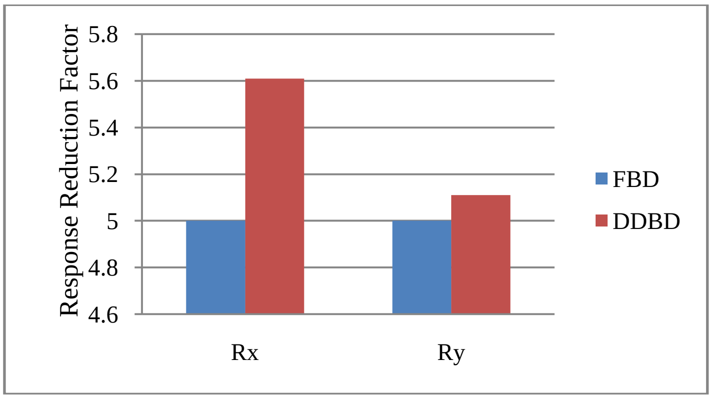

Figure 5:, Response Reduction values in X and Y direction

IV. CONCLUSIONS

The building is modeled, analyzed and designed with FBD and DDBD. From the observations it is cleared that the building designed using DDBD requires less reinforcement compared to those designed with FBD in terms of both beams and columns. And also the Response reduction factor shows an increase of 12.2% from FBD to DDBD. Hence the building will have more strength and ductility when designed with DDBD. And also the building designed with DDBD shows about 132% and 130% increase in base shear in x and y direction respectively compared to FBD. This shows that the capacity of building is more in DDBD compared to FBD.

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