EVALUATION OF THE USE OF CONCENTRIC STEEL BRACING TO IMPROVE SEISMIC PERFORMANCE OF REINFORCED CONCRETE FRAME BUILDING - EQUIVALENT STATIC ANALYSIS

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Abstract

Most of the existing RC frame structures were not designed to withstand seismic effect. To meet those criteria structures should be retrofitted and out of all available retrofitting techniques adding steel braces are considered to be most efficient technique to enhance the seismic performance of the RC frame structure.

In the present study three types of buildings are considered i.e., (G+2), (G+5), (G+8) as low rise, medium rise, high rise respectively, and these buildings are assigned by four different types of braces namely X, V, Inverted V, Eccen Forward at the periphery bays of the building in three different pattern i.e., model A, model B and model C. And these buildings are analyzed by nonlinear pushover analysis by using SAP2000.It is observed that the hinges were first formed in beams and followed by columns in bare frame whereas hinges were first formed in braces and followed by columns and followed by beams in case of X, Eccen forward brace and in case of V and inverted V hinges are formed first in brace followed by beams and followed by columns. It is pointed out that RC frames which are assigned with inverted V brace has least shear force and bending moment in the beams when compared to the other brace frames and there is less amount of variations in axial force shear force and bending moment in case of column.

Keywords: *equivalent static analysis, steel braces, equivalent strut method*

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1. INTRODUCTION

The aftermath of an earthquake manifests great devastation due to unpredicted seismic motion striking extensive damage to innumerable buildings of varying degree, i.e. either full or partial. This damage to structures in turn causes irreparable loss of life with a large number of casualties. Strengthening of structures proves to be a better option catering to the economic considerations and immediate shelter problems rather than replacement of buildings. Moreover it has been often seen that retrofitting of buildings is generally more economical as compared to demolition and reconstruction. Therefore, seismic retrofitting or strengthening of building structures is one of the most important aspects for mitigating seismic hazards especially in earthquake prone areas

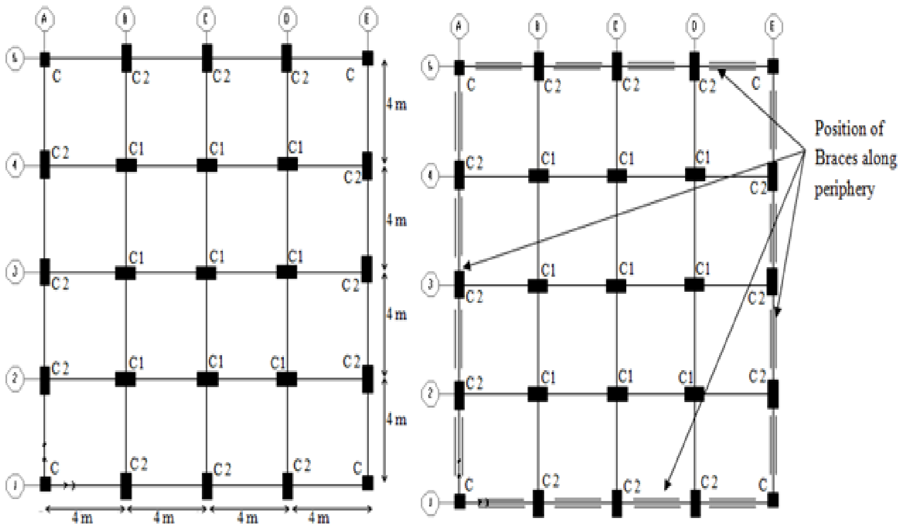
Steel bracing is a highly efficient and economical method of resisting horizontal forces in a frame structure. Bracing has been used to stabilize laterally the majority of the world's tallest building structures as well as one of the major retrofit measures. Bracing is efficient because the diagonals work in axial stress and therefore call for minimum member sizes in providing stiffness and strength against horizontal shear. A number of researchers have investigated various techniques such as infilling walls, adding walls to existing columns, encasing columns, and adding steel bracing to improve the strength and/or ductility of existing buildings. A bracing system improves the seismic performance of the frame by increasing its lateral stiffness and capacity. Through the addition of the bracing system, load could be transferred out of the frame and into the braces, bypassing the weak columns while increasing strength. Steel-braced frames are efficient structural systems for buildings subjected to seismic or wind lateral loadings. Therefore, the use of steel bracing systems for retrofitting reinforced concrete frames with inadequate lateral resistance is attractive.

2 MODELLING AND ANALYSIS

In the present study three kind of buildings are considered i.e., (G+2), (G+5)(G+8) as low rise, medium rise, high rise respectively, as in Fig. 2.1, Fig.2.2 and these buildings are assigned by four different types of braces namely X, V, Inverted V, Eccen Forward at the periphery frames of the building in three different pattern which are shown in Fig. 2.3, Fig.2.4, Fig 2.5, Fig. 2.6. The story height is considered as 3m with foundation level as 1.5m. The building is assumed to be situated on medium soil strata and is located in the seismic zone V as per Indian Standard code IS 1893-2002 with Peak ground acceleration (PGA) as 0.36g.The slab thickness is assumed as 125 mm. Special moment resisting frame(SMRF) is considered with response reduction factor (R) as 5. M25 grade concrete, Fe415 steel for reinforcing bars and Fe 250 for steel braces are used. The sizes of beams, columns, and steel braces are mentioned in Table: 2.1.

Table 2.1 Size details of beams, columns and braces

Storey	Beam (mm)	Column (mm)	Steel braces (Double angle section) (mm)
3	Plinth–230x300 Floor Beam –230x400	Plinth–230x300 Floor Beam – 230x400	V - 90x90x12 IV-110x110x12 X- 130x130x12 EF-130x130x12
6	Plinth–230x300 Floor Beam- 230x400	C-350x350 C1-400x500 C2-300x500	V- 130x130x12 IV- 130x130x12 X- 200x200x12 EF-200x200x12
9	Plinth–230x300 Floor Beam - 230x400	C - 350x350 C1 -500x600 C2 -400x500	V- 150x150x12 IV-130x130x12 X- 200x200x12 EF-200x200x12



a) Plan of building **b) Plan representing the position of brace**

Fig. 2.1 Plan of 3, 6, and 9 storied building

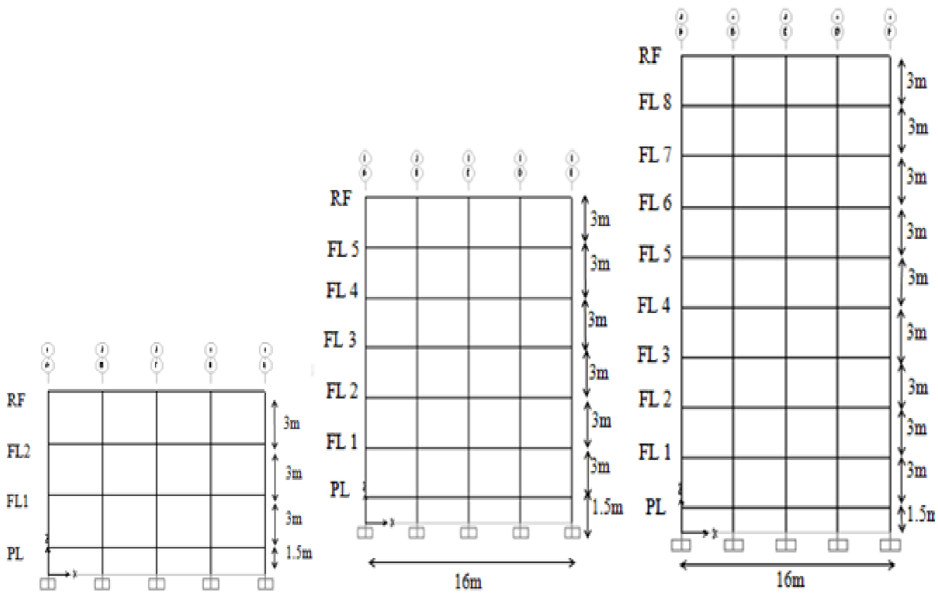


Fig. 2.2 Elevations of 3, 6, and 9 storied building

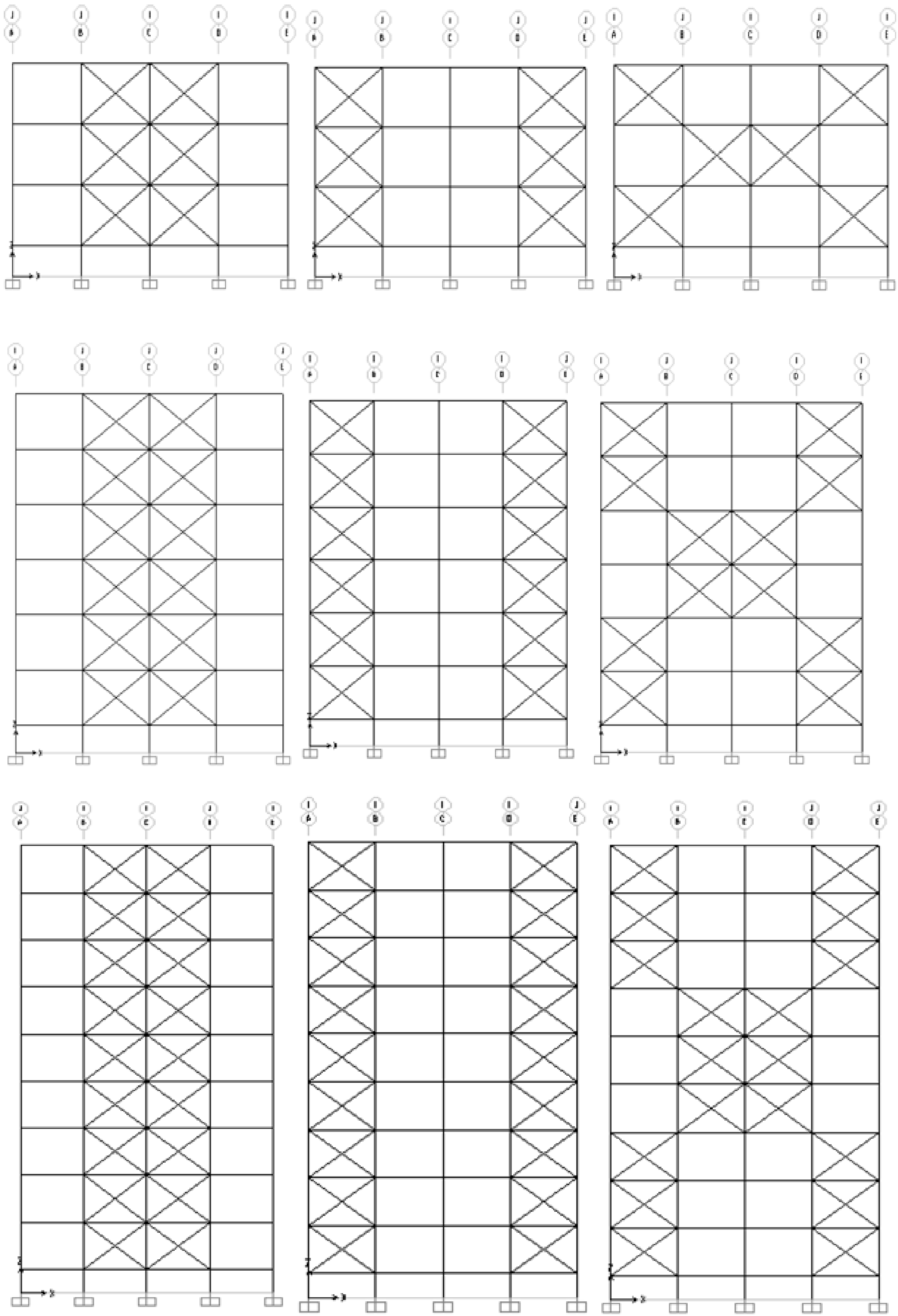


Fig. 2.3 X Brace assigned in three different patterns to 3, 6, 9 storied buildings

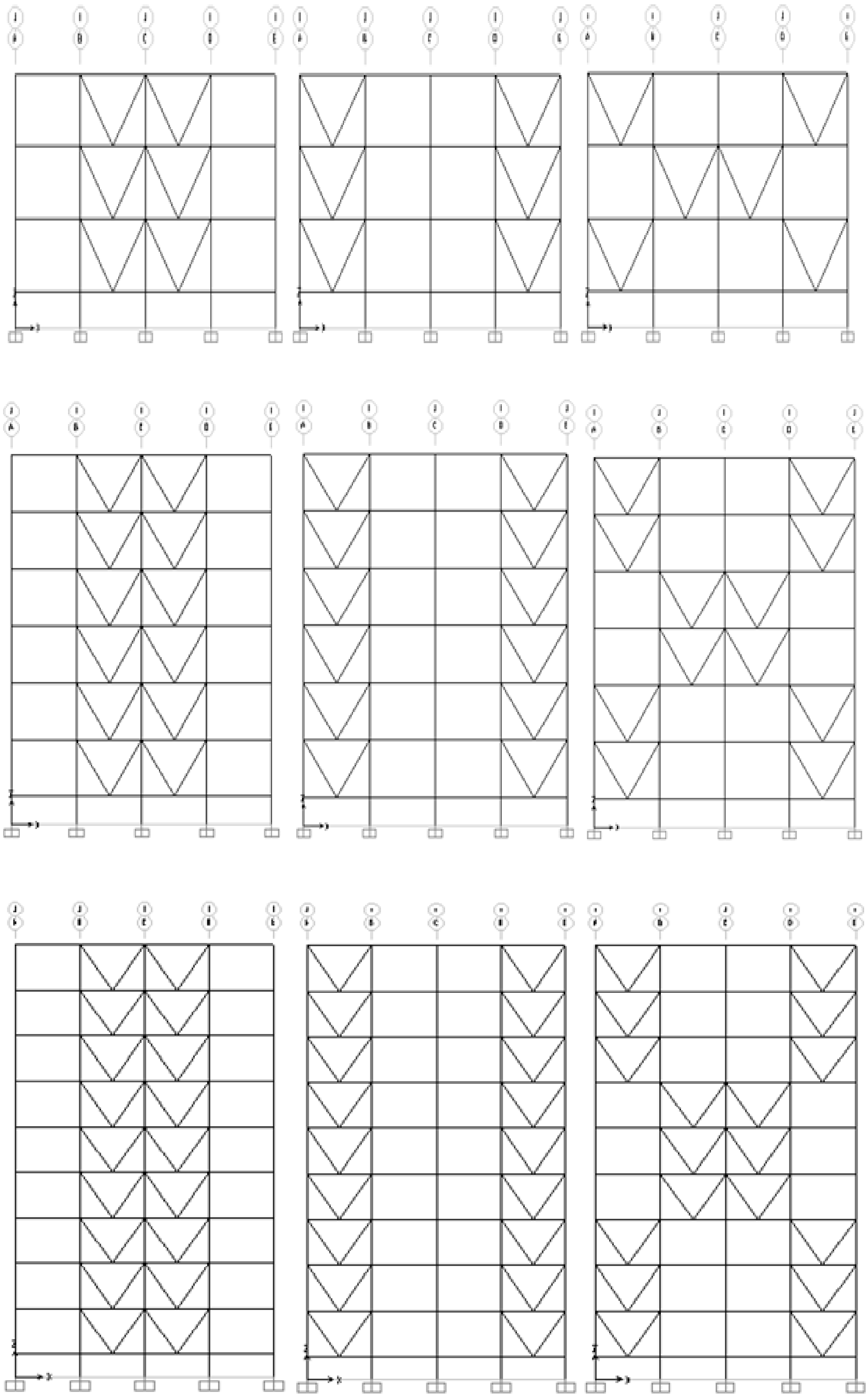


Fig. 2.4 V Brace assigned in three different patterns to 3, 6, 9 storied buildings

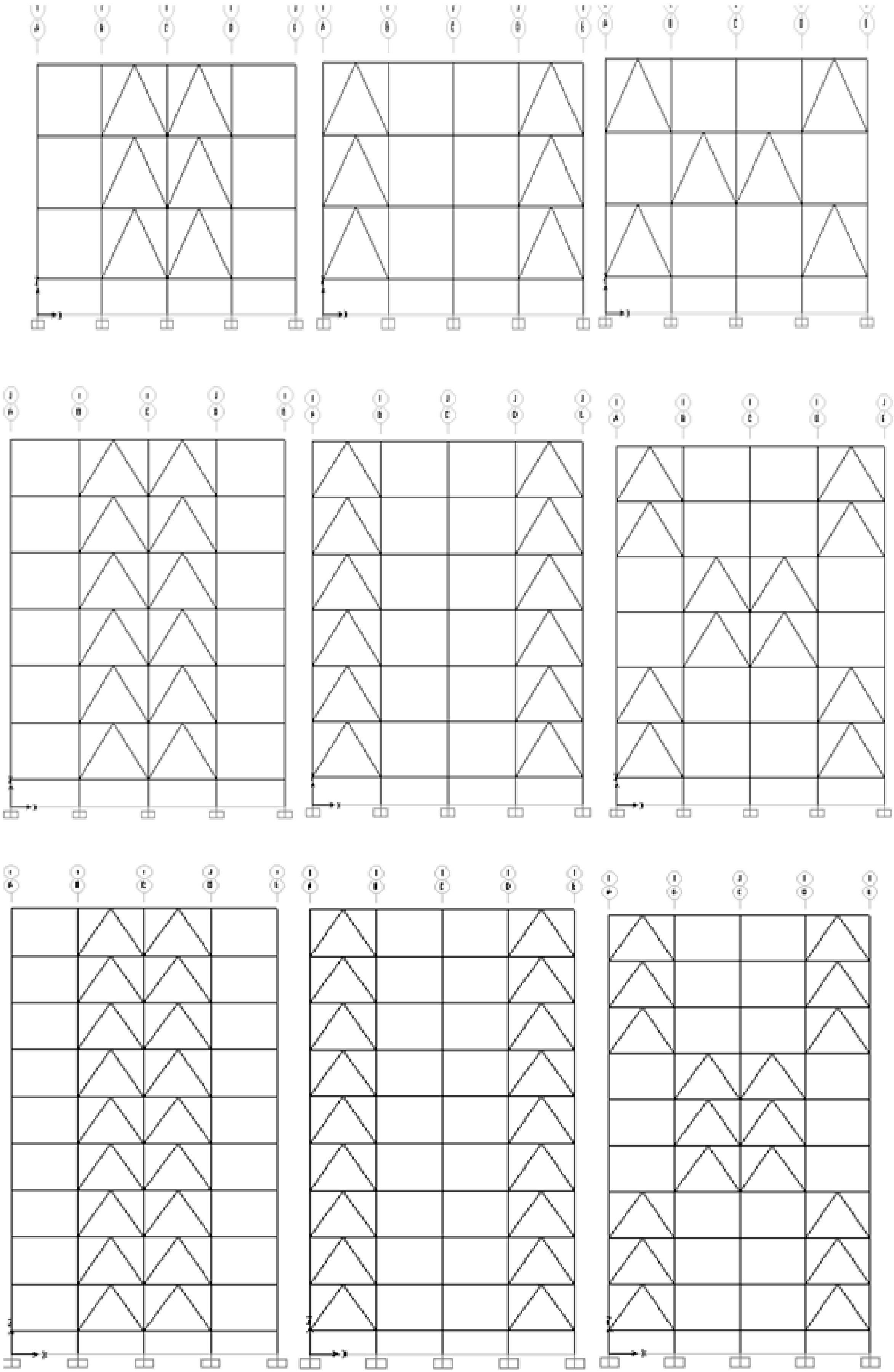


Fig. 2.5 IV Brace assigned in three different patterns to 3, 6, 9 storied buildings

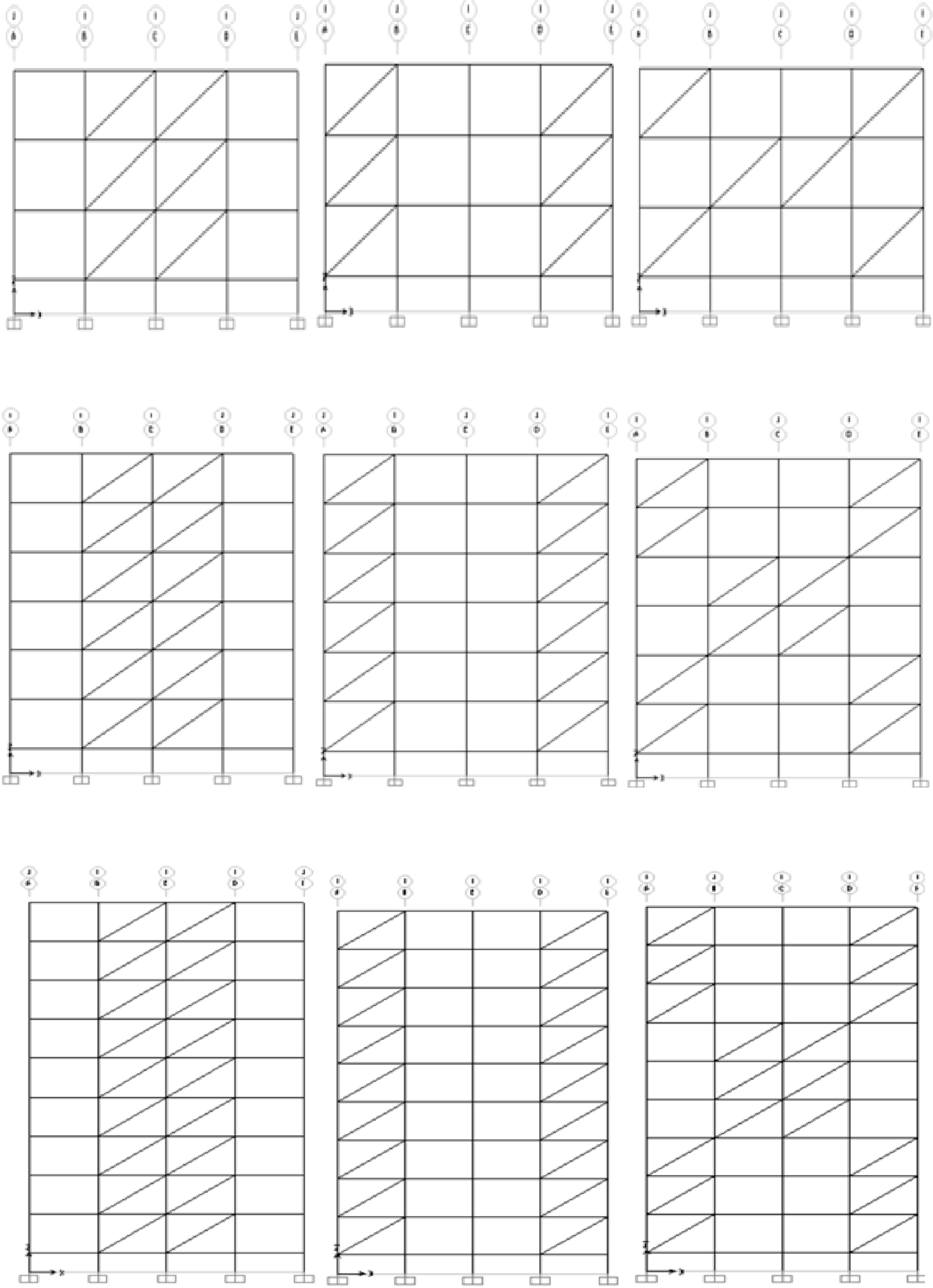


Fig. 2.6 EF Brace assigned in three different patterns to 3,6,9 storied buildings

3 MODELLING OF STRUCTURE

Structural modelling, analysis and design have been performed in SAP 2000 version 14.2.4. Thickness of slab at all floor level and roof level have been assumed to be same and modelled as rigid diaphragm. The beams have been assigned with moment (M3) hinges and columns with coupled axial moment (P-M2-M3) hinges at the two ends and for braces with axial hinges at the centre of brace. In modelling of plastic hinges in the frames, the default hinge properties defined by SAP 2000 as per FEMA 356 have been used. Equivalent static analysis is performed for all the building models. In present study design have been done for Equivalent static analysis.

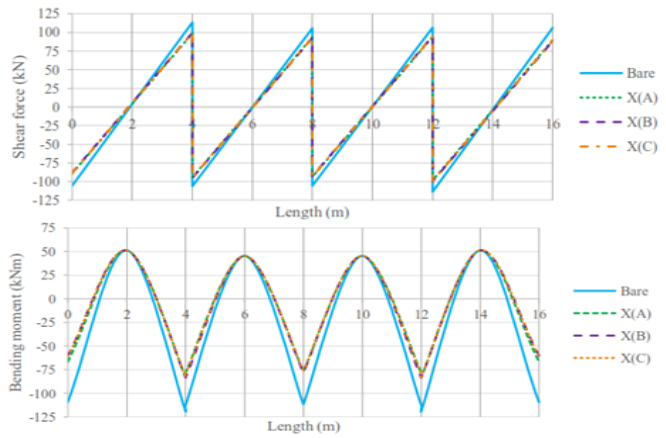


Fig. 3.1 Plot of shear force and bending moment of beams at FL2 in 3storied bare and X brace frame

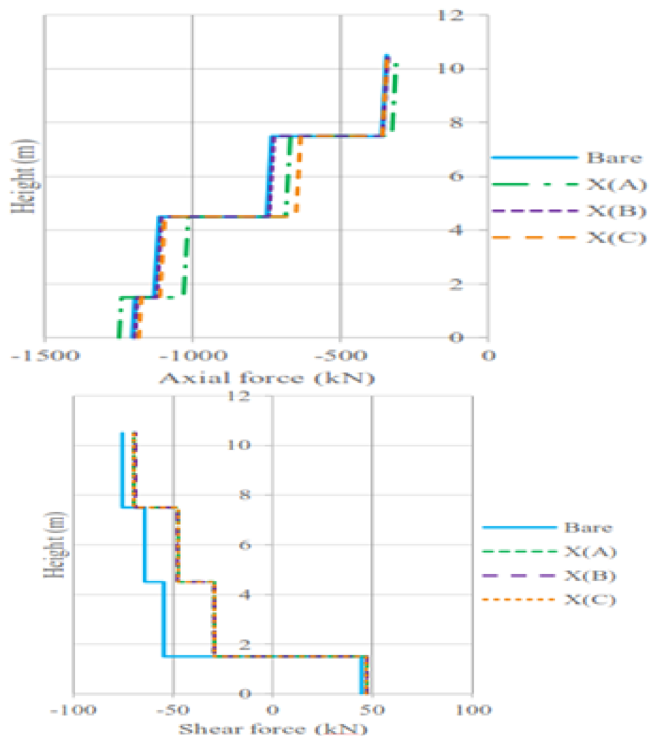


Fig. 3.2 Plot of axial force and shear force of column C1 in 3storied bare and X brace frame

3.1 Equivalent Static Analysis Results

For building under consideration assigned with different types of braces and different pattern of braces, linear equivalent static analysis has been done and comparison of elemental forces for series of beam B and column C is done.

3.1.1 Comparison of Elemental Forces of 3 Storied Building

Comparison of elemental forces of 3 storied bare frame and assigned with X, V, inverted V and EF braces building is shown in Fig.3.1 to Fig. 3.12.

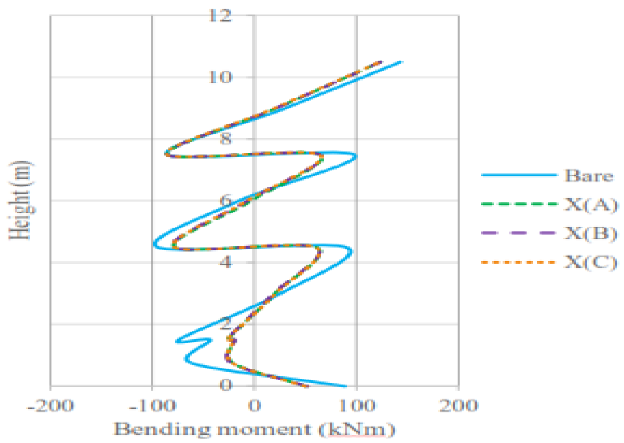


Fig. 3.3 Plot of bending moment of column C1 in 3storied bare and X brace frame

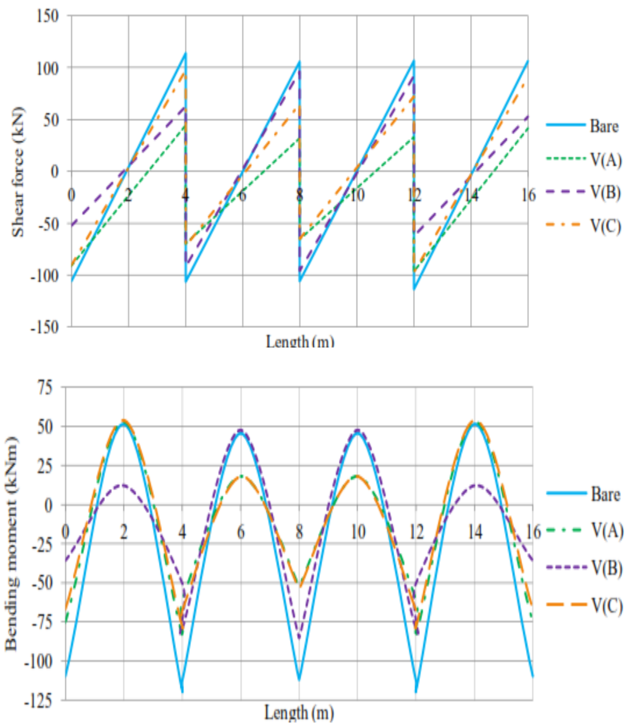
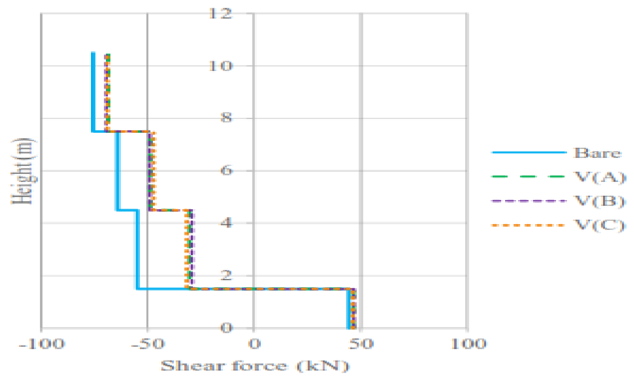


Fig. 3.4 Plot of shear force and bending moment of beams at FL2 in 3storied bare and V brace frame



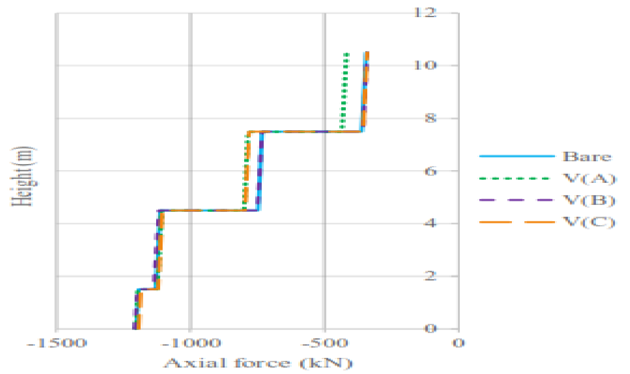


Fig. 3.5 Plot of axial force and shear force of column C1 in 3storied bare and V brace frame

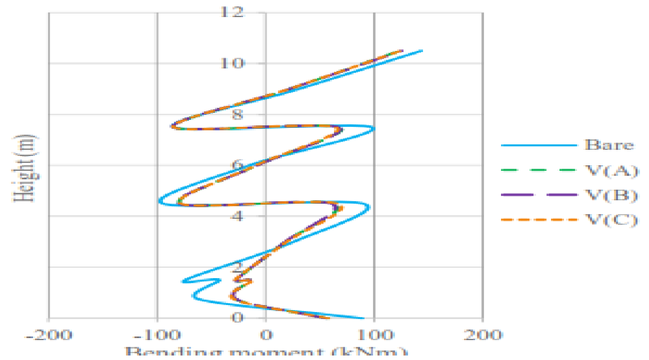
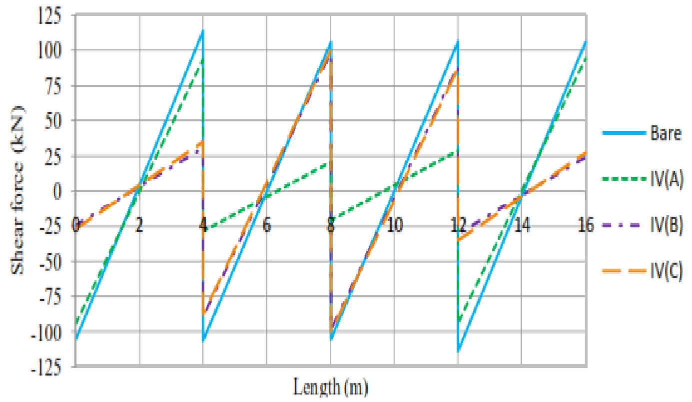


Fig. 3.6 Plot of bending moment of column C1 in 3storied bare and V brace frame



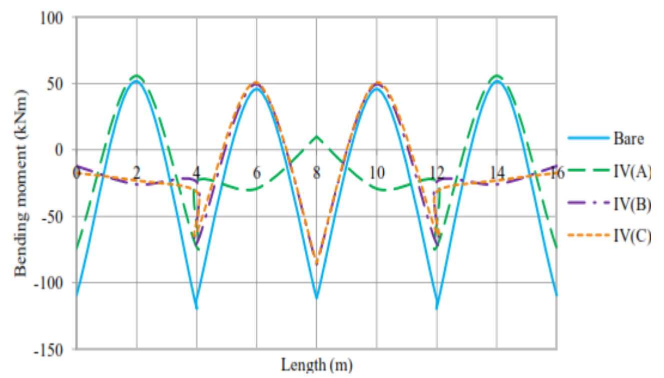
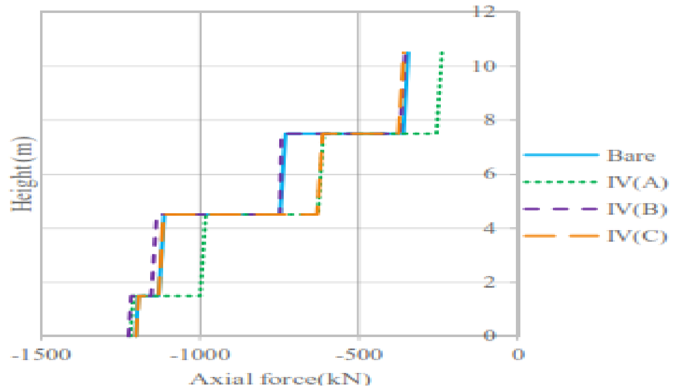


Fig. 3.7 Plot of shear force and bending moment of beams at FL2 in 3storied bare and IV brace frame



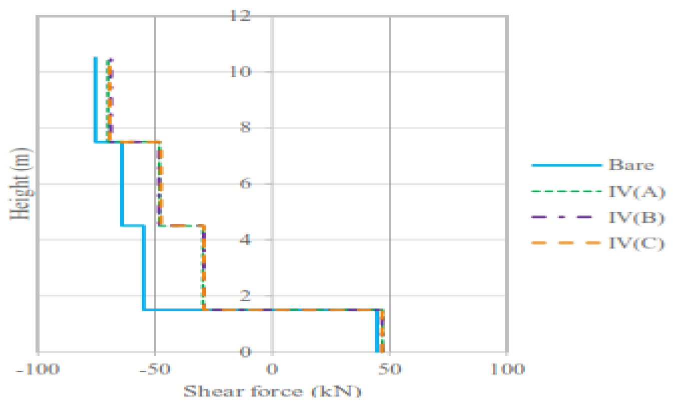


Fig. 3.8 Plot of axial force and shear of column C1 in 3 storied bare and IV brace frame

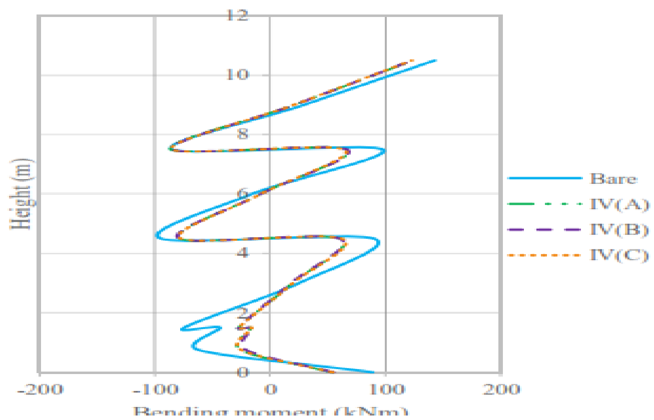


Fig. 3.9 Plot of bending moment of column C1 in 3 storied bare and IV brace frame

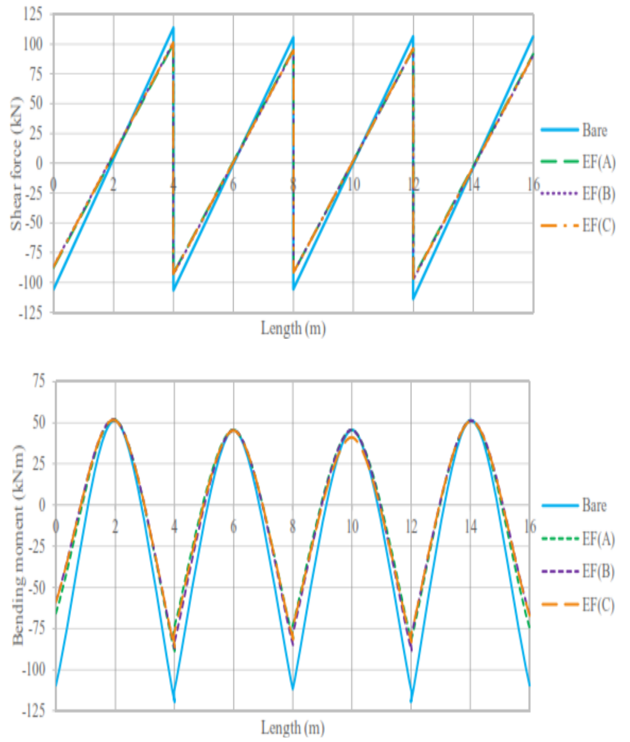


Fig. 3.10 Plot of shear force and bending moment of beams at FL2 in 3storied bare and EF brace frame

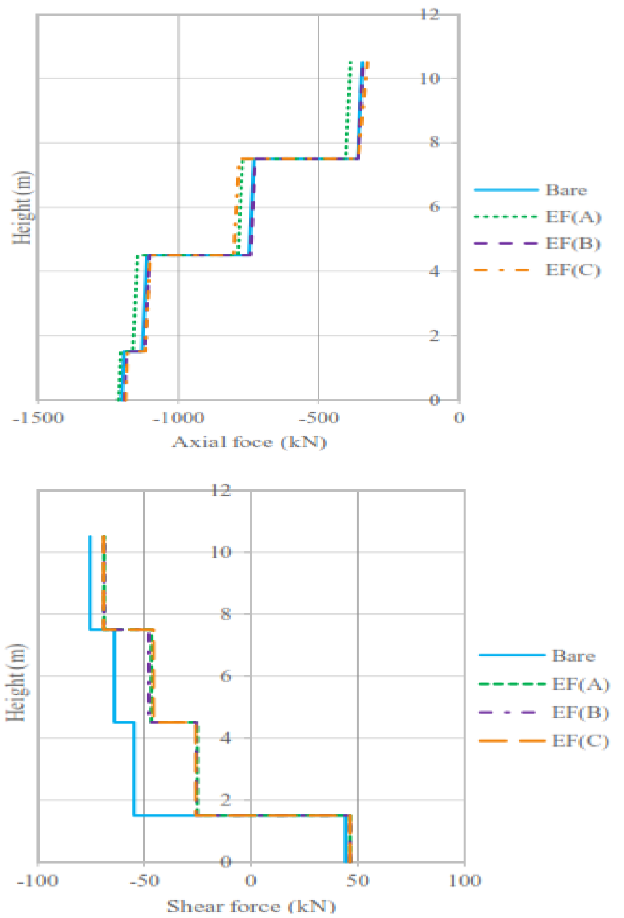


Fig. 3.11 Plot of axial force and shear force of column C1 in 3 storied bare and EF brace frame

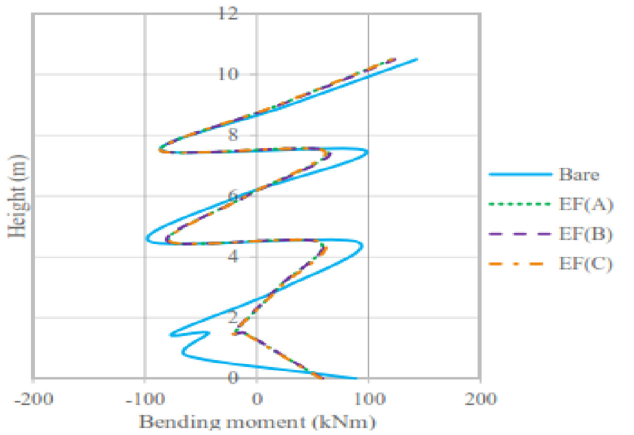


Fig. 3.12 Plot of bending moment of column C1 in 3 storied bare and EF brace frame

It is observed that X brace has less shear force, bending moment and axial force when compared to bare frame and variation of shear forces, bending moment and axial force between X and bare frame and between three different pattern is minor.

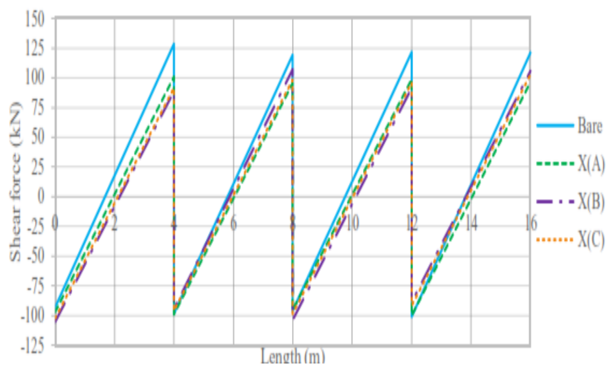
It is observed that V brace has less shear force, axial force and bending moment when compared to bare frame and there is large variations of shear forces and bending moment between three patterns of V brace and out of three patterns V(A) pattern has least shear force and bending moment.

It is observed that IV brace has less shear force bending moment and axial force when compared to bare frame and there is large variations of shear forces bending moment between three patterns of IV brace and out of three patterns IV(A) pattern has least shear force bending moment and axial force .

It is observed that EF brace has less shear force, axial force and bending moment when compared to bare frame and there is large variation of shear forces and bending moment between three patterns of EF brace

3.1.2 Comparison of Elemental forces in 6 Storied Building

Comparison of elemental forces of 6 storied bare frame and assigned with X, V, inverted IV and EF braces building is shown in Fig.3.13 to Fig. 3.24



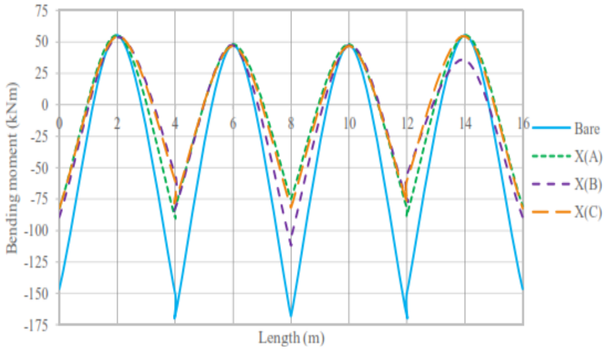


Fig. 3.13 Plot of shear force and bending moment of beams at FL3 in 6 storied bare and X brace frame

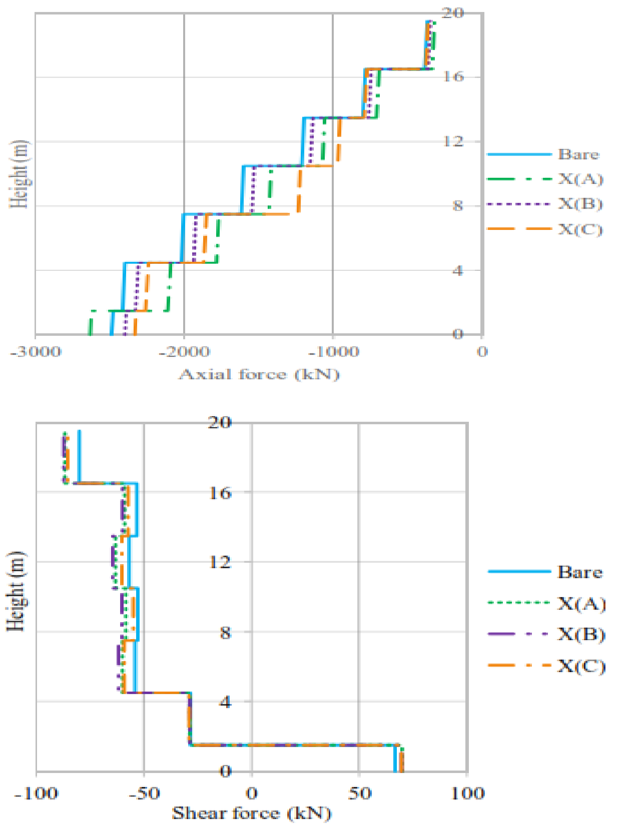


Fig. 3.14 Plot of axial force and shear force of column C1 in 6 storied bare and X brace frame

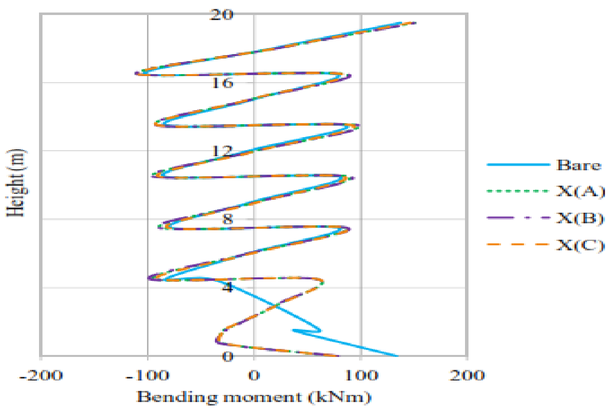


Fig. 3.15 Plot of bending moment of column C1 in 6 storied bare and X brace frame

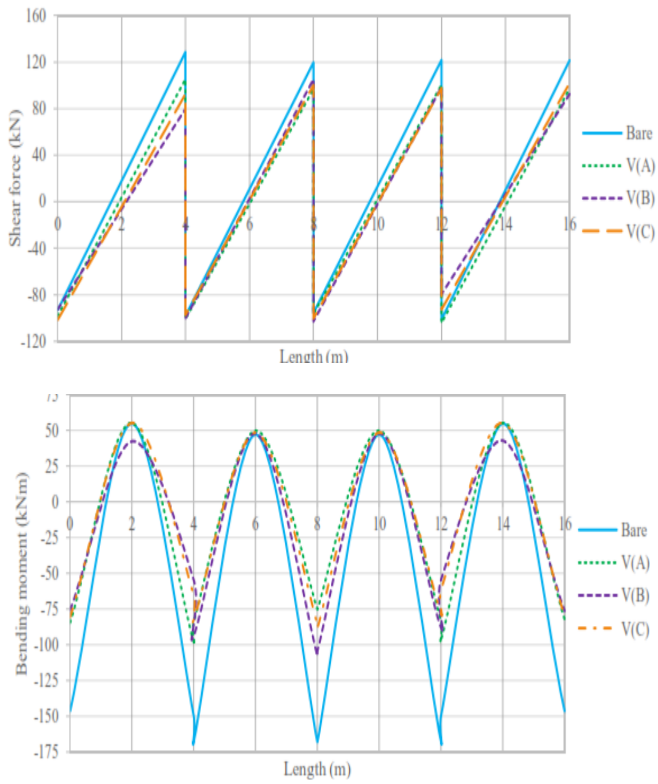


Fig. 3.16 Plot of shear force and bending of beams at FL3 in 6 storied bare and V brace frame

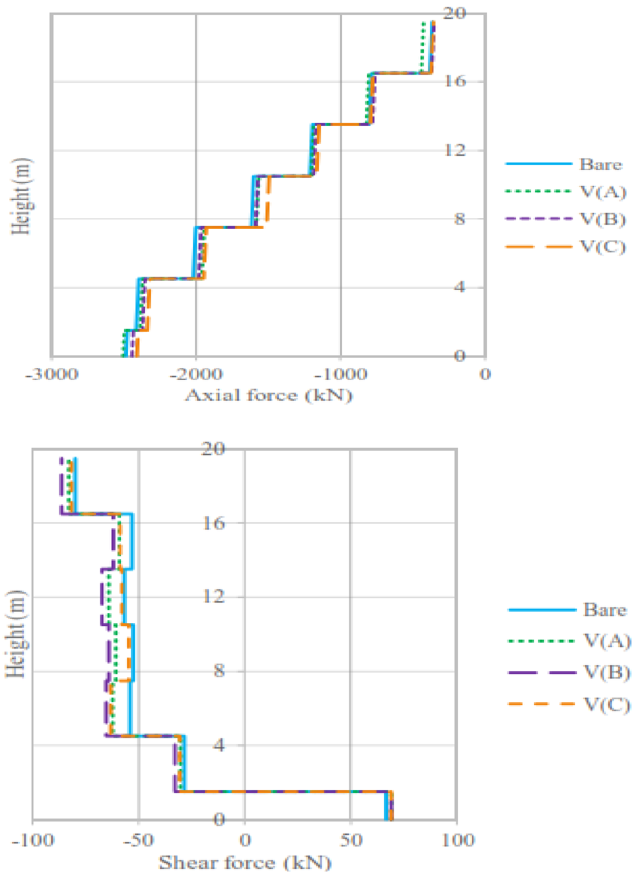


Fig. 3.17 Plot of axial force shear force of column C1 in 6 storied bare and V brace frame

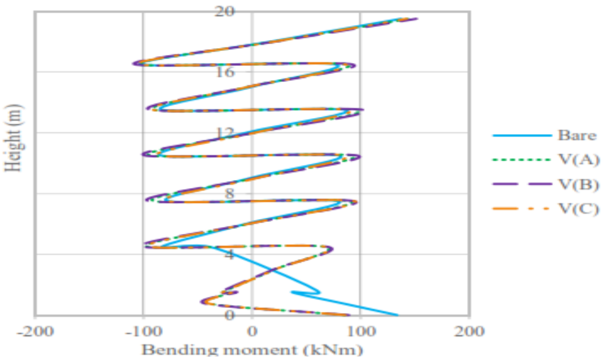


Fig. 3.18 Plot of bending moment of column C1 in 6 storied bare and V brace frame

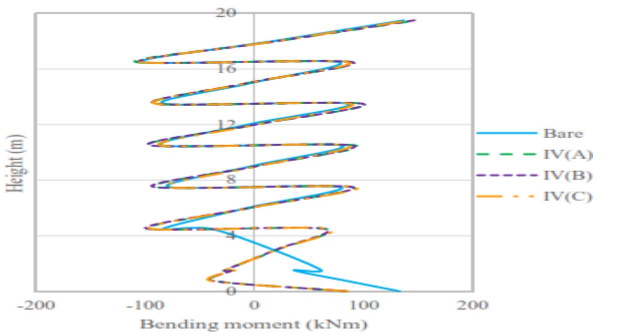


Fig. 3.21 Plot of bending moment of column C1 in 6 storied bare and IV brace frame

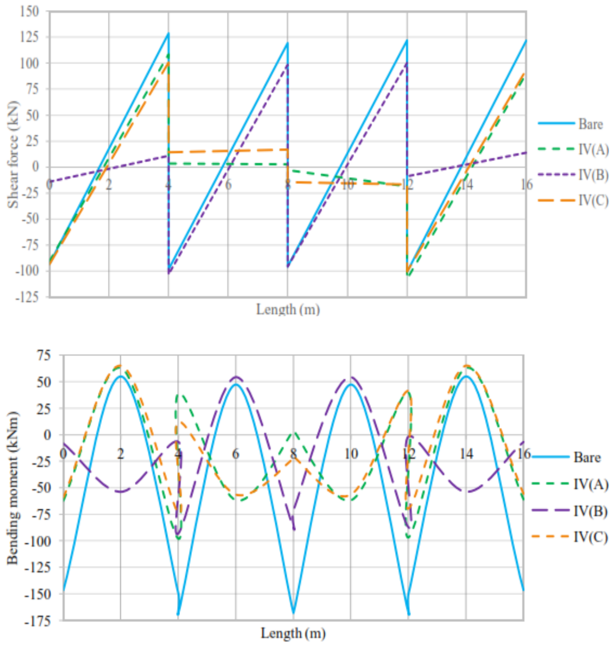


Fig. 3.19 Plot of shear force and bending moment of beams at FL3 in 6 storied bare and IV brace frame

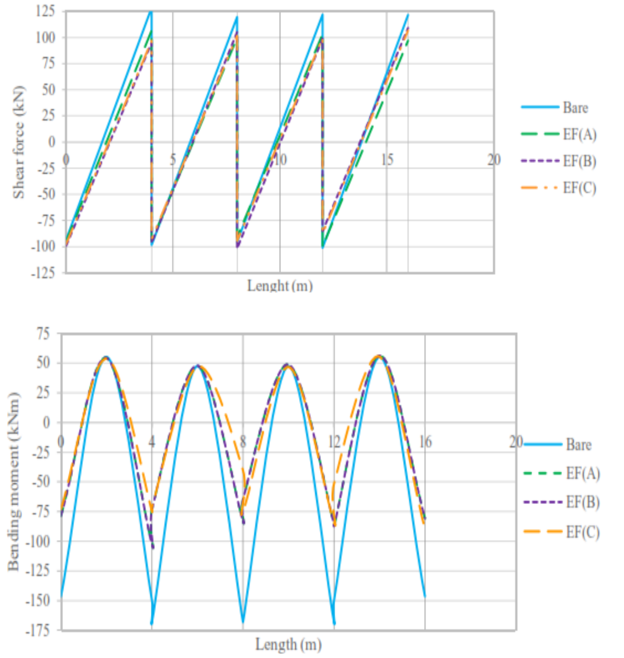


Fig. 3.22 Plot of shear force and bending moment of beams at FL3 in 6 storied bare and EF brace frame

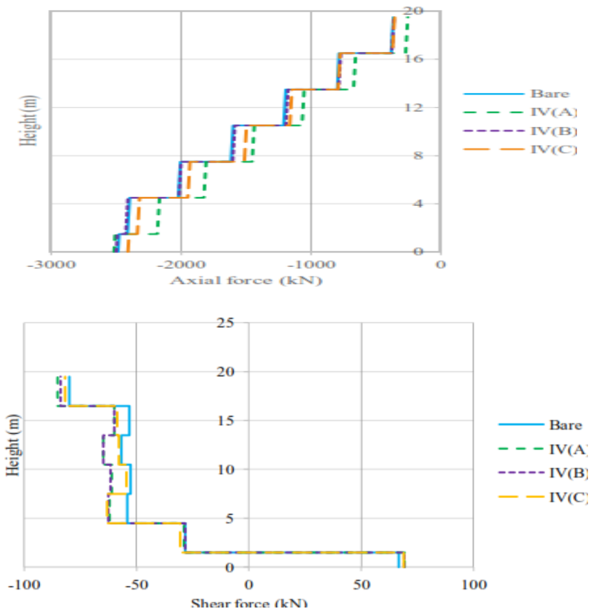


Fig. 3.20 Plot of axial force shear force of column C1 in 6 storied bare and IV brace frame

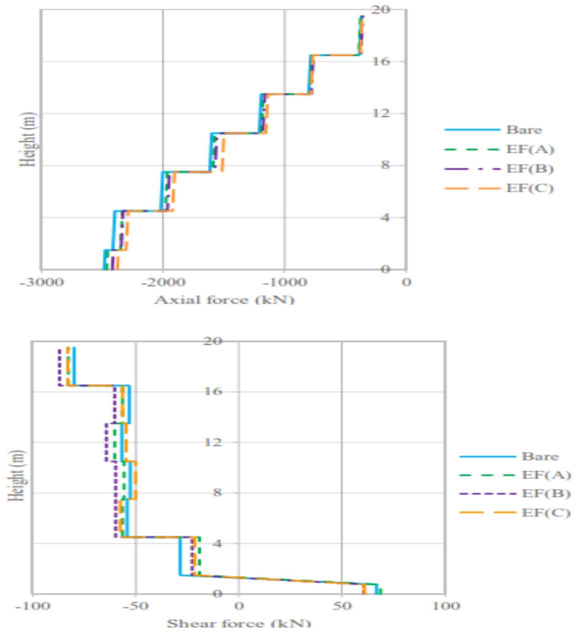


Fig. 3.23 Plot of axial force and shear of column C1 in 6 storied bare and EF brace frame

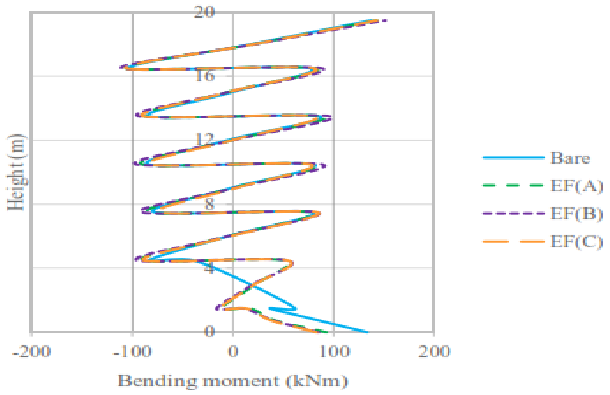


Fig. 3.24 Plot of bending moment of column C1 in 6 storied bare and EF brace frame

It is observed X brace frame has less shear force bending moment and axial force when compared to bare frame and there is large variations of shear forces bending moment and axial force between three patterns of X brace and out of three patterns X(B) pattern has least shear force.

It is observed V brace frame has less shear force bending moment and axial force when compared to bare frame and variation of shear forces bending moment and axial force between V brace and bare frame and between three different pattern is minor.

It is observed IV brace frame has less shear force bending moment and axial force when compared to bare frame and variation of shear forces bending moment and axial force between IV and bare frame and between three different pattern is minor.

It is observed due presence of inverted V brace on that particular bay frame the pattern of bending moment was changed from positive bending moment to negative bending moment and vice –versa when it is compared to bare frame. And there is decrease in bending moment brace frame than the bare frame.

It is observed EF brace frame has less shear force bending moment and axial force when compared to bare frame and variation of shear forces bending moment and axial force between EF brace and bare frame and between three different pattern is minor.

3.1.3 Comparison of Elemental Forces in 9 Storied Building

Comparison of elemental forces of 9 storied bare frame and assigned with X, V, inverted V and EF braces building is shown in Fig.3.25 to Fig. 3.36

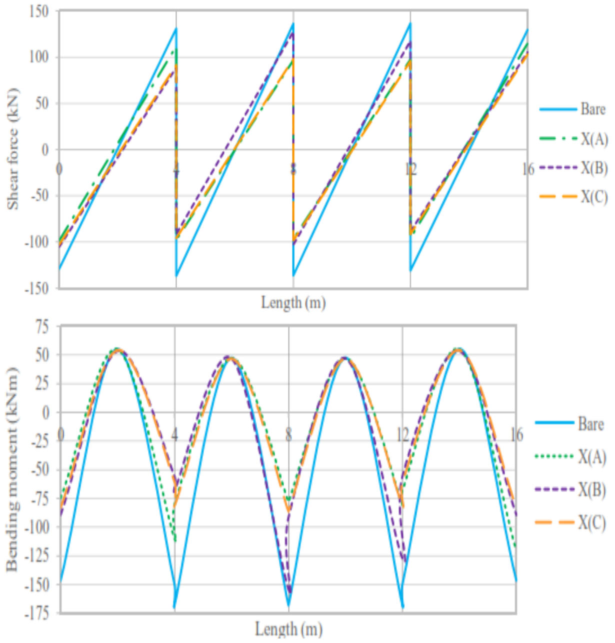


Fig. 3.25 Plot of shear force and bending moment of beams at FL4 in 9 storied bare and X brace frame

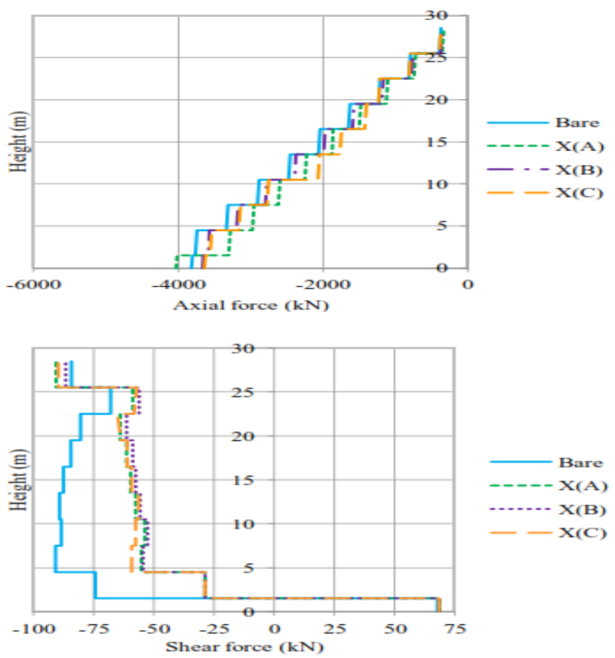


Fig. 3.26 Plot of axial force and shear force of column C1 in 9 storied bare and X brace frame

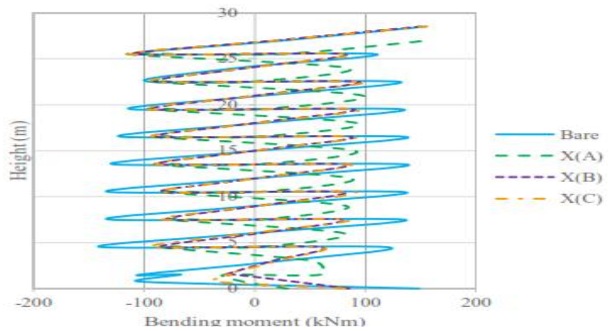


Fig. 3.27 Plot of bending moment of column C1 in 9 storied bare and X brace frame

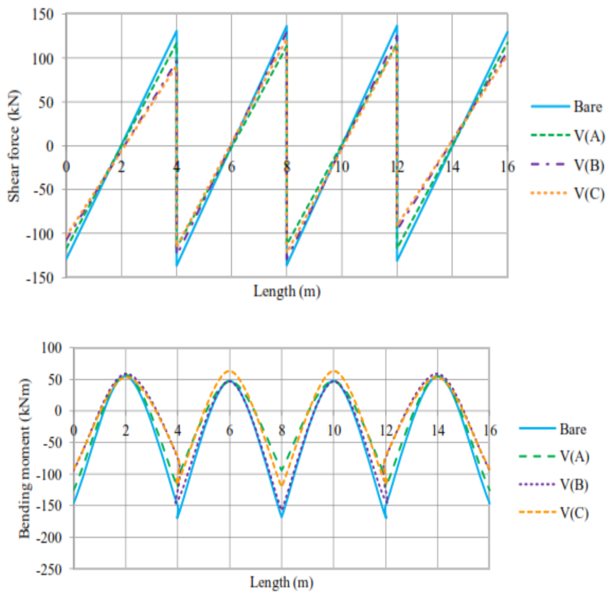


Fig. 3.28 Plot of shear force and bending moment of beams at FL4 in 9 storied bare and V brace frame

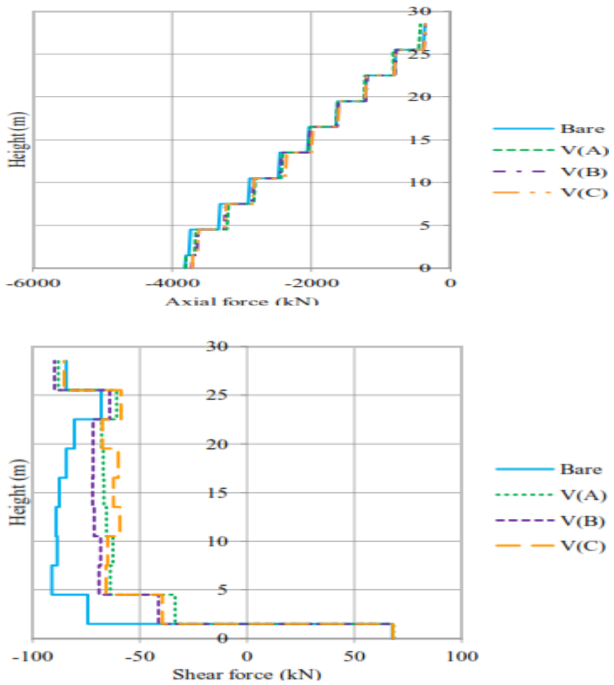


Fig. 3.29 Plot of axial force and shear of column C1 in 9 storied bare and V brace frame

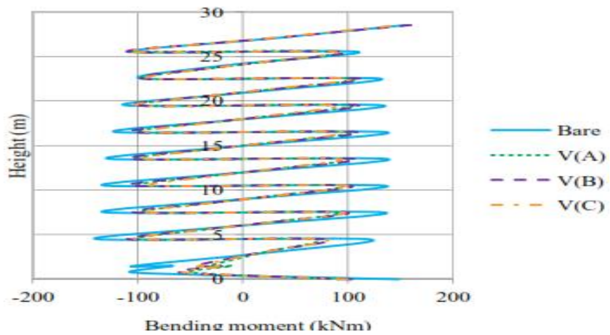


Fig. 3.30 Plot of bending moment of column C1 in 9 storied bare and V brace frame

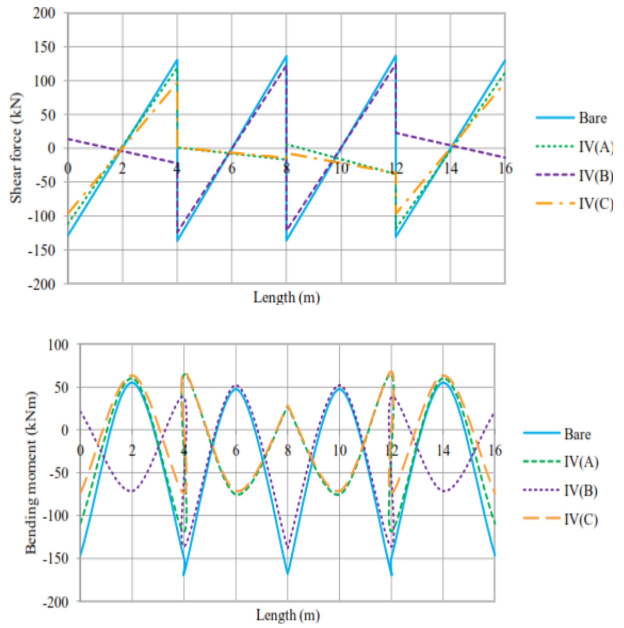


Fig. 3.31 Plot of shear force and bending moment of beams at FL4 in 9 storied bare and IV brace frame

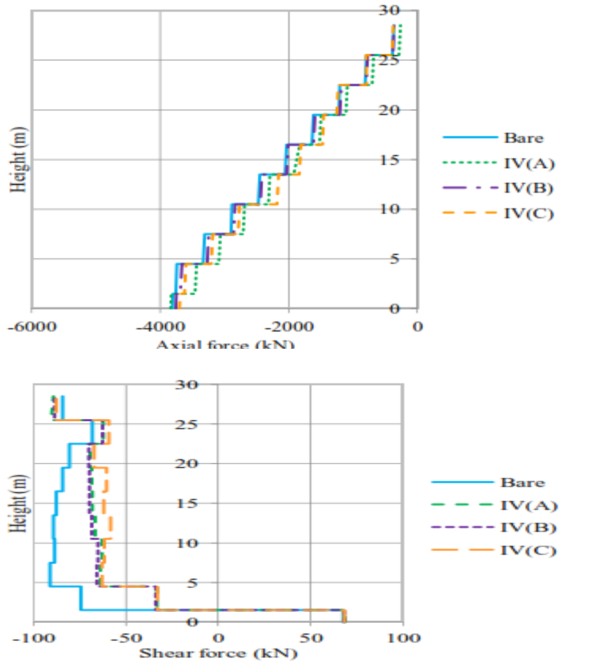


Fig. 3.32 Plot of axial force and shear force of column C1 in 9 storied of bare and IV brace frame

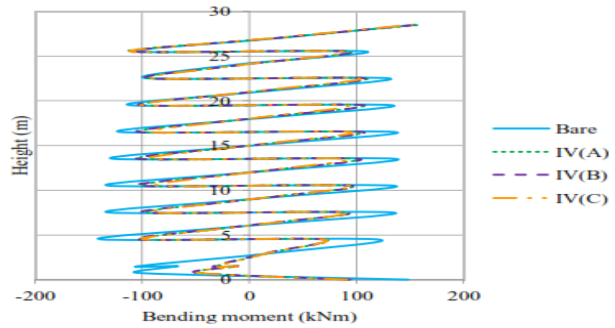


Fig. 3.33 Plot of bending moment of column C1 in 9 storied of bare and IV brace frame

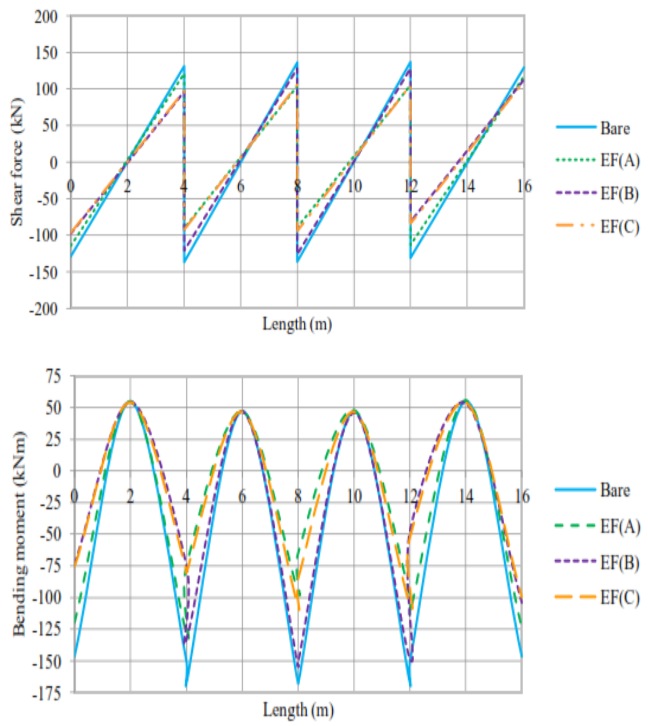


Fig. 3.34 Plot of shear force bending moment of beam B in 9 storied of bare and EF brace frame

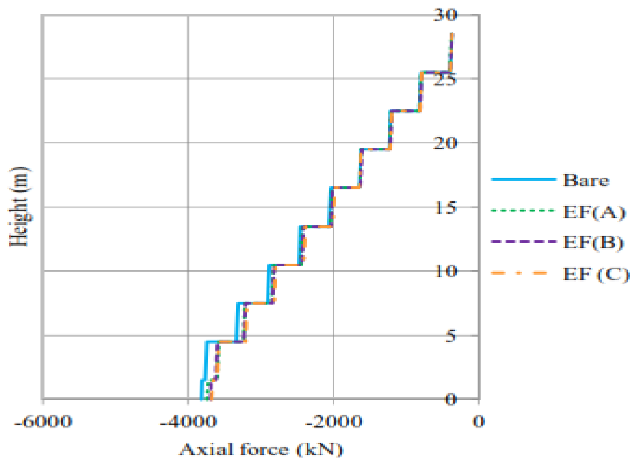
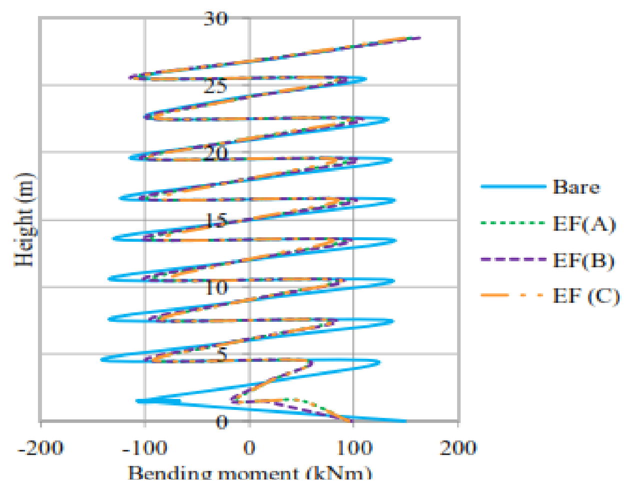


Fig. 3.35 Plot of axial force of column C1 in 9 storied of bare and EF brace frame



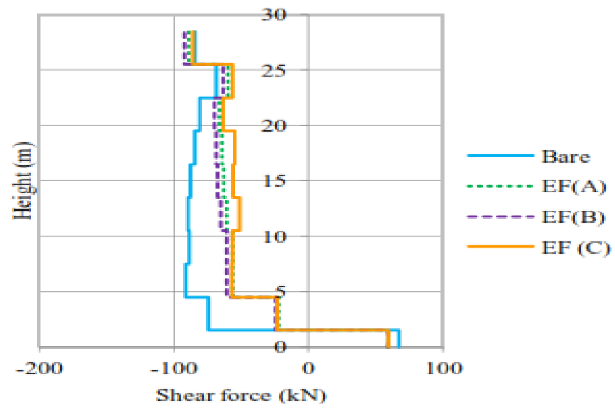


Fig. 3.36 Plot of bending moment and shear force of column C1 in 9 storied of bare and EF brace frame

It is observed X brace frame has less shear force bending moment and axial force when compared to bare frame and variation of shear forces bending moment between X brace and bare frame and between three different pattern is minor.

It is observed V brace frame has less shear force bending moment and axial force when compared to bare frame and variation of shear forces bending moment and axial force between V brace and bare frame and between three different pattern is minor.

It is observed IV brace frame has less shear force bending moment and axial force when compared to bare frame and variation of shear forces bending moment and axial force between IV brace and bare frame and between three different pattern is minor.
It is observed due presence of inverted V brace on that particular bay frame the pattern of bending moment was changed from positive bending moment to negative bending moment and vice –versa when it is compared to bare frame. And there is decrease in bending moment brace frame than the bare frame.

It is observed EF brace frame has less shear force bending moment and axial force when compared to bare frame and variation of shear forces bending moment and axial force between EF brace and bare frame and between three different pattern is minor.

4. OBSERVATIONS AND CONCLUSION

From the analysis results presented in the previous section, following conclusion has been drawn.
1. In brace frame structure shear force and bending moment are less when compared to bare frame structure in all considered models.
2. Out of all braces inverted V bracing has least amount of shear force and bending moment in beam.
3. In case of column the effect of braces on bending moment and shear force is very less there is very less decrease in bending moment and shear force.
4. The difference in pattern of assigning braces has no effect in bending moment and shear force both in beam and column. It only affects the ductility and stiffness of the structure.

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