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Evaluation of Response of OMF, CBF and EBF to Lateral Loads Using Nonlinear Pushover Analysis

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ABSTRACT: Nonlinear Pushover Analysis carried out for 15-Storey Steel Space frame having 4 bays of 4.5m each in X direction and 3 bays of 4.5 m each in Y direction located in Ahmedabad has been analyzed with ordinary moment frame, concentrically braced frame and eccentrically braced frame. All buildings are designed as per relevant BIS codes. XTRACT has been used for the developing Moment-Curvature (M-φ) relationship for beams, and also used for the developing Moment-Curvature (M-φ) & Axial load- biaxial moment (P-M-M) relationship for columns. These parameters are used for the nonlinear hinge properties. Nonlinear Pushover Analysis is carried on all these buildings and the results are compared for various framing systems.

INTRODUCTION:

Several systems can be adopted to provide adequate resistance to lateral forces. The most common systems are: moment frames, a combined systems of moment frames and shear walls, braced frames with horizontal diaphragms, and a combinations of the above systems. Moment frames may be economical for buildings with only up to 5 to 10 storeys. Shear wall and braced systems are economical up to 15 storeys. When frames and shear walls are combined, the system is called dual system. A moment frame, when provided with specified details for increasing the ductility and energy absorbing capacity of its component, is called a *special moment frame*; otherwise it is called an *ordinary moment frame*. Braced frames provide resistance to lateral forces acting on a structure. The members of a braced frame act as a truss system and are subjected primarily to axial stress. Depending on the diagonal force, length, required stiffness, and clearances, the diagonal members can be made of double angles, channels, tees, tubes, or even wide flange shapes. Besides performance, the shape of the diagonal is often based on connection considerations. The braces are often placed around service cores and elevators, where frame diagonals may be enclosed within permanent walls. The braces can also be joined to form a closed or partially closed three-dimensional cell so that torsional loads can be resisted effectively. A height-to-width ratio of 8-10 is considered to form a reasonably effective bracing system. Braces may be grouped into concentrically braced frames (CBFs), and eccentrically braced frames (EBFs), depending on their ductility characteristics.

NONLINEAR STATIC ANALYSIS:

In performance based design response of structure is considered beyond elastic limit as opposed to code based approach. Static non-linear analysis is one of the analysis technique used for performance based design. Pushover or capacity based analysis is more popular as a static nonlinear analysis. Two types of pushover analysis are as:

Force Controlled used when load is known and structure is desired to support this load. For gravity load on structure force controlled, push over analysis is used.

Displacement Controlled used when load is unknown but displacement is known and structure is desired to lose their strength and become unstable. For lateral load on structure displacement controlled, pushover analysis is used.

Three main steps involved in this analysis procedure.

- Evaluation of Capacity of building i.e. Representation of the structure's ability to resist a force.
- Evaluation of Demand curve i.e. Representation of earthquake ground motion.
- Determination of Performance point i.e. Intersection point of demand curve and capacity curve.

PROBLEM:

In this paper, a 15 - storey building, having regular plan geometry is considered for analysis. This building is analyzed for three different framing systems and located in Ahmedabad. The plan of the building is shown in Figure 1 and bracing orientation is shown in Figure 2.

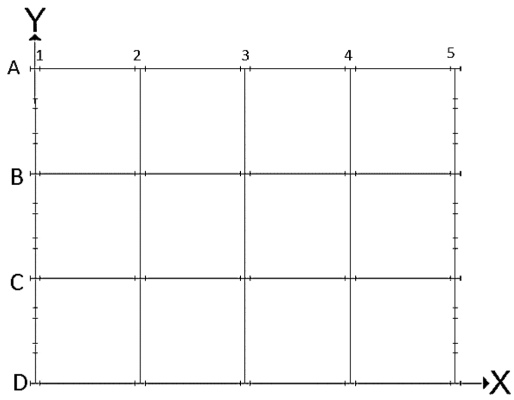


Figure 1: Plan of Building

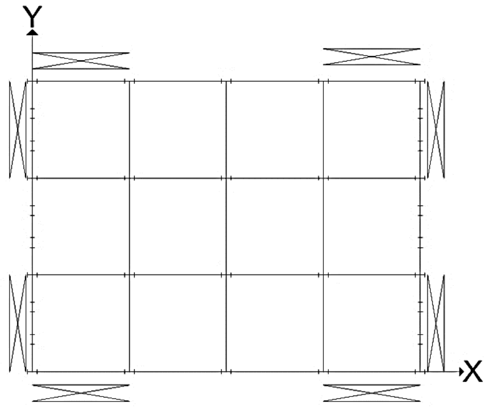


Figure 2: Bracing Orientation

Building Data	**Loading Data**
Building Size :18m X 13.5m	
Typical storey height :3.5m	**Dead Load**
Frame material except slab :Structural steel	Due to outer infill walls: 10 kN/m
Seismic Zone/City :III / Ahmedabad	Due to Slab self-weight: 1.75 kN/m2
Typical Floor Detail :70 mm thick Precast slab	Floor Finish: 1 kN/m2
Young's Modulus E (all members) :2.0x105 N/mm2	
Density of Steel :78.5 kN/m3	**Live Load**
Poisson's Ratio :0.3	All floors except top most floor: 3 kN/m2
Yield Strength of Steel (all members) :250 N/mm2	Top most floor: 1.5 kN/m2

Seismic Loading	**Wind Loading**
Seismic Zone (Z): III	Basic Wind Speed: 39 m/s
Soil type: II	Life Period: 50 Years
Importance Factor: 1	Terrain Category:
Damping: 2%	Terrain Class:
Response Reduction Factor : 5 for EBF	Topography Factor: 1
: 4 for OMF and CBF	

Loading Combination

1) Limit State of Strength

1) 1.5 DL + 1.5 LL
2) 1.2 DL + 1.2 LL ± 0.6 EQ/WL
3) 1.2 DL + 1.2 LL ± 1.2 EQ/WL
4) 0.9 DL ± 1.5 EQ

2) Limit State of Serviceability

1) DL + LL
2) DL + 0.8LL ± 0.8EQ
3) DL ± EQ

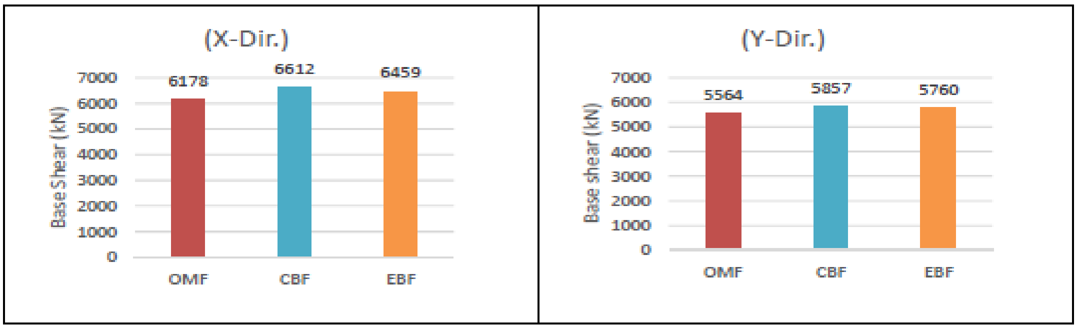
Member Properties for Structures with 15-Storey

Specification	**OMF**	**CBF**	**EBF**
Columns (A1 to D1, A5 to D5)	UC 305 305 240 (13 to 15) BU UC 305 305 240 + 2PLT 350 X 16 (10 to 12) BU UC 305 305 240 + 2PLT 400 X 18 (7 to 9) BU UC 305 305 240 + 2PLT 450 X 20 (4 to 6) BU UC 305 305 240 + 2PLT 500 X 25 (1 to 3)	UC 305 305 158 (13 to 15) UC 305 305 198 (10 to 12) BU UC 305 305 198 + 2PLT 350 X 16 (7 to 9) BU UC 305 305 198+ 2PLT 400 X 20 (4 to 6) BU UC 305 305 198 + 2PLT 450 X 25 (1 to 3)	
Columns	UC 305 305 283 (13 to 15) BU UC 305 305 283 + 2PLT 350 X16 (10 to 12) BU UC 305 305 283 + 2PLT 400 X 18 (7 to 9) BU UC 305 305 283 + 2PLT 450 X 20 (4 to 6) BU UC 305 305 283 + 2PLT 500 X 25 (1 to 3)	UC 305 305 240 (13 to 15) BU UC 305 305 240 + 2PLT 350 X 16 (10 to 12) BU UC 305 305 240 + 2PLT 400 X 18 (7 to 9) BU UC 305 305 240 + 2PLT 450 X 20 (4 to 6) BU UC 305 305 240 + 2PLT 500 X 25 (1 to 3)	
Beam (1 To 6)	ISMB 600	ISMB 500	
Beam (A To D)	ISMB 600	ISMB 500	
Secondary Beams	ISMB 200	ISMB 200	
Braces	NA	ISA 200 X 200 X 15	

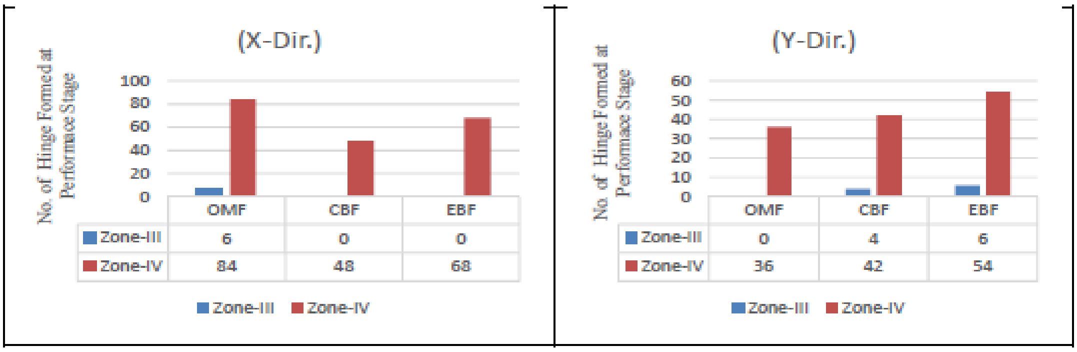
BU = Built-up Section & UC = Universal Column

ANALYSIS RESULTS:
Models of structure are analyzed in SAP2000v16 for given data, and analysis results are compared for different parameter. OMF, CBF and EBF are checked for displacement and drift for seismic Zone - III and wind forces. In frames where no/low plastic hinge formation takes place in Zone – III are checked for performance in Zone – IV.

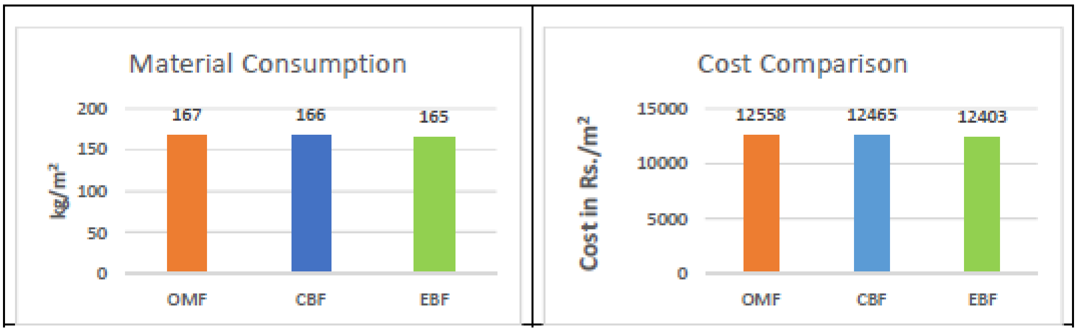
Base Shear at Performance Stage:



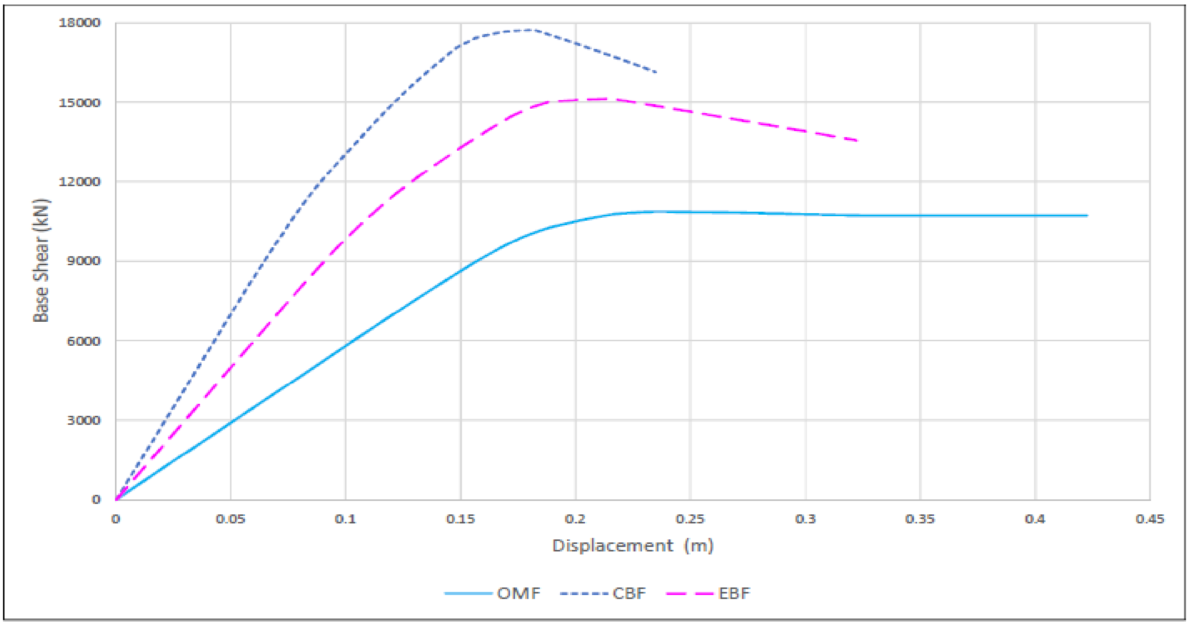
Number of Hinge formed at Performance Stage:



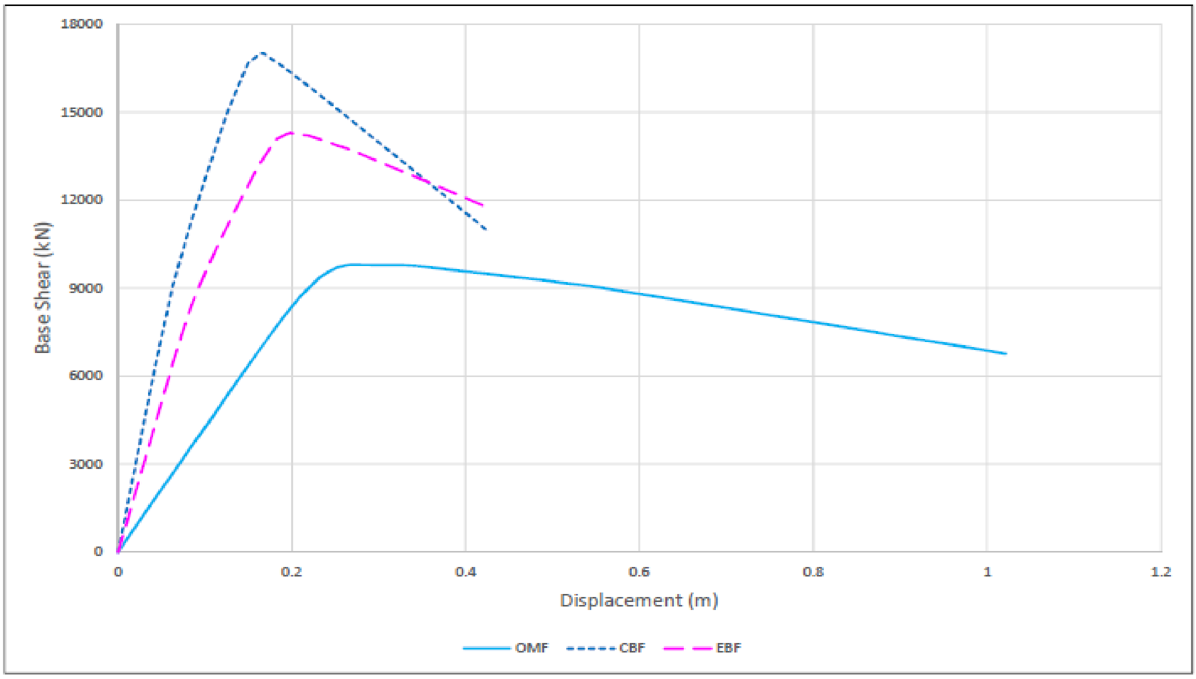
Material Consumption and Cost Comparison:



Capacity Curve for Pushover Analysis (X-Dir.)



Capacity Curve for Pushover Analysis (Y-Dir.)



Conclusion:

1) Concentrically braced frame (CBF) structures are considerably stiffer as compared to Ordinary moment frame (OMF) and Eccentrically braced frame (EBF), So Concentrically braced frame (CBF) attract higher seismic forces.
2) The buildings considered in the present work are designed for the Zone-III and Wind forces for Basic Wind Speed. As seen from Nonlinear Pushover Analysis all the frames i.e. Ordinary moment frame (OMF), Concentrically braced frame (CBF) and Eccentrically braced frame (EBF) meet the demand imposed on them for different stories considered. These buildings with various framing systems are further checked for compliance in Seismic Zone-IV and are found safe for the demand imposed on them.
3) As seen from Capacity Curves from different framing systems used, the behaviour of Eccentrically braced frame (EBF) lies between the behaviour of Ordinary moment frame (OMF) and Concentrically braced frame (CBF). Hence it can be concluded that Eccentrically braced frame (EBF) meets both Strength and Stiffness criteria along with increased ductility.
4) Presently available Hot-rolled sections are weak in one direction and need strengthening along that directions. It could be better to use Symmetrical Sections.
5) wt./m2 and cost/m2 are almost same for Concentrically braced frame (CBF) & Eccentrically braced frame (EBF). Eccentrically braced frame (EBF) should be preferred as it is more ductile.

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