Design of RC Frame- ShearWall Building Using UPBD Method

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***Abstract*--The RC frame-shear wall building or dual system is a common form of reinforced concrete tall building. The frame are generally designed to independently resist 25% of the design base shear and the rest 75% of the base shear is resisted by the shear walls. The present study is aimed at ascertaining the applicability of UPBD (Unified Performance-Based design) method in carrying out performance-based design of reinforced concrete frame- shear wall buildings for any given target performance objectives under specified hazard level. Frame-shear wall buildings of heights 16 storey and 20 storey have been considered as sample buildings. The target performance objectives considered is IO performance level with 1% drift. For analysis and design of buildings, SAP2000 v14 has been used . Beams and columns have been modeled as frame elements and shear walls have been modeled as wide columns. Beam and shear wall sizes have been obtainedusing UPBD method and column sizes have been taken according to demand maintaining 3% to 4% of steel in column. Nonlinear default hinges are assigned to column and beam elements as per FEMA 356. User defined hinges have been provided to shear wall as per FEMA 356. For nonlinear time history analysis, spectrum compatible ground motions (SCGM) have been used.**

I. INTRODUCTION

General:Reinforced Concrete frame-shear wall building is a common form of reinforced concrete tall buildings. The frame-wall structure is also known as a dual system. Typically, it consists of an assembly of shear walls and moment-resisting frames. In the present paper the effect of frame shear wall building without infill struts has been studied. The design method used is UPBD method.

***Performance-Based Design*:**InPerformance-based design (PBD) method a structure is designed for some target performance objectives under specified hazard level. The PBD methodology is the deformation-based design rather than a force-based design. Therefore, due consideration is given to the nonlinear behavior of the structure. PBD methods differ from codal method in the way that here the building is designed for a set of target performance objectives. In codal design, it is not possible to design a building for a laid down performance-objectives.

II. LITERATURE REVIEW

Fajfar(2000)presented a nonlinear analysis method for performance based seismic design. The method is formulated in the acceleration displacement format which enables the visual interpretation of the procedure and the relation between the basic quantities controlling the seismic response.

Sullivan*et al*.(2003)presented the limitations and performances of different displacement based design(DBD) methods. This paper presents the findings of a study that uses eight different DBD methods to undertake the seismic design of five different case studies. Some significant limitations with the eight methods have been identified through their application to realistic examples.

Kappos and Gregories(2004) presented PBD procedure of realistic 3DRC buildings. Pettinga and Priestly (2005) presented the direct displacement based design methodology for reinforced concrete tube frame structures. An improved design displacement profiles and equivalent lateral force distribution were developed for the DDBD method.

Sullivan*et al*.(2006) presented the procedure of direct displacement based design of frame wall structures. Within the new procedure, strength proportions between the walls and frames are assigned and are used to establish the design displacement profile. This paper also gives an expression for the equivalent SDOF system or equivalent viscous damping that takes into account the frame-wall interaction.

Priestly *et al.* (2007) presented a book on Displacement Based seismic design of structures. This book gives the full details of the procedure of displacement based design structures.

Choudhury (2008) improved the DDBD method of Sullivan*et al*. (2006) byincorporating both performance level and drift limit together. The method was called as UnifiedPerformanceBasedDesign(UPBD)method.

Singh and Choudhury(2013) established a new approach in UPBD method so that the estimation of column size was incorporated in the design.

III.DIRECT DISPLACEMENT BASED DESIGN (DDBD) OF FRAME-WALL STRUCTURES

The direct displacement based design of frame wall structure is given by Sullivan, *et al*.(2006). Various steps have to be followed for seismic design of frame- wall structures. The MDOF system has to be converted into an equivalent SDOF system by assigning strength proportions and subsequently using moment profile in the walls to set a design displaced shape. The required effective period and stiffness of the structure is determined using the substitute structure approach. The design base shear is obtained though multiplication of the effective stiffness by design displacement. The wall inflection height isestablished by assigning strength proportion to the members. The storey shear and consequently the moment in the walls are used to establish the inflection height (h_{inf}) in the walls, where the moment and curvature is zero. The inflection height will be used to find the displacement of the structure at yield of the walls and to develop the design displacement profile.

Equivalent single degree of freedom (ESDOF) properties are determined using the following relations:

Design displacement $\Delta_d = \sum_{i=1}^{n} m_i \Delta_i^2 / \sum_{i=1}^{n} m_i \Delta_i$

Effective mass $m_e = \sum_{i=1}^{n} m_i \Delta_i / \Delta_d$

Effective height $H_e = \sum_{i=1}^{n} m_i \Delta_i h_i / \sum_{i=1}^{n} m_i \Delta_i$

Where, h_i = storey height, m_e = effective mass of the structure, H_e = effective height, m_i = seismic mass of i-th floor.

Frame and wall ductility demand are determined.

The yield displacement profile of wall is given by,

$$\Delta_{i,y} = \frac{\phi_{y,W} h_i h_{\text{inf}}}{2} - \frac{\phi_{y,W} h^2{}_{\text{inf}}}{6} \text{ when } h_i \geq h_{inf}$$

$$\Delta_{i,y} = \frac{\phi_{y,W} h^2{}_i}{2} - \frac{\phi_{y,W} h_i^3}{6 h_{\text{inf}}} \text{ when } h_i < h_{inf}$$

Wall ductility demand $\mu_W = \Delta_d / \Delta_{he,y}$

Frame ductility $\mu_{i,F} = \left(\frac{\Delta_i - \Delta_{i-1}}{h_i - h_{i-1}} \right) \frac{1}{\theta_{y,F}}$

Where, $\theta_{y,F} = \frac{l_b \varepsilon_y}{2 h_b}$

The equivalent viscous damping for the frame and walls is obtained adding the elastic and hysteretic component together as follows,

$$\xi_e = \frac{M_W \xi_W + M_{O,F} \xi_F}{M_W + M_{O,F}}$$

Where ξ_e is equivalent viscous damping of system, M_W is wall moment, $M_{O,F}$ is frame overturning moment, ξ_W is equivalent damping of wall, ξ_F is equivalent damping of frame.

The effective stiffness (K_e) is determined by,

$$K_e = 4\pi^2 \frac{m_e}{T_e^2}$$

Here, T_e is obtained from displacement spectra corresponding to Δ_d .

The base shear (V_b) is determined ,

$$V_b = K_e \Delta_d$$

The base shear force (V_b) is distributed up the height of structures

$$F_i = V_b \frac{\Delta_i m_i}{\sum \Delta_i m_i}$$

Where the F_i is the portion of base shear applied at the i-th floor.

IV. UNIFIED PERFORMANCE BASED DESIGN (UPBD) METHOD FOR FRAME-WALL BUILDINGS

Choudhury (2008) has further improved the Direct Displacement Based Design of frame wall buildings proposed by Sullivan *etal.*(2006), by combining the inter-storey drift and performance level through theoretical treatment. The performance level of building is related directly with the beams size. The beam depth is given by,

$$h_b = 0.5 \varepsilon_y l_b / (\theta_d - \theta_{pb})$$

Where, h_b is depth of beam, ε_y is yield strain of rebar, l_b is length of beam, θ_d is design drift and θ_{pb} is plastic rotation in beam corresponding to the performance level considered. The width of beam as kept half to two-third of beam depth.

The length of the frame wall is given by,

$$L_w = \varepsilon_y h_{inf} / (/(\theta_d - \theta_{pW})$$

Where, L_w is horizontal length of wall, ε_y is yield strain of rebar, h_{inf} is height of inflexion, θ_d is design drift and θ_{pW} is plastic rotation in wall corresponding to the performance level considered. The thickness of wall is obtained from base shear consideration and number of wall used in a particular direction.

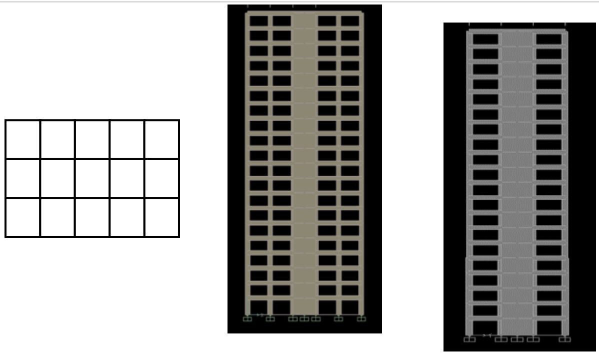
The inflection height of the frame shear wall building is calculated by finding the moments carried by shear wall.The vertical distribution of wall moment found out by subtracting the linear distribution of frame moments from the total overturning moments. At the wall moment , there exist a contra flexure point and the height up to that point from the base is the inflection height.

V.SCOPE OF THE PRESENT WORK

In the present study, reinforced concrete frame-shear wall buildings with heights 20 storey and 16 storey and are considered as sample buildings. IO target performance level is considered . Plan is shown in Fig. 1. Shear walls are shown in Fig. 1.

The materials used in the structure are M30 grade concrete and Fe500 HYSD grade steel bars.

For capacity design we used EC-8 2000 is used. The spectrum compatible ground motions have been generated by using software developed by Kumar (2004).



(a) (b) (c)

Fig. 1:(a) Plan; (b) & (c) Elevation of shear wall in long and short directions.

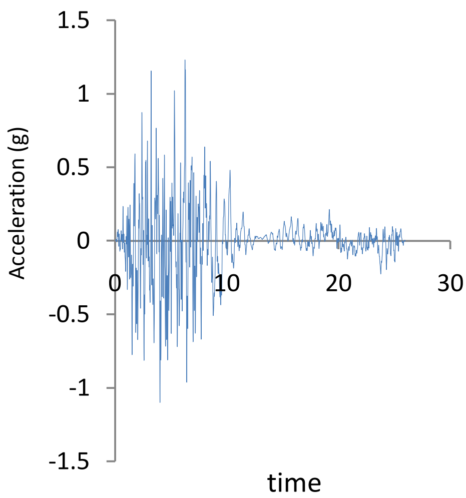


Fig. 2: SCGM (IS Spectra) after Mammoth Lakes, 1980 Earthquake

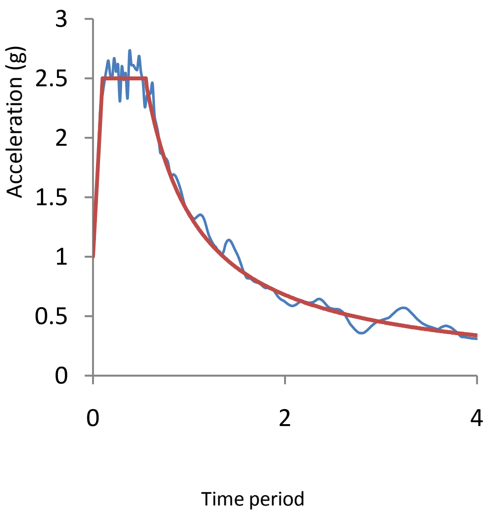


Fig. 3: IS Spectra and response spectra corresponding to SCGM.

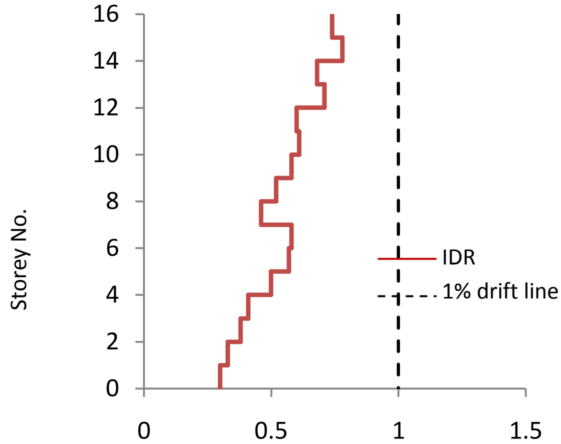


Fig. 4: IDRfor 16-storey in short direction

VI. RESULTS AND DISCUSSIONS

The results obtained out of nonlinear analysis are discussed here. Sample SCGM is shown in Fig. 2. The match of the SCGM with IS design spectrum is shown in Fig. 3. Roof displacement histories have been captured for all floor levels along two orthogonal directions of the buildings. From this, the Interstorey Drift Ratio (IDR) have been computed.

Fig. 4 shows the IDR diagram for 16-storey building along the short direction of the building. Fig. 5 shows the IDR diagram for the same building along the long direction of plan of the building.

Fig. 6 and Fig. 7 show the IDR diagram for 20-storey building along the short and long direction respectively. From these IDR diagrams it is found that the buildings have achieved drifts less than 1% which was the target drift.

Fig. 8 shows a typical pushover curve for 20-storey building. The curve shows that IO has been achieved.

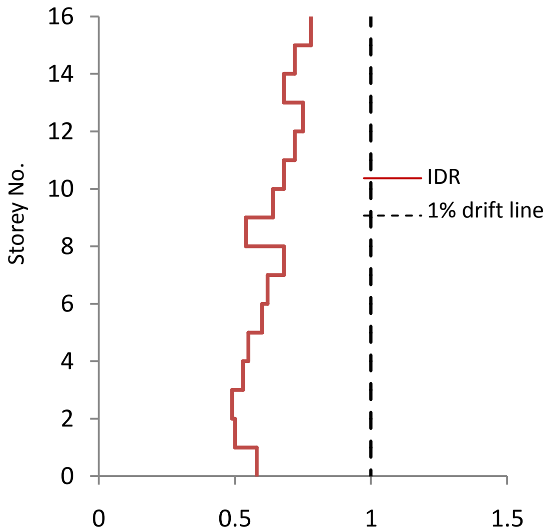


Fig. 5: IDRfor 16-storey in short direction

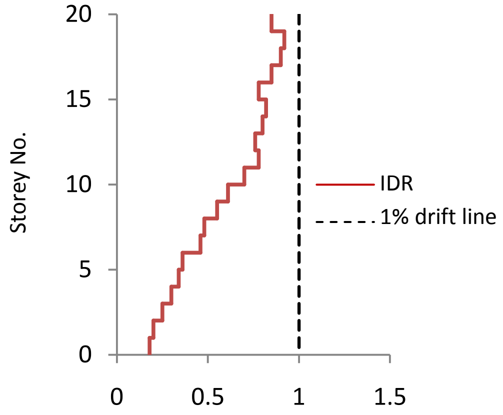


Fig. 6: IDRfor 20-storey in short direction.

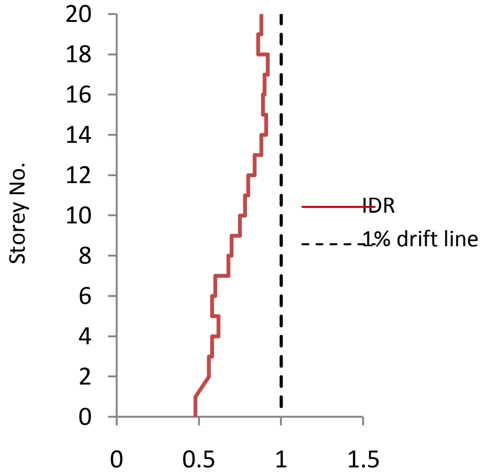


Fig. 7: IDR for 20-storey in long direction.

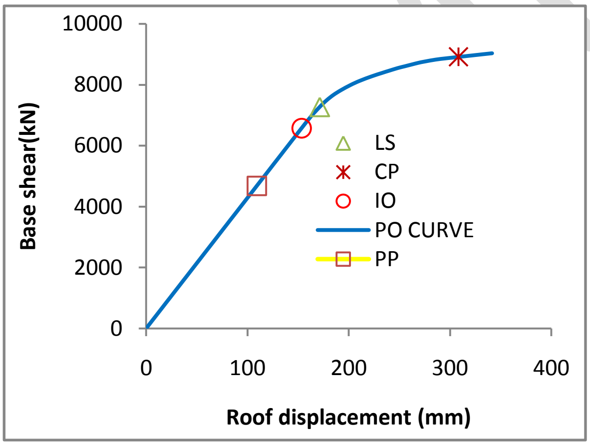


Fig. 8: Pushover curve for 20-story building

Table 1: Target vs. achieved performance

Buildings	Target		Achieved		
	Drift	PL	Drift		PL
			Short dir	Long dir	
16 storey	1%	IO	0.75	0.80	IO
20 storey	1%	IO	0.95	0.90	IO

Table 1 gives the gist of the findings. It shows that the target performances have been achieved for the reported buildings.

VII.CONCLUSION

The performance of RC frame shear wall buildings designed with UPBD method have been evaluated. The performance have been evaluated under non linear static analysis (NSA) and non linear time history analysis (NLTHA). Within the purview of the study following conclusions have been drawn.

1. The UPBD method for RC frame-shear wall buildings can be used for any target performance objective under any given hazard level.
2. For the buildings considered it has been found that inter drift ratio (IDR) remained in the design drift limit.
3. The target performance level for the buildings considered has been achieved.

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