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TIME HISTORY ANALYSIS OF ECCENTRICALLY BRACED FRAMES AND BUCKLING-RESTRAINED BRACED FRAMES: A REVIEW

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Abstract— In previous two decades, use of bracing system is in very large amount especially for steel structures or in retrofitting to resist ground motion. Application of bracing system is mostly seen in western countries, to resist seismic loads or ground motions. Buckling-Restrained Braced Frames (BRBFs) and Eccentrically Braced Frames (EBFs) are generally used to provide bracing system. Design EBFs & BRBFs we need ground motion data or perform earthquake analysis. In previous years seismic analysis is done but comparison of Time History Analysis for both bracing systems are not done. In simple language time history analysis is step by step analysis of the dynamical response of structure to a specified loading that may vary with time and it can linear or non linear. BRBFs are nothing but just a special case of Concentrically Braced Frames (CBFs) and EBFs are similar to CBFs just difference is at junction of two braces in CBFs there are no spacing or link between them but in EBFs there is a link of specific length as per section property. As per opinion of previous researchers, both BRBFs and EBFs are suitable to resist lateral loadings or in retrofitting. In this paper, previous researches on BRBFs, EBFs and Time history analysis are thoroughly studied and compiled.

Keywords— Buckling-Restrained Braced Frames (BRBFs), Eccentrically Braced Frames (EBFs), Time history analysis, ground motion data, linear, non linear, earthquake analysis

I. INTRODUCTION

Steel structures are obviously one of the most common choices for residential buildings in the world [11], excluding some countries. Main idea to provide bracing system is to resist ground motion, or other lateral forces. Basically, bracing system is generally used in steel structures or in retro-fittings. If we move on to the types of bracing systems, there are eccentric and concentric which have specific characteristics and requirements [11]. For earthquake prone areas structures are subjected to earthquake forces in addition to primary gravity loadings. Performance of structure during earthquake is dependent on earthquake intensity and structural properties. In case of high-rise buildings, stiffness is more important than strength [11]. That's why we use moment resisting frames (MRF) or bracing systems in structure. In general use of MRF and bracing system is in steel structures or in retrofitting. To install bracing systems in steel structures or in retrofitting, we need some data for suitable bracings and those data are taken from earthquake analysis or seismic analysis. From all methods of seismic analysis, we choose Time history analysis, because Time history analysis gives all deformed shapes as per ground motion data (which is very with time), where response spectrum takes only peak values. Time history analysis is just one of the methods for Analysis of Earthquake Forces. Which can be done in two ways, linear Time history analysis, and non-linear Time history analysis? Buckling-Restrained Braced Frames are generally special case of Concentrically Braced Frames (CBFs) [1]. In BRBFs most common cross-sections are rectangular, circular or cruciform [12]. In BRBFs special thing is its cross-section, i.e. materials use to make Buckling-Restrained Brace. There is also several sub part of BRBFs. Eccentrically Braced Frames (EBFs) are characterized by both excellent ductility and good energy dissipation [18]. EBFs are generally used when we have to get advantage of Moment resisting frames & Concentrically Braced Frames, to perform also lateral load resisting system in single structural system [3].

II. TIME HISTORY ANALYSIS

Seismic analysis is related to calculation of response of a building or other structures under earthquakes. During earthquake many of the buildings collapse due to lack of understanding of the inelastic behaviour of structure. Time history analysis is one of the methods for dynamic analysis. Time history analysis is a step-by-step analysis of the dynamical response of a structure that may be very with time. Time history analysis can be done in two ways:

1) Linear Time history analysis
2) Non-linear Time history analysis

a) *Linear Time history analysis:* Linear Time history analysis calculates the solution to the dynamic equilibrium equation for the structural behavior (displacement, member force etc…) at an arbitrary time using the dynamic properties of the structure and applied loading when a dynamic load is applied.[4]
b) *Non-linear tome history analysis:* Some buildings are too complex to rely on the non-linear static procedure. Those cases may require Time history analysis of the non-linear behavior of structure during analysis of particular example of earthquake [4].

For particular example of earthquake, we need ground motion data. And which is taken from particular database website for different countries. To perform linear Time history analysis in software the ground motion data is provided as input.

III. BUCKLING-RESTRAINED BRACED FRAMES

Buckling restrained braced frames (BRBFs) were introduced in Canada and the United States at the end of the 1990's and their use has since expanded considerably, especially in high seismic regions along the Pacific west coast [16]. Buckling-Restrained Braced Frames (BRBFs) are special class of Concentrically Braced Frames (CBFs) which resist lateral forces in newly constructed building or restoration projects and did not consider safety measures of lateral forces [1]. BRBFs are basically divided into several parts as shown in Figure 1.

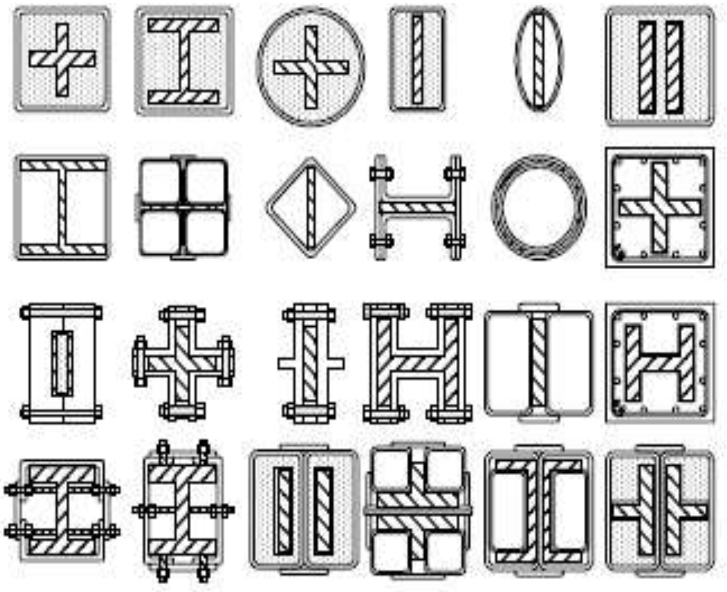


Figure 1: Typical Cross-Section of BRBs [17]

Basically BRBs are divided into several parts as shown in Figure 1. But mainly we can divide it into single core BRB, double core BRB, hybrid BRB, all steel BRB etc. basically single-core BRB is known as conventional BRB[12]. Arrangement of BRB is as shown in Figure 2

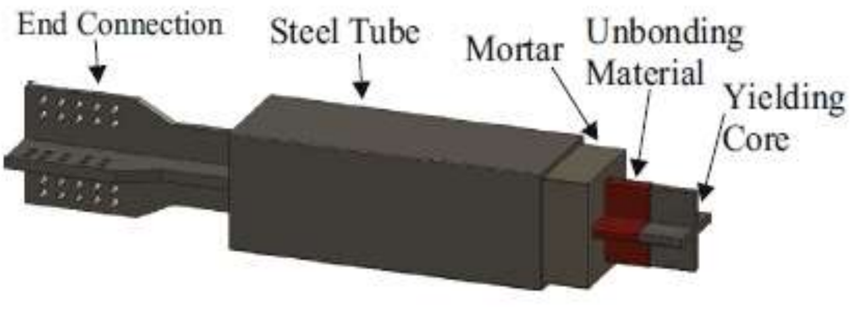


Figure 2: Scheme of arrangement of all Material [12]

As shown in Figure 2, end connection and yielding core are single member in whole BRB, like steel[1] then it's time for unbonding material so as per table 1[17] we can use unbonding material to make unbonding between mortar and yielding core. Debonding material has to be applied to the core to enable its free lateral expansion under compression, and to keep the transmission of the axial force from the core to the restraining unit low [12]. There is one system of BRB known as Buckling-Restrained Knee Brace [7].

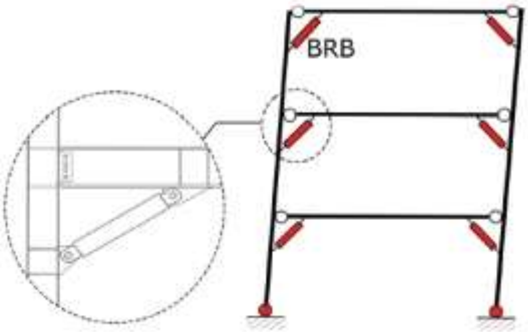


Figure 3a: Arrangement of BRKB

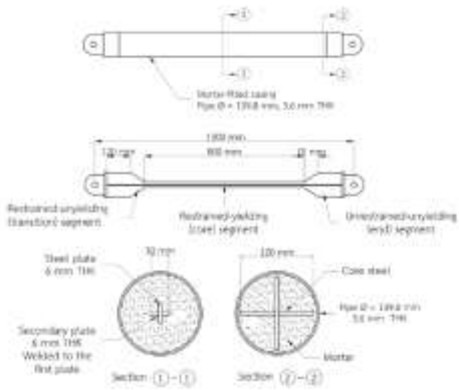


Figure 3b: Detailing of BRKB

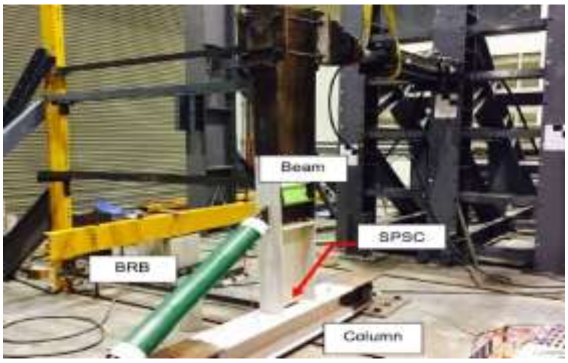


Figure 3c: Testing of BRKB

Figure 3: Buckling-Restrained Knee Brace [7]

Table I: specimen schedule for Unbonding Material tests [17]

Specimen	Unbonding Material	Unbonding Material Thickness	Loading History
AS-1	Asphalt Paint	N. A.	Standard
VF-1	Vinyl Sheet + Foaming Tape	2 mm	Standard
VK-1	Vinyl Sheet + Kraft Tape	2 mm	Standard
R2-1	Rubber Sheet	2 mm	Standard
R5-1	Rubber Sheet	5 mm	Standard
SR1-1	Silicone Rubber Sheet	1 mm	Standard
SR2-1	Silicone Rubber Sheet	2 mm	Standard
SR2-2	Silicone Rubber Sheet	2 mm	Low-Cycle Fatigue
SR2-3	Silicone Rubber Sheet	2 mm	Near-Fault
SR5-1	Silicone Rubber Sheet	5 mm	Standard

Connection of BRB are also plays a very important role in seismic performance. Connections are mainly three types i) Bolted connection, ii) Pinned connection iii) Welded connection [19] as shown in Figure 4

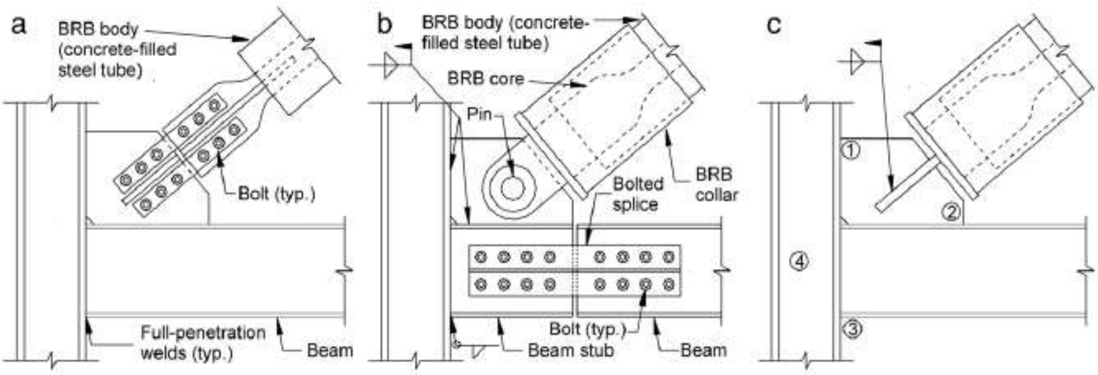


Figure 4: a) continuous beam bolted brace b) split beam pinned brace c) continuous beam welded brace [19]

For modelling of structure we can use ETABS[1], SAP2000[9], PERFORM 3D v.4[1], etc. To model the structure we can take steel structure to perform Time History analysis, and units will be standard that will N and mm. Modeling the steel frame is easily done in SAP2000 software, but modeling of buckling restrained brace has some implications that should be considered. Buckling resistant brace modeling was done using the definition of the plastic joints. However, the remarkable thing here is that the plastic joints of the buckling resistant braces have been defined at the two ends of the brace like the plastic joints of columns. In the buckling resistant brace, the joints can be formed at the two ends like the columns because buckling is not given to the brace, and it will not be like the common braces that the plastic joints are defined at the center of the element. [9]

There are also other types of BRBs available like Hybrid Buckling-Restrained Brace. Hybrid Buckling-Restrained Brace is generally made from two different core materials, which are High-performance steel & low yield point i.e. HPS & LYP steel plates. In Figure 5 HBRB arrangements is shown.

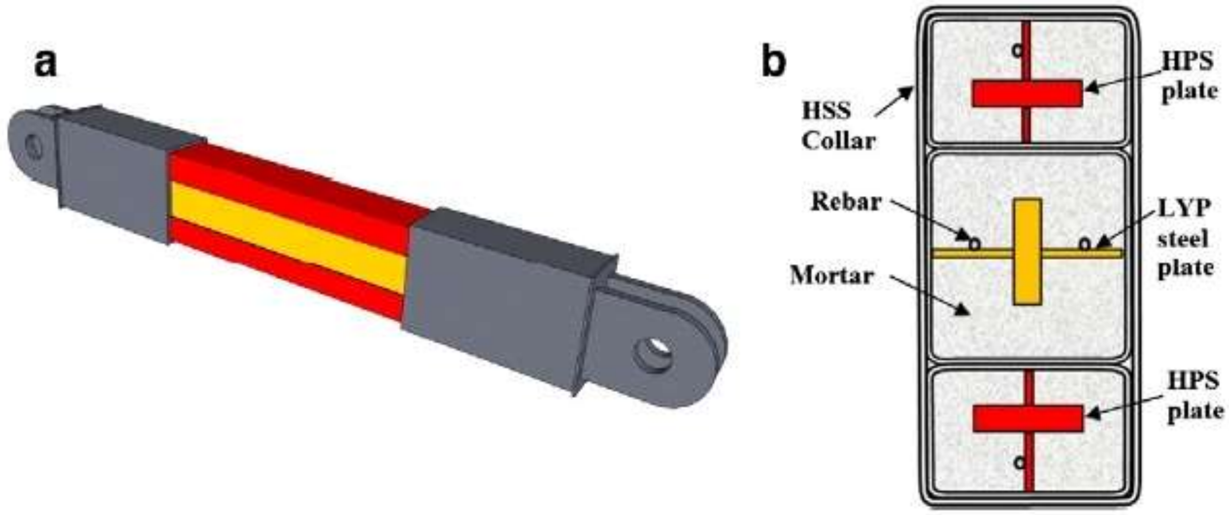


Figure 5: Hybrid Buckling-Restrained Brace [2]

IV. ECCENTRICALLY BRACED FRAMES

Eccentrically braced frames (EBFs) are characterized by both excellent ductility and good energy dissipation. Eccentrically braced frames fabricated with high-strength steel (HSS-EBFs) are a new type of seismic structural system [18]. Eccentrically braced frames are generally used when we have to get advantage of MOMENT RESISTING FRAMES & CONCENTRICALLY BRACED FRAMES, to perform also lateral load resisting system in single structural system[3]. Eccentrically Braced Frames (EBFs) have attained recognized status as a viable structural steel system for resisting lateral seismic forces [13]. There are several conFigureurations for an EBF system, some of which are depicted in Figure 6 along with their expected plastic mechanisms. Eccentrically braced frames (EBFs) have the same advantage as that of concentrically braced frames (CBFs), that is, desirable stiffness, as well as the high energy absorption and ductility of moment-resisting frames [10].

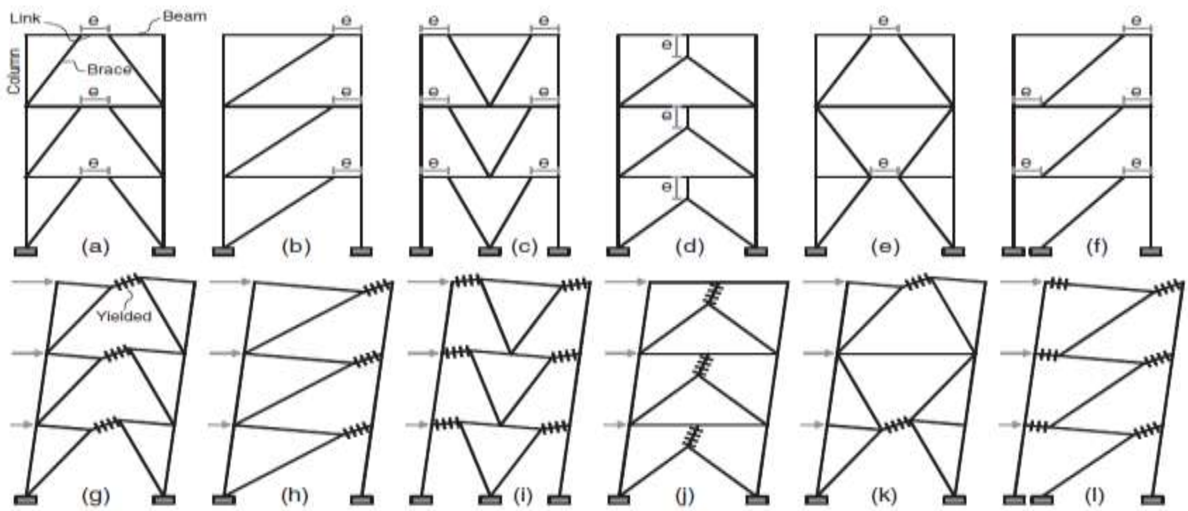
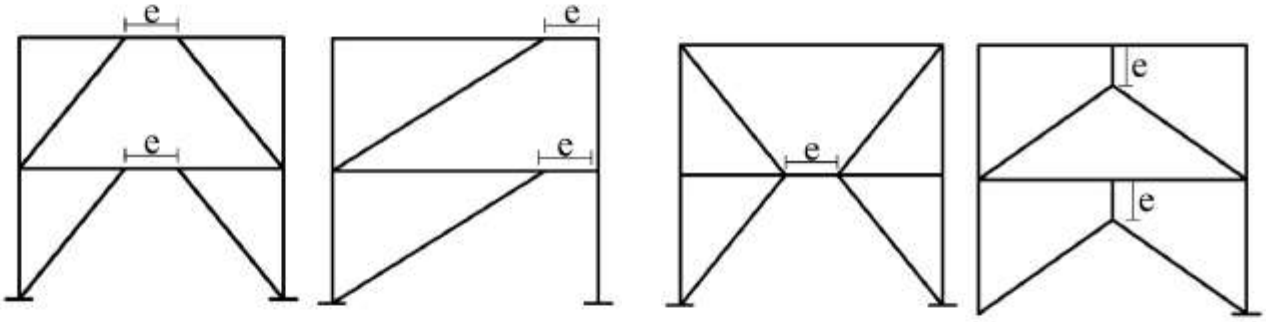


Figure 6: EBF configurations and their corresponding plastic mechanisms. [3]

As shown in Figure 7 short segment of the frame is generally designed by the length “e” called as the link[3]. In EBF systems, yielding is concentrated only at link segments and all other members of the frame are proportioned to remain essentially elastic. Therefore, during severe earthquakes, links can be considered as structural fuses which will dissipate the seismic input energy through stable and controlled plastic deformations. There several type of EBFs as shown in Figure 2. The link is configured either horizontally or vertically. Therefore, there are two general types of EBFs: horizontal (H-EBF) and vertical (V-EBF) [3]. A number of EBF structures located in a lower seismic geographical location of Canada were designed based on NBCC 2005 and CSA S16-94[8].
For modelling steel properties, multi linear kinematic hardening rule with von mises yielding criterion was applied. Yield stress and ultimate strength of steel are assumed based on nominal properties of S235 steel, i.e. 235 and 360 N/mm2, respectively. A Poisson's ratio of 0.3 and modulus of elasticity of 2100 N/mm2 were considered for modelling. Two different properties are reported for flange and web materials both made of ASTM A992 steel[6].



K-Shaped *D-Shaped* *X-Shaped*
Y-Shaped

Figure 7: Typical Eccentrically Braced Frames [19]

To model the structure as shown in Figure 8, arrangement of all materials is shown. i.e. beam column frame, slab section, position of braces as well as link.

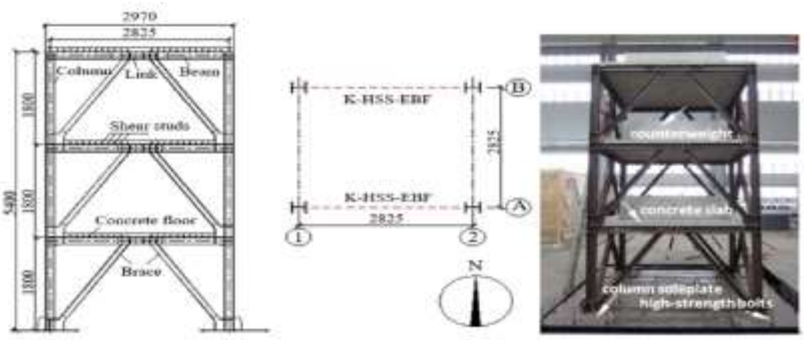


Figure 8: Test Model [15]

Links are classified into short, intermediate length and long links as reported in Euro code 8 (2003) [5]. In EBFs as shown in Figure 9 arrangement of braces, three types of bolted connections are available (1) TS-FR-1 (2) TS-FR-2 (3) TSAW-PR.

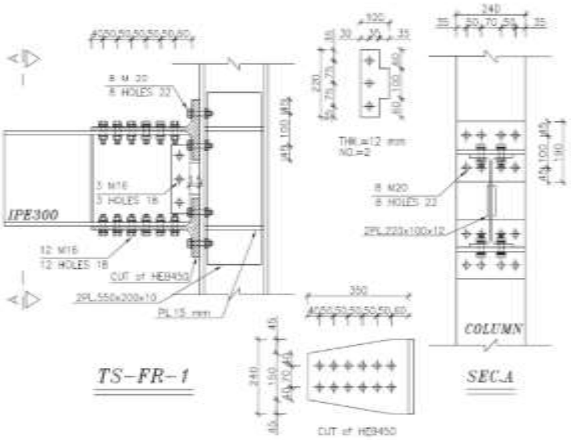


Figure 9(a): TS-FR-1 Connection Details

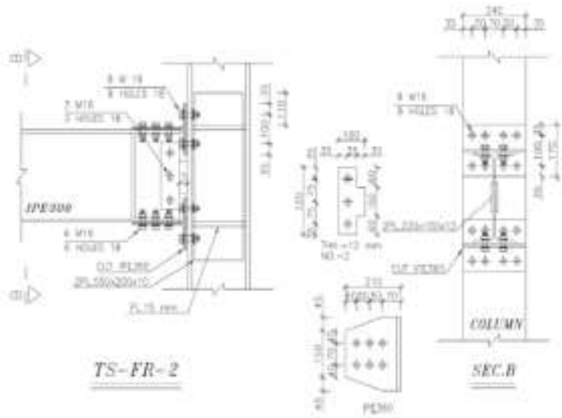


Figure 9(b): TS-FR-2 Connection Details

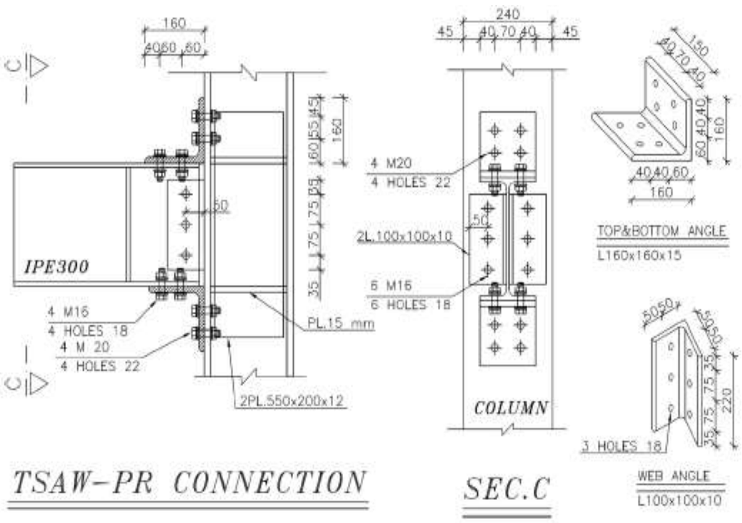


Figure 9(c): TSAW-PR Connection Detail

Figure 9: Bolted Link-to-Column Detail [10]

V. CONCLUDING REMARKS

From the study, can able to understand need of bracing system in steel structure or in retrofitting. Buckling restrained braced frames are use to resist lateral loadings which acting on buildings. Application of eccentrically braced frames are also same as well as Buckling restrained braced frames just difference is that material contains are different so that assembly of bracing system is Different and also priority of section is change. Time history analysis is also import to design the structure or we can say design braces for particular structure.

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