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Comparative Analysis of Frames with Varying Inertia

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ABSTRACT
This paper presents an elastic seismic response of reinforced concrete frames with 3 variations of heights, i.e. (G+2), (G+4), (G+6) storey models are compared for bare frame and frame with brick infill structures which have been analyzed for gravity as well as seismic forces and their response is studied as the geometric parameters varying from view point of predicting behavior of similar structures subjected to similar loads or load combinations. In this study, two different cases are selected i.e. frames with prismatic members and frames with non-prismatic members. The structural response of various members when geometry changes physically, as in case of linear and parabolic haunches provided beyond the face of columns at beam column joints or step variations as in case of stepped haunches was also studied. Frames have been analyzed statically as well as dynamically using ETABS-9.7.4 software referring IS: 456-2000, IS: 1893 (Part-1)2002 and the results so obtained are grouped into various categories.

Keywords: Non-Prismatic Members, Base Shear, Time Period, Storey Displacement, Seismic Coefficient Method and Response Spectrum Method.

I. Introduction

In last few years the widespread damage to reinforced concrete building during earthquake generated demand for seismic evaluation and retrofitting of existing buildings in Indian sub-continents. In addition, most of our buildings built in past decades are seismically deficient because of lack of awareness regarding structural behavior during earthquake and reluctance to follow the code guidelines. Due to scarcity of land, there is growing responsiveness of multi-storied reinforced concrete structures to accommodate growing population. In developing countries, multi-storied buildings are generally provided with prismatic sections. Structural engineers should design the structures in such a way that the structural systems perform their functions satisfactorily and at the same time the design should prove to be economical. This helps to choose the right type of sections consistent with economy along with safety of the structure. The industrial structures, bridges and high rise buildings are provided with non-prismatic members, in which depth or width varies along length of the member. Haunched members can be used to shape the members in accordance with the distribution of the internal stress. By using these types of members, one can achieve the required strength with the minimum weight and material and also may satisfy architectural or functional requirements.

Members that do not have the same cross-sectional properties from one end to the other are called Non-prismatic members. Members having reinforcement over parts of their lengths and members that do not have a straight axis are also known as Non-prismatic members. The most common forms of structural members that are non-prismatic have haunches that are either stepped or tapered or parabolic in shape. Abbas Abdel and Majid Allawi [1] presented stiffness matrix for haunched members by including effect of transeverse shear deformations. It has been found that haunched members can be analyzed as a single member using derived stiffness matrix. Hans I. Archundia-Aranda and Arturo Tena-Colunga [2] worked on cyclic behavior of reinforced concrete haunched beams failing in shear. It is shown that haunched beams have higher deformation and energy dissipation capacities. Kulkarni J.G. et al. [3] presented an elastic seismic response of reinforced concrete frames with varying inertia for gravity as well as seismic forces. It is shown that the provision of non prismatic sections in beams prove to attract more load in turn carry more forces.

II. Methodology

2.1 Equivalent Static Method

Seismic analysis of most structures is still carried out on the assumption that the lateral (horizontal) force is equivalent to the actual (dynamic) loading. This method requires less effort because, except for the fundamental period, the periods and shapes of higher natural modes of vibration are not required. The base shear which is the total horizontal force on the structure is calculated on the basis of the structures mass, its fundamental period of vibration, and corresponding shape. The base shear is distributed along the height of the structure in terms of lateral force according to the codal formula. Planar models appropriate for each of the two orthogonal lateral directions are analyzed separately, the results of the two analyses and the various effects, including those due to torsional motions of the structure, are combined. This method is usually conservative for low to medium-height buildings with a regular configuration.

2.2 Response Spectrum Method

This method is also known as Modal Method or Mode Super-Position Method. This method is applicable to those structures where modes other than the fundamental one significantly affect the response of structures. Generally, this method is applicable to analysis of the dynamic response of structures, which are asymmetrical or have geometrical areas of discontinuity or irregularity, in their linear range of behaviour. In particular, it is applicable to analysis of forces and deformation in multi-storey buildings due to intensity of ground shaking, which causes a moderately large but essentially linear response in the structure.

This method is based on the fact that, for certain forms of damping which are reasonable models for many buildings the response in each natural mode of vibration can be computed independently of the others, and the modal responses can be combined to determine the total response. Each mode responds with its own particular pattern of deformation (mode shape), with its own frequency (the modal frequency), and with its own modal damping.

III. Description of Analytical Model

Different types R.C. moment resisting frame models with prismatic and non-prismatic members are developed using ETABS Non-Linear 9.7.4.

3.1 Material Properties

Density of concrete and brick masonry is taken as 25 KN/ m^3 and 20 KN/m^3 respectively. M-25 grade of concrete and Fe 500 grade of reinforcing steel are used for all the frame models considered in this study. The modulus of elasticity for concrete and brick masonry is taken as 25000MPa and 3500MPa respectively.

3.2 Geometry and Loading Conditions

Bare frame and Frame with brick infill are considered with variations of heights, i.e. (G+2), (G+4), (G+6). Depending upon different height of building, depth of foundation is taken as 1.5m (G+2), 1.5m (G+4), 2.0m (G+6) and storey height taken is 4m (for all models). The analytical model consists of single bay of 10m in global X direction and 5 bays of 3m each in Y direction. Beams in X direction are made non-prismatic. Three types of non-prismatic members are developed which includes linear haunch, parabolic haunch and stepped haunch. In the model, the support condition is assumed to be fixed and soil condition is assumed as medium soil.

The size of beam in X direction is taken as 250mmX1000mm (for prismatic member) and 230mmX530mm (medium soil) in Y direction. Length of haunch is taken as 1000mm, depth of haunch at centre as 675mm and depth of haunch at supports as 1000mm, width of haunch is 250mm. Sizes of columns have been varied according to loading conditions. Thickness of slab as well as brick wall is taken as 150 mm; floor finish load is 1 KN/m^2, Live load on floor slabs 4 KN/m^2. These models are developed for seismic zone V. Seismic coefficient method is used for static analysis and Response spectrum method is used for dynamic analysis.

The plan, 3D view and elevation of frames with prismatic and non-prismatic members for G+ 2 bare frame structures are shown in Fig.1-6 respectively.

IV. Results and Discussion

Different types R.C. moment resisting frame models with prismatic and non-prismatic members are developed and static as well as dynamic analysis is carried out.

4.1 Results

The variations of different parameters like Time Period, Base Shear and Storey Displacement at Top for G+2, G+4 and G+6 buildings are represented in following Tables 1-6.

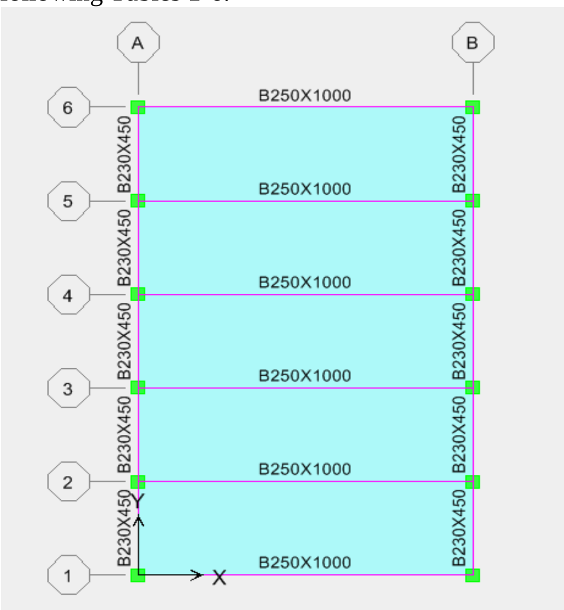

Fig. 1 – Plan of building

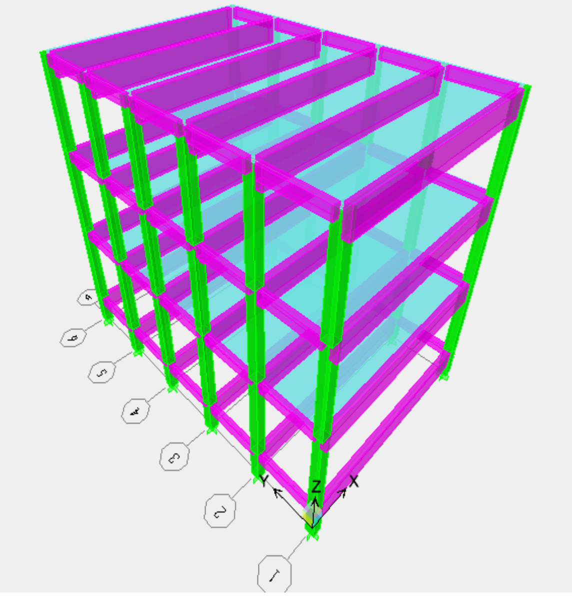

Fig. 2 – 3D view of Frame with Prismatic member

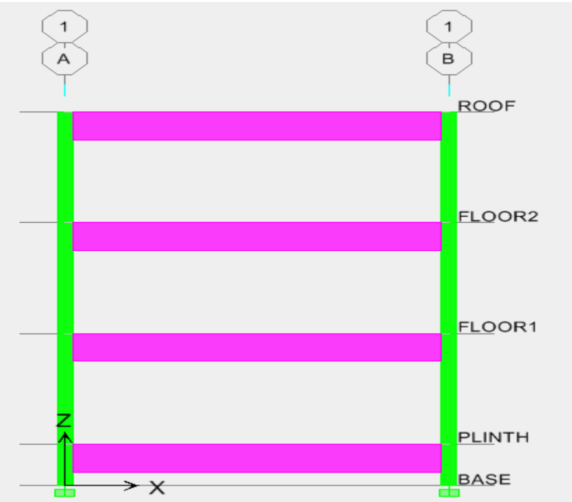

Fig. 3 – Elevation of Frame with Prismatic member

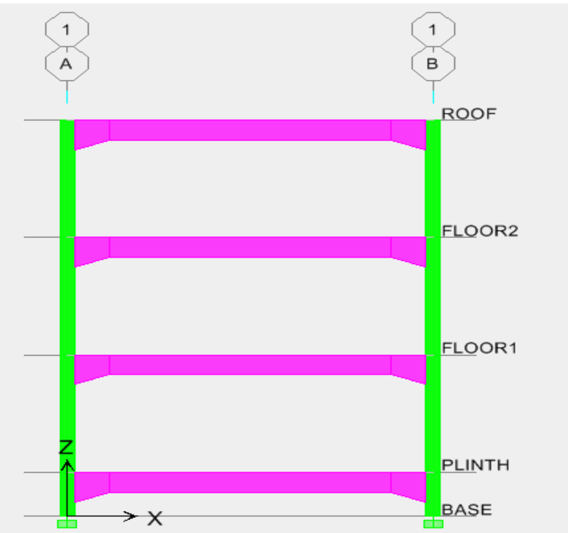

Fig. 4 – Elevation of Frame with Linear haunch

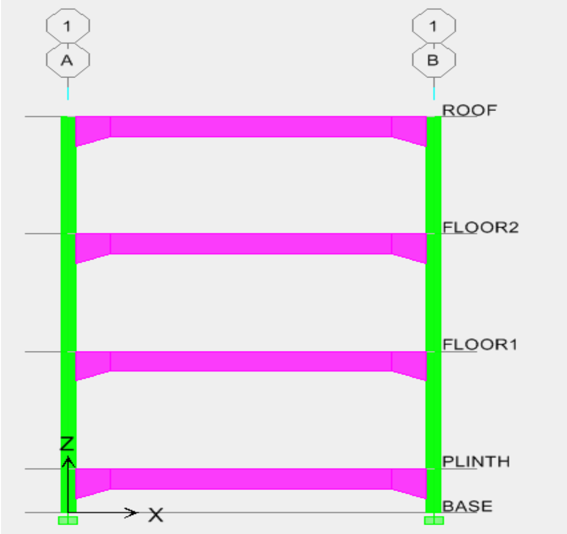

Fig. 5 – Elevation of Frame with Parabolic haunch

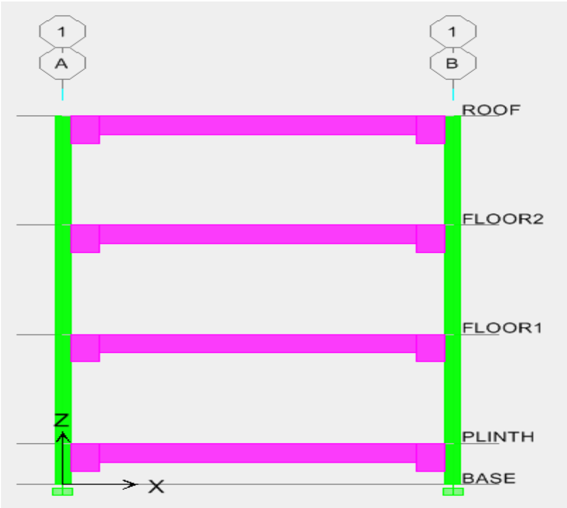

Fig. 6 – Elevation of Frame with Stepped haunch

Table-1 Variation of Time Period in X-dir^{n}. in seconds for Bare frame(Seismic Coefficient Method)

Height of building	Seismic Coefficient Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Parabolic Haunch	Stepped Haunch
G+2	0.8440	0.8259	0.8259	0.8269
G+4	1.2164	1.2312	1.2312	1.2106
G+6	1.4878	1.6550	1.6643	1.6409

Table-2 Variation of Time Period in X- dir^{n}. in seconds for Bare frame (Response Spectrum Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	0.8440	0.8259	0.8259	0.8269
G+4	1.1058	1.2312	1.3362	1.2132
G+6	1.4878	1.6550	1.6738	1.6758

Table-3 Variation of Time Period in X- dir^{n}. in seconds for Frame with brick infill (Seismic Coefficient Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	0.5317	0.5735	0.5747	0.5721
G+4	0.8487	0.8552	0.9151	0.9109
G+6	1.0699	1.1811	1.1844	1.1775

Table-4Variation of Time Period in X- dir^{n}. in seconds for Frame with brick infill (Response Spectrum Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	0.5317	0.5735	0.5747	0.5721
G+4	0.8487	0.8552	0.9151	0.9109
G+6	1.0699	1.1811	1.1844	1.1775

Table-5 Variation of Base Shear in X- dir^{n}. in seconds for Bare frame(Seismic Coefficient Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	805.08	767.37	776.37	769.46
G+4	921.55	888.49	888.49	895.29
G+6	998.79	956.36	956.36	958.71

Table-6 Variation of Base Shear in X- dir^{n}. in seconds for Bare frame (Response Spectrum Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	518.50	407.10	405.52	409.79
G+4	548.52	438.17	409.22	444.43
G+6	585.33	465.35	461.85	468.73

Table-7 Variation of Base Shear in X- dir^{n}. in seconds for Frame with brick infill (Seismic Coefficient Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	854.05	816.34	816.34	818.43
G+4	1197.55	1158.71	1140.80	1143.60
G+6	1195.97	1146.80	1140.43	1143.08

Table-8 Variation of Base Shear in X-dir^{n}. in seconds for Frame with brick infill (Response Spectrum Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	679.47	633.81	632.82	636.48
G+4	705.10	664.75	629.47	633.79
G+6	772.75	679.27	673.16	678.73

Table-9 Variation of Top Storey Displacement in mm for Bare frame(Seismic Coefficient Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	19.14	26.76	27.02	26.39
G+4	36.74	46.50	46.99	46.00
G+6	46.54	69.60	70.37	68.47

Table-10 Variation of Top Storey Displacement in mm for Bare frame (Response Spectrum Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	12.35	13.95	14.02	13.85
G+4	18.04	21.90	23.53	21.33
G+6	25.77	30.87	31.48	31.08

Table-11 Variation of Top Storey Displacement in mm for Frame with brick infill (Seismic Coefficient Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	11.12	12.90	12.96	12.84
G+4	26.03	27.50	30.18	29.91
G+6	32.33	38.65	38.90	38.48

Table-12 Variation of Top Storey Displacement in mm for Frame with brick infill (Response Spectrum Method)

Height of building	Response Spectrum Method			
	Frame with prismatic member	Frame with non-prismatic member		
		Linear Haunch	Linear Haunch	Linear Haunch
G+2	8.31	9.36	9.49	9.34
G+4	13.97	14.38	15.12	15.05
G+6	18.66	20.25	20.25	20.27

4.2 Discussion

The discussion on different parameters is presented in the following lines:

4.2.1 Discussion on Time period

- The time period for frames with prismatic beam is 6% less than that of frames with non-prismatic beam.
- The time period of bare frames with prismatic beam in x direction is 47% & 43% more than the frames with brick infill with prismatic beam for all the models considered in the study by both SCM & RSM resp.
- The time period of bare frames with non-prismatic beam in x direction is 40% & 42% more than the frames with brick infill with non-prismatic beam for all the models considered in the study by both SCM & RSM resp.

4.2.2 Discussion on Base Shear

- The base shear for frames with prismatic beam is 18% more than that of frames with non-prismatic beam.
- The base shear of bare frames with prismatic beam in x direction is 15% & 23% less than the frames with brick infill with prismatic beam for all the models considered in the study by both SCM & RSM resp.
- The base shear of bare frames with non-prismatic beam in x direction is 15% & 33% less than the frames with brick infill with non-prismatic beam for all the models considered in the study by both SCM & RSM resp.
- The base shear of frames with parabolic haunch is nearly same as that of frames with linear haunch and base shear of frames with stepped haunch is 2% more than that of frames with linear haunch for bare frames as well as frames with brick infill considered in the study by both SCM & RSM resp.

4.2.3 Discussion on Top Storey Displacement

- The top storey displacement for frames with prismatic beam is 7% less than that of frames with non-prismatic beam.
- The top storey displacement of bare frames with prismatic beam in x direction is 53% & 39% more than the frames with brick infill with prismatic beam for all the models considered in the study by both SCM & RSM resp.
- The top storey displacement of bare frames with non-prismatic beam in x direction is 82% & 51% more than the frames with brick infill with non-prismatic beam for all the models considered in the study by both SCM & RSM resp.
- The top storey displacement of frames with parabolic haunch is nearly same as that of frames with linear haunch and top storey displacement of frames with stepped haunch is 3% more than that of frames with linear haunch for bare frames as well as frames with brick infill considered in the study by both SCM & RSM resp.

V. Conclusions

In this paper seismic analysis of R. C. frames with and without prismatic member has been carried out. Frames with non-prismatic member include beams provided with different haunches such as linear haunch, parabolic haunch and stepped haunch. The comparison of results of different R.C.C. models shows that:

- The time period for frames with non-prismatic member is less than that of frames with prismatic member. This makes the frames with non-prismatic member flexible, which is the result of reduction in weight.

- The presence of non-prismatic member can affect the seismic behavior of frame structure i.e. it decreases the stiffness of the structure which in turn reduces the base shear.
- The top storey displacement in bare frames with non-prismatic beam is nearly double than that of bare frames with brick infill with non-prismatic beam, but the deflection is within the permissible limit.
- Frames with parabolic haunch have lesser base shear as compared to linear haunch and stepped haunch. Therefore analysis of frames with non-prismatic beam should be done considering parabolic haunch to get effective results.

This study can be extended for different seismic parameters. In present study, non-prismatic beams are provided only in x-dir.; Therefore, non-prismatic beams can be provided in both x and y dir. The study can be repeated by changing the plan dimensions of building.

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