Seismic Reduction Factor for Simple Moment Resisting Steel Frames

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Abstract— In last decades moment resisting steel structures has played an important role in construction industry. Moment resisting steel frames are commonly used as the dominant mode of lateral resisting system in seismic regions for a long time. The seismic performance of multi storey steel frame buildings designed according to the provisions of the current Indian codes IS 800-2007 and IS 1893-2002. IS codes recommends unique value of R for steel frames. The objective of present study in moment resisting steel frame is to estimate the R values for frames having varying number of stories, designed as per IS codes and to compare them. The structures are subjected to non-linear static pushover analysis in SAP2000 version 19.2.2, to check its adequacy compared to code recommended R values. The R factors of these frames can be evaluate from their non- linear baseshear versus roof displacement curves (pushover curves).

Index Terms— Moment resisting steel frames, Pushover analysis, Response reduction,Non linear static analysis

1 INTRODUCTION

Earthquakes are most tragic natural hazards that makes major damage and fatalities in popular areas. Due to the aesthetic and economical constraints, engineers are forced to design the structures with most aesthetic beauty and cost effective and it should be adequately safe and strong enough. Nowadays an intensive life safety can be economically achieved by considering inelastic energy dissipation. When structural and non-structural members are subjected to lateral motion, and they are assured to return to their initial state without any permanent deformation and damages, then the structure is said to be in elastic range. But utilizing inelastic behaviour definitely makes the construction economical by reducing number sizes thus reducing material amounts and construction time resisting frame are primary lateral load resisting system. This type of construction was considered the safest one to be able to sustain large deformation in bending and shear.

The present study is conducted for a symmetric building with varying number of storeys with and without damper so as to effectively reduce the response of the structure to external excitation (seismic excitation) along with economy. By performing force based pushover analysis, the response reduction factor can be calculated for the building models. A comparative study of seismic performance is done. The parameters considered for the comparison are storey displacement and base shear. The frame is assumed as moment resisting frame, column bases are assumed to be fixed and connections as welded in all cases in the study.

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2 METHODOLOGY

The response reduction factor for multi-storey steel frame buildings designed and detailed as per IS code. In the force based seismic design procedures the R factor is the one used to reduce the linear elastic response spectra to the inelastic ones.in other words, response modification factor is the ratio of strength required to maintain the structural elasticity. Fig.1 represents the base shear versus roof displacement relation of a structure which can be developed by a non-linear static analysis. In this figure, real nonlinear behaviour is idealized by a bilinear elasto-plastic relation.

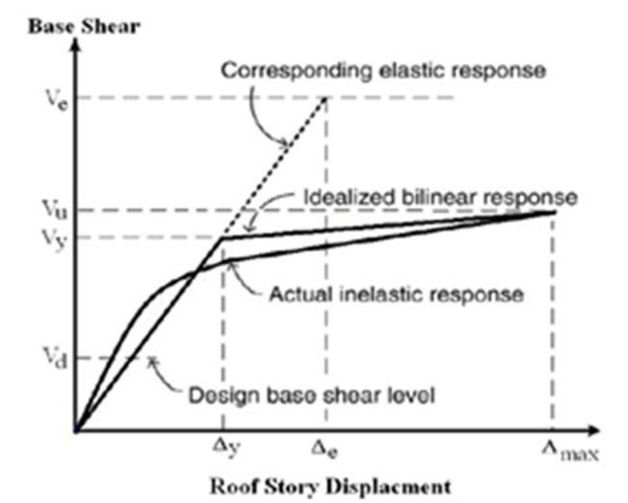

Fig 1 General structure response

A structure's mathematical model is required for the design and their performance evaluation. In this particular study program SAP2000 is used to perform both linear elastic analysis and non-linear static analysis (pushover) for capacity evaluation of the individual systems.

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2.1 Description of Structural System Consideration

A symmetric plan of four bays along X and Y direction each bay having length of 5m is chosen for all the case study models. The height of each storey is 5m. Different type of steel moment resisting framing systems are taken into consideration and subjected to the analysis. Frame systems and their variations of 3, 6, 9 storeys with and without damper are modelled. The seismic demands on these buildings are calculated following IS 1893. The steel design for these buildings are based on IS 800 guidelines.IS 1893 (part 1), 2002 criteria for earthquake resistant design of structures part 1, General provisions and Buildings, Bureau of Indian standards (BIS) specifies the value of response reduction factor as 4 for steel buildings. The variation of response reduction factor for all the cases are determined and compared with the codal provision.

TABLE 1
SECTION DETAILS

Section	Height, h (mm)	Width, b (mm)	Flange thicness, t_f (mm)	Web thickness, t_w (mm)
Beam IPE 200	200	100	8.5	5.6
Sec. beam IPE 80	80	46	5.2	3.8
Column HE 450M	478	307	40	21
Column HE 400M	432	307	40	21
Column HE 340B	340	300	22.5	12.5

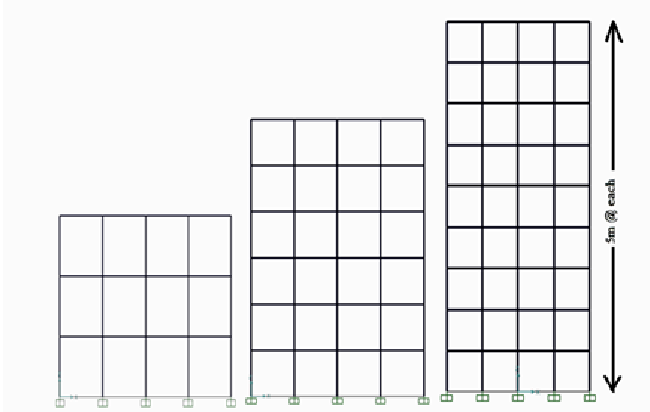

Fig 2. Building configuration models

The frames are assumed to be located in seismic zone IV, the soil type chosen is medium and the importance factor assumed is 1. IS 875 part 1 (1987) is used to calculate the dead and live load and lateral loads are calculated as per IS 1893 (2002). The grade of steel used in the present study is Fe250. The live load is taken as 3.5 kN/m2 for floors and 1.5 kN/m2 for roof. Here slab of M25 and secondary beam of I section supporting them are provided.

2.2 Pushover analysis

Pushover analysis is a static, non-linear procedure to analyse the seismic performance of a building where the computer model of the structure is laterally pushed until a specified displacement is attained or collapse mechanism has occurred. The gravity load is kept as a constant during the analysis. The structure is pushed until the sufficient hinges are formed such that a curve of base shear versus corresponding roof displacement can be developed and this curve is known as pushover curve. From the pushover curve the design base shear is obtained as the base shear corresponding to design displacement and the elastic base shear is obtained as base shear corresponding to the displacement of first member yielding of structure.

2.3 Equivalent lateral load analysis

According to IS 1893: 2002, the total design lateral force or seismic design base shear (Vb) acting on the entire building along any principal direction shall be determined by the following expression:

$$Vb = Ah * W \text{ --------- } (1)$$

Ah = Design horizontal acceleration spectrum using the fundamental natural period T, and shall be determined by the following expression:

$$Ah = (Z\, I\, Sa \,/\, 2\, R\, g) \text{ -------- } (2)$$

Z = Zone factor, I = Importance factor, R = Response reduction factor, Sa/g = Average response acceleration co-efficient T is the fundamental natural period for the buildings. The total seismic weight of the structure, W, shall be calculated as the seismic weight of each floor which is its full dead load plus approximate amount of imposed load. The seismic weight of the whole building is sum of the seismic weights of all the floors.

The total design base shear V_b calculated shall be distributed along the height of the building as per the following expression

$$Qi = V_b \,.\, \{Wi.hi^2 \,/\, \sum Wi.hi^2\}$$

Qi = Design lateral force as i^{th} floor and hi = height of i^{th} floor from base

3 Results and Discussions

In this section, results of analysis and evaluation of this study are tried to be summarised

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3.1 Effect of number of storeis on R value

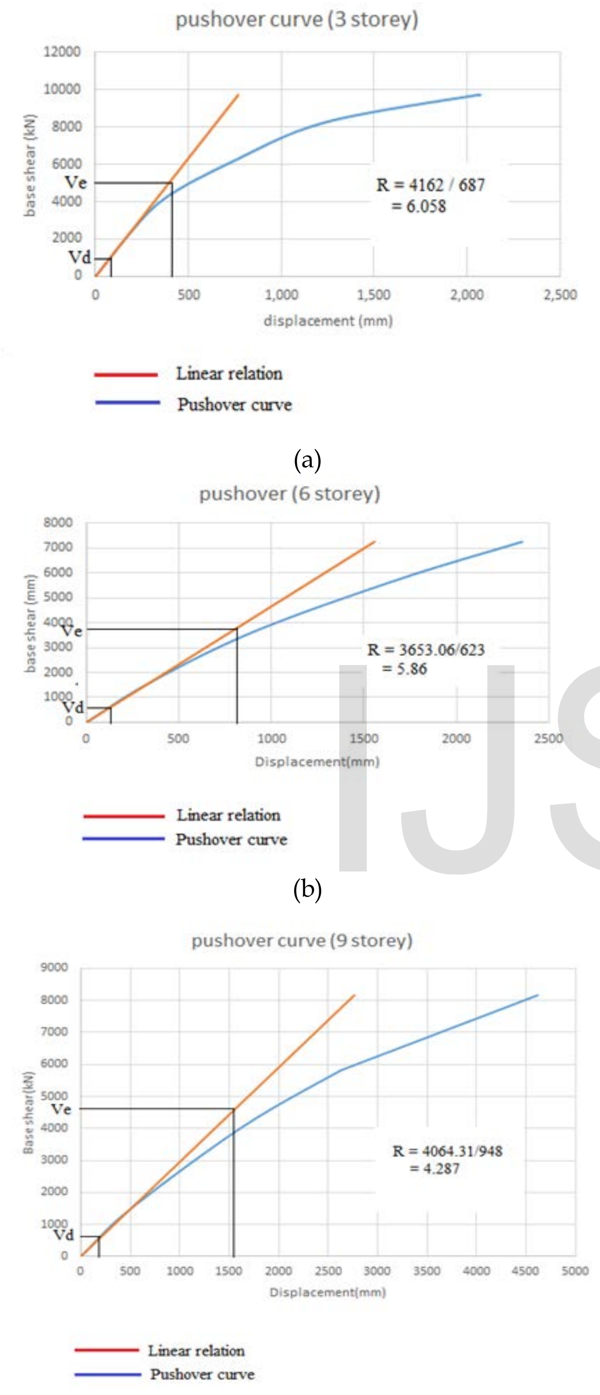

Fig.3 Pushover Curves for (a) 3 storey (b) 6 storey (c) 9 storey

TABLE 2
RESULTS OF ANALYSIS FOR VARIATION OF NUMBER OF STOREYS

Storey height	Disp u1 (m)	V_e (kN)	V_d (kN)	$R = V_e / V_d$
3 storey	0.36849	4162.03	687	6.058
6 storey	0.8861	3653.06	623.01	5.86
9 storey	1.645	4064.31	948	4.287

Based on this study, overall results of R factors obtained for most of the systems are considerably higher when compared to codal specified value of 4 for steel moment resisting frames.

4 Summary of Results

The following are the conclusions of the study:

1. The R factor tends to decreases as with the number of storeys increases.
2. The shorter exhibit higher R values as compared with taller ones.
3. As per IS code the R value is 4, but it is not realistic. In actual case, response reduction factor depends upon symmetry of plan, over strength provided by material ductility of the structure

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