Effect Of Location Of Lateral Force Resisting System On Seismic Behaviour Of RC Building

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ABSTRACT- In this study the influence of location of lateral force resisting systems on the response reduction factor (R), ductility and plastic hinge status at performance point of the RC buildings were studded. The present paper made an attempt to study 4 types of 10 storey RC frame structure with different positions of shear wall on the symmetrical floor plans. Nonlinear pushover analysis has been performed using ETABS software in according with IS1893-2002. The actual values required for determination of response reduction factor (R), ductility and performance of the building are work out on the basis of pushover curve which is a plot of base shear verses roof displacement and pushover curve gives the actual capacity of the structure in the nonlinear rang. The results show that due to transfer the shear wall to the inner core, response reduction factors (R) and ductility reduce, but the number of plastic hinges beyond collapse increase. So it is essential to consider the effect of shear wall shifting for the seismic evaluation of RC buildings.

Keywords - Plastic hinge, performance point, response reduction factor, ductility, nonlinear pushover

I. INTRODUCTION

A. Torsional irregularity

Torsional irregularity mentioned in IS1893-2002 is just description of definition of torsional irregularity as the maximum storey drift, computed with design eccentricity, at one end of the structure transverse to an axis is more than 1.2 times the average of the storey drift at the two ends of the structure [1]. There is no mention of effect of this irregularity in building frames. As compression with FEMA273 for liner analysis of building with rigid diaphragms when the ratio of maximum storey drift $(\delta_i)_{max}$ to the average storey drift $(\delta_i)_{ave}$ due to total torsional moment exceeds 1.2, the effect of accidental torsion be amplified by a factor $A_x = [\frac{\delta_{max}}{1.2\,\delta_{ave}}]^2$ and $1 \le A_x \le 3$, [2].

In this study due to the transfer the lateral force resisting systems to the inner core of structure, in model-4 torsional irregularity is appeared because of inner core shear wall.

The accidental torsion, that is an accidental torsional moment produced by horizontal offset including the given floor, equal to maximum of 5% of the horizontal dimension at the given floor level measured perpendicular to the direction of the applied load [2]. Thus when a structure does not satisfy $[\frac{\delta_{max}}{\delta_{ave}}] < 1.2$, accidental torsion must be increase.

B. Response reduction factor

The response reduction factor or force modification factor (R) reflects the capacity of structure to dissipate energy through inelastic behavior. It is combined effect of over strength, ductility and redundancy represented as

$$R = R_s * R_R * R_\mu$$

Where:

$\boldsymbol{R_s}$: Is the over strength that defined as the ratio of the base shear at yielding to the design lateral strength, $R_s = \frac{V_y}{V_d}$

$\boldsymbol{R_R}$: This factor is intended to quantify the improved reliability of seismic framing system that uses multiple lines of vertical seismic framing in each principle direction of the building.

A system with little redundancy in the lateral force resisting system would have a lower redundancy factor than that of a system with greater redundancy. The more redundant a structural system, the higher the redundancy factor. R_R Cannot however, be larger than one. ATC-19 proposed draft values of the redundancy factor. ATC-19 published R_R values to encourage research and thought on the effects of redundancy on the behavior of a structural system under lateral seismic loads. The committee did not intend the values to be used in design ATC-19 because the effects of redundancy had not been studied in depth [3]. Redundancy factors are tabulated in table 1.

Table 1. Draft redundancy factors, ATC19- 1995

Lines of Vertical Framing	Draft Redundancy Factor
2	0.71
3	0.86
4	1.00

$\boldsymbol{R_\mu}$: Is the ductility reduction factor. The ductility factor is period dependent and based on the ductility ratio. The ductility ratio is the ratio of the yield displacement to the allowable displacement or maximum considered displacement. Several teams of researchers, such as Miranda and Bertero or Nassar and Krawinkler, each developed methods to determine the period dependent ductility factor from the ductility ratio and the fundamental period of the structure. All methods produced similar results, so the method selected for determining R_μ has no significant effect on the outcome of *R*. Miranda and Bertero in 1994 present one method for rock, alluvium or soft soil sites [3].

$$R_\mu = \frac{\mu - 1}{\emptyset} + 1 \geq 1$$

$$\emptyset = 1 + \frac{1}{12T - \mu T} - \frac{2}{5T} e^{-2(lnT-0.2)^2}$$ For alluvium soli

Where: μ = ductility ratio, $\frac{\Delta_{max}}{\Delta_y}$

The key components of R factor, over strength and ductility can be worked out on the basis of pushover curve as shown in fig1.

Over strength and ductility were obtained from nonlinear static pushover analysis that has been suggested in FEMA365 and ATC40. The guidelines ATC and FEMA mentioned include modeling procedures, acceptance criteria and analysis procedures for pushover analysis. These documents define force–deformation criteria for potential locations of lumped inelastic behavior, designated as plastic hinges used in pushover analysis [4,5]. ETABS implements the plastic hinge properties described in FEMA365 and ATC40 [6].

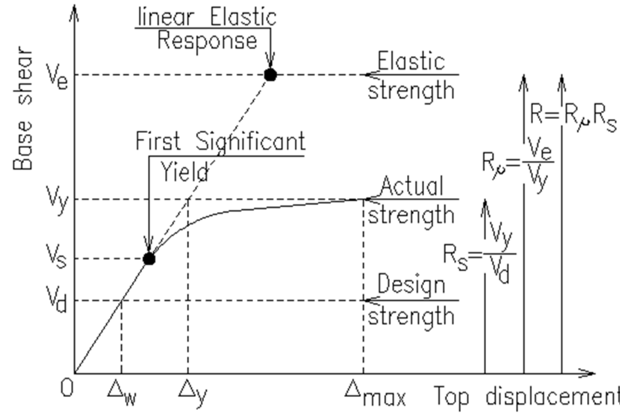

Figure 1. Relationship between force reduction factor (R), over strength (R_s) and ductility (R_μ)

C. *Objective of the study*

To obtain the response reduction factor (R), ductility, plastic hinge status at performance point of the building on different position of lateral force resisting system located in seismic zone IV of India, and also identify the most vulnerable building among the models.

D. *Scope of the study*

This work is focused on the study of seismic demands of different position of shear wall in RC buildings using various analysis techniques such as Equivalent static analysis method, response spectrum method and pushover analysis for seismic zone IV India. The analysis result would be compered for 10 storey buildings in terms of the response reduction factor (R), ductility, and plastic hinge status at performance point in nonlinear analysis using IS1893-2002.

II. DESCRIPTION OF STRUCTURAL MODEL

In this study symmetrical floor plan layout of 3D reinforced concrete residential building with moment resisting RC frame and dual systems were selected as shown in fig 2 to 6. The buildings consist of 10 storey floor and a storey height of 3.0 m each in all the floors, but the plan was unaltered to avoid any irregularity effects. Buildings are located in seismic zone IV, and soil profile type was assumed to be medium. Response reduction factor for the special moment resisting frame has taken as 5. All the four models are designed and analyzed as per IS456, 2000 [7]. Further inputs include unit weight of the concrete is 25 KN/m^3, elastic modulus of concrete is $25*10^6$ KN/m^2, compressive strength of concrete is 25 N/mm^2 (M25), yield strength of steel is 415 N/mm^2 (Fe 415),elastic modulus of steel is $2*10^8$ KN/mm^2. The loading of building was assumed to be dead load 5.5 KN/m^2, live load 2.0 KN/m^2, and weight of floor finishes is 1 KN/m^2. Percentage of imposed load to be considered in seismic weight calculation 25.The support condition of columns was assumed to be fixed at ground level. All columns and beams had different dimensions in height, dimension of columns vary between 0.40*0.40 m and 0.65*0.65 m, dimension of beam vary between 0.40*0.30 m and 0.30*0.30 m and thickness of slab is 0.15 m, and thickness of shear walls vary between 0.35*0.20 m. finally the example structure used in this study are following.

1. Model-1: Moment resisting RC frame.
2. Model-2: Dual system, shear walls are arranged in outer periphery.
3. Model-3: Dual system, shear walls are arranged in middle of building.
4. Model-3: Dual system, shear walls are arranged as inner core.

And elevation of buildings is shown in fig 6.

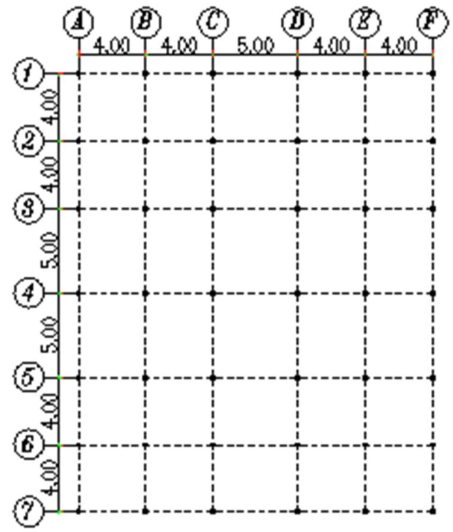

Figure 2: Model-1

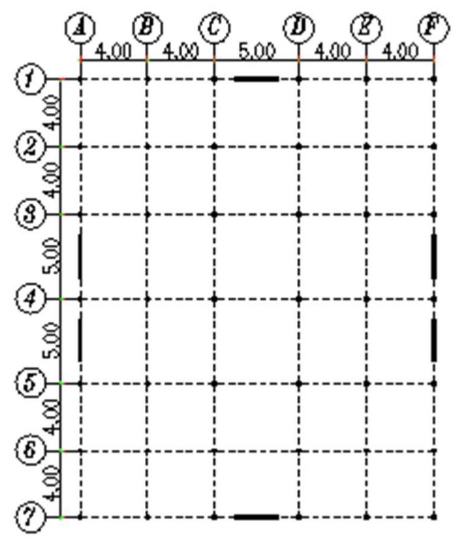

Figure 3: Model-2

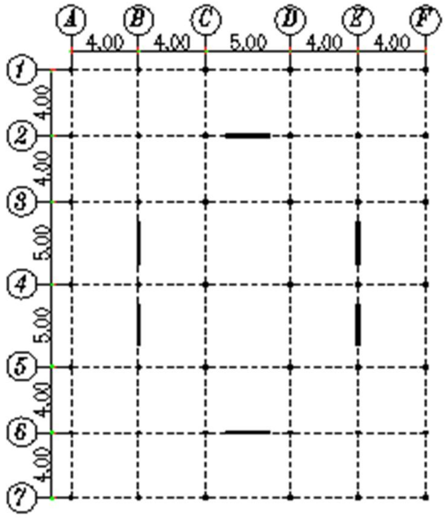

Figure4: Model-3

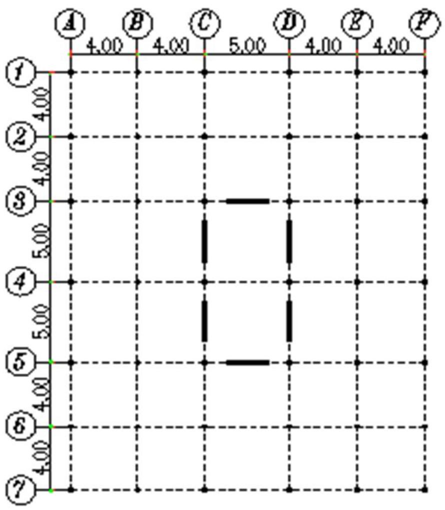

Figure 5: Model-4

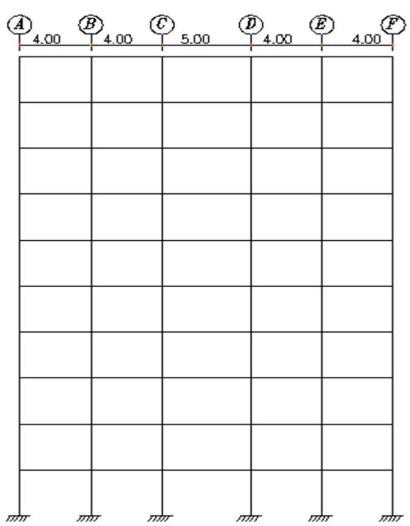

Figure 6: Elevation of buildings

III. ANALYSIS AND RESULTS

The nonlinear static pushover analysis was performed for all models. Models were designed and checked as per IS456, [7]. The comparative results of torsional irregularity, ductility and response reduction factor as per IS1893. Capacities of structures along with performance point as Immediate Occupancy (IO), Life Safety (LS), and Collapse Prevention (CP), for all models are shown in table 5.

A. Torsional irregularity results

Regarding with shifting the shear walls into inner core the ratio of maximum storey drift $(\delta_i)_{max}$ to the average storey drift $(\delta_i)_{ave}$ increase due to torsional moment, results are presented in table 2.

Table 2: Maximum and average store drift ratio

Type of Models	$(\delta_i)_{max}$	$(\delta_i)_{ave}$	Ratio
Model-1	0.021	0.0188	1.12
Model-2	0.0234	0.0221	1.058
Model-3	0.0128	0.0107	1.196
Model-4	0.0038	0.0030	1.27

B. Ductility ratios

Reinforced concrete structures for earthquake resistance must be designed, detailed and constructed in such a way that ductility factor will be limited to 3, [8]. The ductility ratios of the models analyzed are given in table 3.

Table 3: Ductility ratio in x-direction

Type of Models	Δ_{max}(cm)	Δ_y(cm)	μ
Model-1	44.76	11.01	4.06
Model-2	28.64	5.98	4.78
Model-3	24.59	5.39	4.56

Model-4	**19.65**	**4.9**	**4.01**

C. Hinge Status at Performance Point

Pushover curves obtained from nonlinear static pushover analysis shows capacity of the structure under axial forces and performance point. The first changes in curves, shows yield point for structural system. The performance of the structure is estimated by the state of the structure at performance point it can be done by studying the status of the plastic hinges formed at different location of structure. The point is that studying the state of hinges at performance point is important. The statuses of plastic hinges at performance point are tabulated in table 4. From the data presented in table 4, the effect of torsional irregularity on the status of plastic hinges at performance point can be seen. In this case as the torsional irregularity increase the number of hinges beyond collapse (D-E range) also increase.

Table 4: Hinge status at performance point in x- direction for all models

Models	**Disp (cm)**	**Base Shear**	**A-B**	**B-IO**	**IO-LS**	**LS-CP**	**CP-C**	**C-D**	**D-E**	**>E**	**Total**
Model-1	**36.72**	**215**	**2027**	**112**	**116**	**418**	**0**	**1**	**6**	**0**	**2680**
Model-2	**26.48**	**545.8**	**2035**	**169**	**371**	**101**	**0**	**0**	**4**	**0**	**2680**
Model-3	**23.14**	**544.0**	**2009**	**225**	**344**	**97**	**0**	**0**	**5**	**0**	**2680**
Model-4	**18.2**	**507.9**	**2042**	**298**	**293**	**37**	**0**	**2**	**8**	**0**	**2680**

*D. **Response reduction factor***

Base shear and displacement at performance level obtained from pushover curve are given in table 5.

Table 5: Base shear (ton) and Displacement (cm) at Performance level for all models

Type of Models	**IO**		**LS**		**CP**	
	Base Shear	**Disp**	**Base Shear**	**Disp**	**Base Shear**	**Disp**
Model-1	**169.35**	**11.01**	**187.79**	**13.64**	**217.74**	**44.76**
Model-2	**207.37**	**5.98**	**445.16**	**17.94**	**566.82**	**28.64**
Model-3	**212.90**	**5.39**	**423.04**	**13.89**	**561.29**	**24.59**
Model-4	**212.90**	**4.9**	**420.28**	**12.31**	**528.11**	**19.65**

From the data presented in table 1, 3 and 5, response reduction factor (R) is obtained as fallowing.

$$R = R_s * R_R * R_\mu$$

Results are tabulated in table 4

Table 6: Response reduction factor for all models

Type of Models	**R_s**	**R_R**	**R_μ**	**R**
Model-1	**1.28**	**1.00**	**3.98**	**5.10**
Model-2	**2.73**	**1.00**	**4.89**	**13.35**
Model-3	**2.63**	**1.00**	**4.7**	**12.36**
Model-4	**2.48**	**1.00**	**4.15**	**10.29**

IV. CONCLUSINONS

1. There is no mention for the effect of torsional irregularity in IS1893-2002, thus result shows that when shear walls shift to the inner core the ratio of maximum storey drift to the average storey drift, increase to more than allowable value 1.2. In this case the value of accidental torsional (5%) must be increase.

2. Ductility ratio for model with inner core shear wall has value 4.01, in comparison with outer periphery shear wall that has 4.78 value, from the above observation it can be seen that model with inner core shear wall regarding with shifting shear walls into inner core is going to be less. Although ductility ratio in model, without shear wall value in comparison with other models is less it can be said that building with inner core shear wall and without shear wall are more pronounce towards brittle failure.

3. It can be seen that when structural ductility increases, response reduction factor (R), increases.

4. In case of building without shear wall according to its value of response reduction factor R= 5.10 it can be observed that the buildings have less value of R as compared to building with shear wall.

5. It can be observed that due to shifting shear walls into inner core, the number of hinges in beyond collapse (D-E range) increase. Overall the performance of structure with outer periphery shear wall is satisfactory and more elements in model with inner core shear wall require retrofitting.

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