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STRENGTHENING OF RC FRAME STRUCTURE WITH DEFICIENT BEAM COLUMN JOINTS USING STEEL BRACES

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Abstract — *this research presents the performance of an RC frame structure with deficient beam column joints (no lateral ties at joint panel) retrofitted with eccentric steel braces using a FE software (SAP2000). Such deficient structures are mostly present in underdeveloped countries like Pakistan. A two storey single bay frame were selected and modeled in SAP2000. Seismic zone 4 and soil type Sb were selected as site conditions in order to find the seismic response of the structure. After analysis it was concluded that eccentric steel braces improved the performance of the structure in terms of lateral stiffness, joint shear demand and ductility of the structure.*

Keywords- *Keywords: RC- Reinforced concrete, FE- Finite Element*

I. INTRODUCTION

Reinforced Concrete structure with beam column configuration is broadly used in construction industries. The purpose of its popularity is due to simplicity of construction, comparatively low cost and good thermal resistance [3]. This type of structure normally fulfills its proposed function under gravity load. However current earthquakes around the world as well as in Pakistan and also from experimental work done by different researchers in the previous many years (Priestly, Pauley, Manganese, Park, among others, appropriate reference is required) have confirmed the vulnerability of this type of structure under earthquake excitation, if built improperly. The failure of Margalla tower in Islamabad, Pakistan (Figure 1.1), during the 2005 Kashmir earthquake is one such example between many others, which caused tremendous casualties. Similar catastrophic failures have been observed also in other worldwide earthquakes [1]. Figure 1.2 shows destruction of structures due to beam-column joint failures. (Ghobarah and Said, 2002). The damageability of beam-column joints has resulted in total and partial failure of structures during 2008 Wenchuan earthquake (Zhao et al. 2009) as shown in Figure 1.2b. In designing the RC frame structural member, such as beams and columns it must be confirmed that failure of these members must be in ductile manner and to avoid brittle failure mechanism [7]. These members are proportioned in such a way that the steel reinforcement should yield before the concrete reached its maximum limiting strain (i.e. core crushing). Proper designing and describing is carried out to avoid shear failure of beams and columns. Traditionally, it was considered that beam column joints work elastically, however, this approach was accurate for RC frame structure designed for gravity load only because in such case joint panel is not visible to large force/deformation. During strong earthquake shaking the structure components undergoes large deformation and therefore beam column joints panel undergoes high shear stress state. These shear stresses are due to moments of opposite sign on member’s ends (beam and column ends) on sides of joint. Furthermore, large development length requirement is enforced on beam longitudinal reinforcement framing into joint core due to high bond stress. Finally, due to axial and shear stresses in joint core principal tensile and principle compressive stresses are settled, which result in diagonal cracks leading to crushing of concrete core and buckling of column longitudinal reinforcement. This can further lead to soft story mechanisms due to the improvement of pin-jointed state. These principal tensile and compressive stresses are resisted by strut and tie mechanism in joints (Paulay and Priestley, 1992). Ordinary concrete has no tensile resistance afar multiple cracks, so the proper detailing of reinforcement confirms the ductility and strength of RC frame junctions. The behavior of beam column joint during the earthquake excitation has an essential role on structure global stability of RC frame. To confirm strength and deformability of joints, various codes recommend transverse reinforcement within the joint plate including ACI 318 (2011), NZS 3101 (2006), EC8 (2004), IS13920 (2002) amongst other codes [5]. Plastic hinge formation should be evaded in column, because its leads to enlightened collapse of RC frame structure, therefore design capacity (reference is required) recommends strong column – week beam configuration that allow destruction to beams only, as the beam mechanism is a local phenomenon while the column mechanism is global phenomena.

II. MATERIALS AND METHODS

The modeling of a bare frame and braced frame are designed in sap 2000 and the competitive study was done. For this purpose, material properties steel properties, loads are assigned, cross sections are assigned in sap 2000.
Model description, material properties and load combinations are given in table 1, 2 and 3 below.

Table 1: Model description

No of storeys	2
Hight of each storey	12 ft
Total hight of both storeys	24 ft
Span length	18 ft
Column size	15”X15”
Beam size	12”X18”
Slab thickness	6”

Table 2: Model Properties

Material Properties		
Material	Property	Consider Values
Concrete	Concrete Compressive Strength, fc’	2000 psi
	Concrete Modulus of Elasticity, Ec	2549117 psi
	Weight per unit volume	150 psf
Steel	Steel type	Grade 60, ASTM A615
	Reinforcement Yield Strength, fy	60,000 Psi
	Steel Modulus of Elasticity, Est	29000000 Psi
Zone	Zone	4
Soil Type	Soil Type	Sb

Table 3: Model Properties

Loads and Load Combination	
Self-Weight of Structure	
Floor Finish and Live Load (1st Floor)	40 psf and 60 psf
Floor Finish and Live Load (roof Floor)	60 psf and 40 psf
Load Combination	
U=1.4 Dead	
U=1.4 Dead +1.6 Live Load	
U=1.1(1.2 Dead+.5 Live Load±1.0 Earthquake)	
U=1.1(0.9 Dead ± 1.0 Earthquake)	

II.1 Cross sectional details

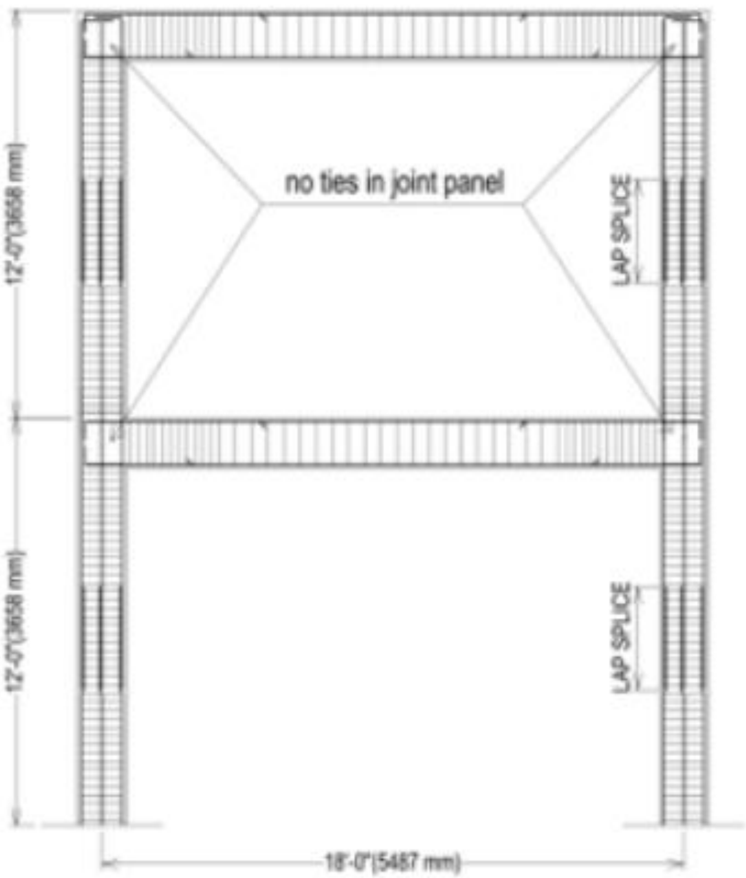

Figure 1: Frame cross section details

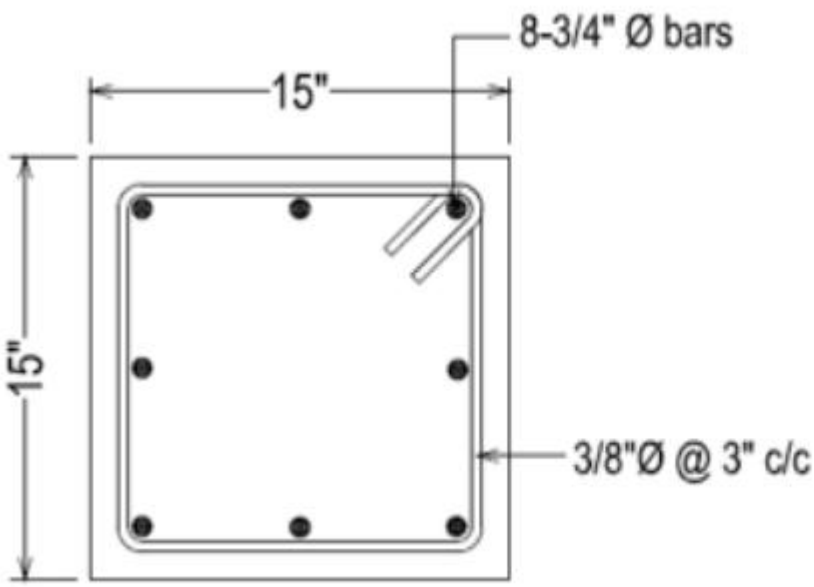

Figure 2: Column cross section

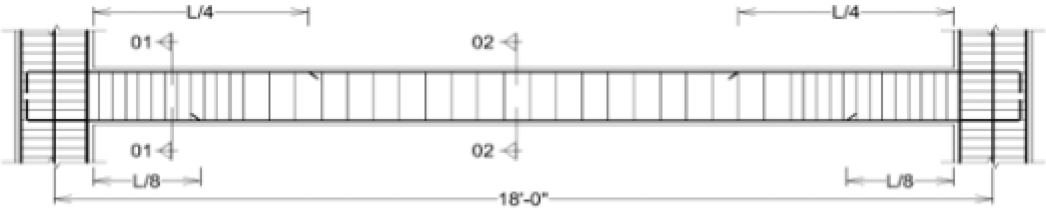

Fig 3.4: Beam Section

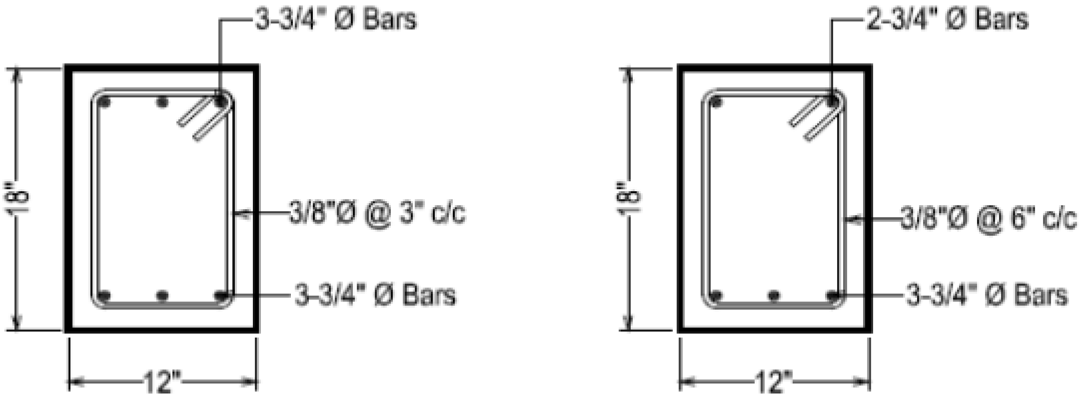

Figure 3: Beam cross sections

Then after a bare frame analysis we install braces in the bare frames in order to have comparative analysis. We installed different size steel braces I-e 3in, 4.5in and 6in respectively to reduce shear demand on beam column joints.

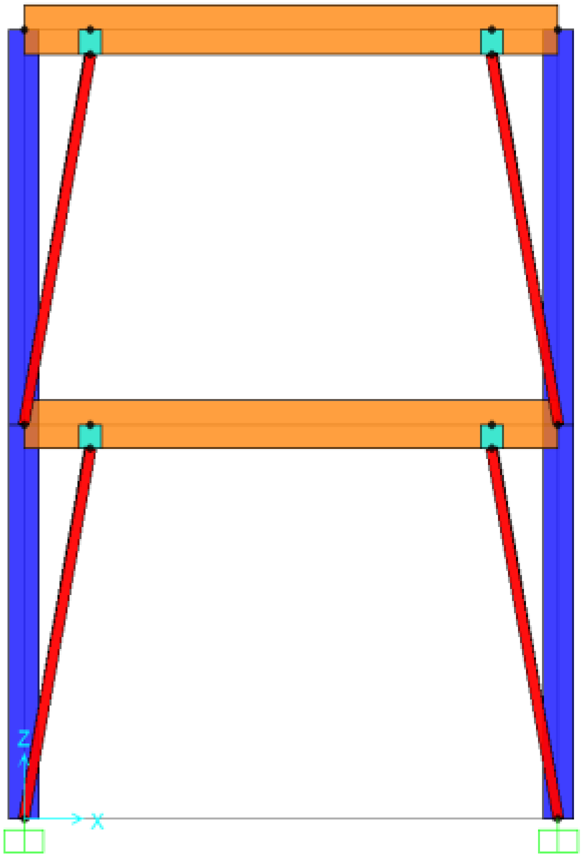

Figure 4: steel braces

II.2 Computer Modeling

Frames were modeled using SAP 2000 Integrated Software for Structural Analysis and Design. A model is composed of three main groups of structural components. These are the reinforced concrete bare frame, the steel frames inserted into frame bays and the steel eccentric-bracing system in each bay which is attached to internal steel frame.

II.3 Results

The numerical study on the RC frame structure were conducted using the finite element based software "SAP 2000". The bending moment diagrams for both frames are given in figures below.

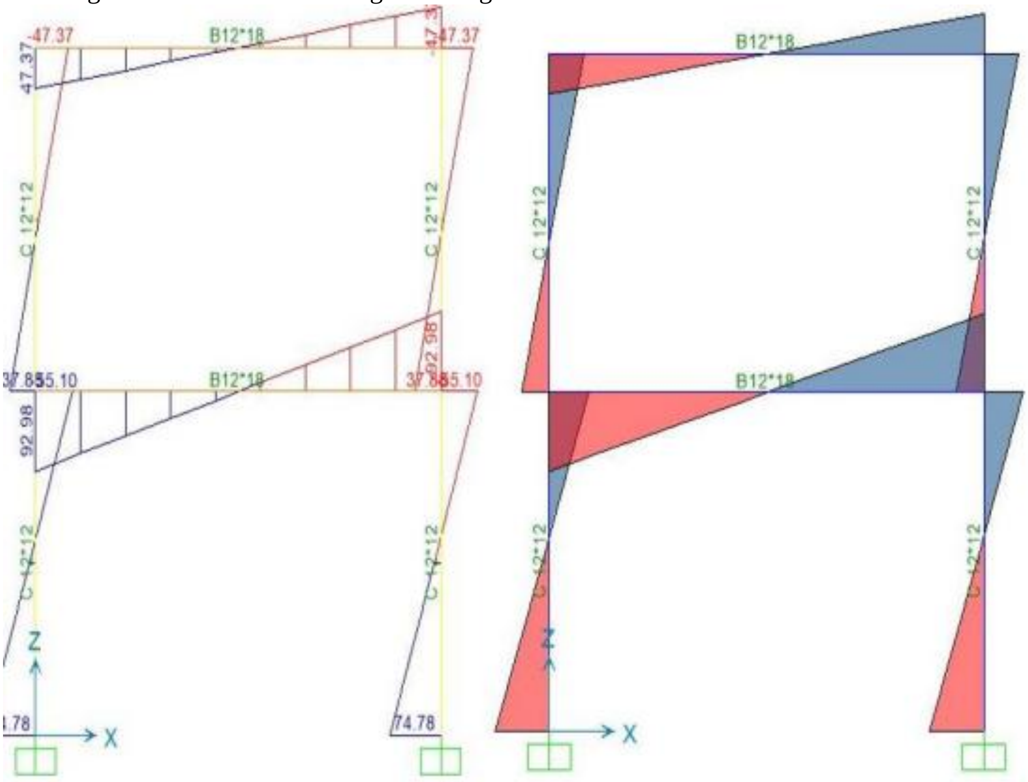

Figure 5: Bare Frame bending moment diagram

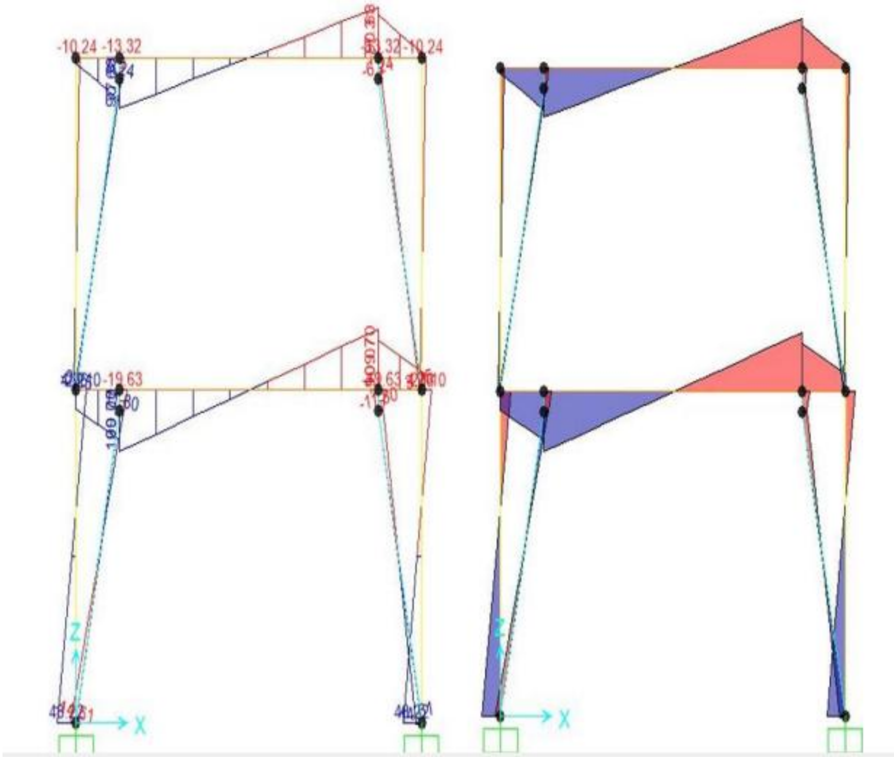

Figure 6: Braced Frame bending moment diagram

The shear demand decreases at the beam column joint with a certain percentage. The table shows a decrease in the shear demand for the beam column joint in the braced frame. With the installment of 3in steel tubes the percent decrease in the shear demand at the joint in the 1st storey is 6.53% and in the 2nd storey is 2.39% .For 4.5in steel tubes the percent decrease in the shear demand at the joint in the 1st storey is 30.44% and in the 2nd storey is 42.86% and for 6in is 36.96% and 52.4% respectively.

III. CONCLUSION

Concluding from this research studies that:

- Shear demand on beam column joint decreases with the installment of the braces.
- Global Stiffness increases when braces are installed in the structure.
- 3in tube is economical but it does not reduce shear demand on the beam column joint significantly.
- 4.5in tube is costly than 3in tube but is economical than 6in tube. 4.5in tube is used because it is economical as well as it reduces the joint shear demand significantly.
- 6in tube gives us the highest percent decrease in shear demand of the beam column joint but is relatively uneconomical.

V. RECOMMENDATIONS

- Use of steel braces are recommended for enhancing the joint shear capacity of an RC frame structure with deficient beam column joints.
- This retrofitting solution can be readily use for parking lots type buildings.
- If functionality of a structure is not of great importance at basement or ground floor, then other schemes like (L/4 and L/2) can also be used and will give better results.

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