Behavior of Shear Link of WF Section with Diagonal Web Stiffener of Eccentrically Braced Frame (EBF) of Steel Structure

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Abstract. This paper presents results of numerical and experimental study of shear link behavior, utilizing diagonal stiffener on web of steel profile to increase shear link performance in an eccentric braced frame (EBF) of a steel structure system. The specimen is to examine the behavior of shear link by using diagonal stiffener on web part under static monotonic and cyclic load. The cyclic loading pattern conducted in the experiment is adjusted according to AISC loading standards 2005. Analysis was carried out using non-linear finite element method using MSC/NASTRAN software. Link was modeled as CQUAD shell element. Along the boundary of the loading area the nodal are constraint to produce only one direction loading. The length of the link in this analysis is 400mm of the steel profile of WF 200.100. Important parameters considered to effect significantly to the performance of shear link have been analyzed, namely flange and web thicknesses, thickness and length of web stiffener, thickness of diagonal stiffener and geometric of diagonal stiffener. The behavior of shear link with diagonal web stiffener was compared with the behavior of standard link designed based on AISC 2005 criteria. Analysis results show that diagonal web stiffener is capable to increase shear link performance in terms of stiffness, strength and energy dissipation in supporting lateral load. However, differences in displacement ductility's between shear links with diagonal stiffener and shear links based on AISC standards have not shown to be significant. Analysis results also show thickness of diagonal stiffener and geometric model of stiffener to have a significant influence on the performance of shear links. To perform validation of the numerical study, the research is followed by experimental work conducted in Structural Mechanic Laboratory Center for Industrial Engineering ITB. The Structures and Mechanics Lab rotary PAU-ITB. The experiments were carried out using three test specimens with model and dimension identical to the model in the numerical study. Experimental testing apparently has shown results of the same behavior as predicted in the numerical study. However, when it is compared to the shape of the hysterical curve, a slight difference is apparent. This is due to the influence of stiffness of bolt joints and the supports which is difficult to model precisely in the numerical studies.

Keywords: *cyclic loading; diagonal web stiffener; ductility; energy dissipation; monotonic loading; shear link; stiffness; strength.*

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1 Introduction

Indonesia is located in a tectonic area with high occurrences of earthquakes. This has resulted in many efforts to reduce risk created by this situation. Most fatalities due to earthquakes are caused by building collapse. To prevent such risks, designs of earthquake resistant buildings are based on a prevention concept where in the case of a major earthquake, buildings may experience damages, and however people inside the building must remain unharmed. Based on Indonesia's National Standard (SNI) for earthquake resistant buildings is designed by allowing the ductility concept. Based on this concept, in the event of a major earthquake, certain elements of a structure may undergo plastification. This plastification is a mechanism to dissipate earthquake energy on the structure, preventing the structure to collapse. To allow this, elements need to be designed to experience a stabile inelastic deformation during a major earthquake.

A steel structure is regarded as an earthquake resistant structure with a remarkable performance. This is due to unique characteristics of steel. By relying on the ductility and high strength characteristics, steel is suitable to be applied in areas with high seismic activity. Under the steel structure's category, there are three systems which are resistant to earthquakes, (1) Moment Resisting Frame (MRF); (2) Concentrically Braced Frame (CBF); and (3) Eccentrically Braced Frame (EBF). MRF has superiority in energy dissipation ability to achieve required ductility, however this structure lacks of strength and stiffness resulting the requirement of a larger surface area and an expensive double plate panel zone to fulfill drift requirements. CBF efficiently fulfills deformation limits through its framework action; however the stability in the mechanism of energy dissipation is limited [1]. The limitation of both structures has resulted in the development of a new structure system named Eccentrically Braced Frame (EBF) structures. The difference in the three steel structural systems is shown in Figure 1.

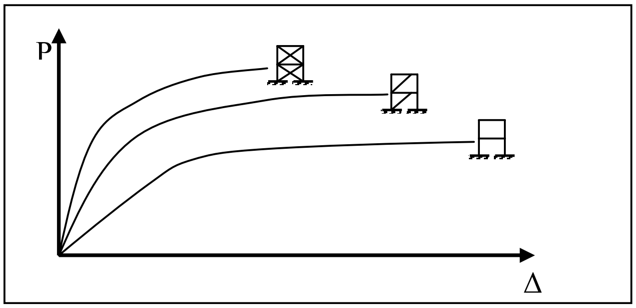

Figure 1 Behavior Differences in Three Steel Structure's System [2].

2 The Objective of Research

The article presented in this paper is part of a Doctor's student research conducted in Civil Engineering Department of Institute of Technology Bandung (ITB) division of structural engineering. The specimen of the study is to obtain an EBF structure with maximum performance through increasing performance of link elements. To achieve the specimen, this study is aims to: 1) Understand mechanism of earthquake energy dissipation in eccentric braced frame steel framework structure. 2) Determine parameters which significantly affect link element behavior in eccentric braced frame, 3) examine each parameter in resulting an improvement of performance link, 4) examine the usage of diagonally placed web stiffeners on link element increasing link performance in EBF.

3 Literature Study

3.1 General Overview of Eccentric Braced Frame (EBF) Structure System

Eccentric braced frame (EBF) structure system is a development from the two previous lateral force resistant systems, which are MRF and CBF. MRF has superiority as it is very ductile and it capable of for large energy dissipation capacity, but low in stiffness, while CBF has high stiffness but a small energy dissipation capacity. Therefore EBF was developed to perfect both MRF and CBF systems. Figure 2 illustrates forms of EBF system which are generally applied [3].

EBF system joins each advantage from both structure systems, and decrease the weakness. The EBF characteristics are: 1) has a high elastic stiffness; 2) has a stable inelastic response under lateral cyclic loading; 3) has a high ductility and energy dissipation ability.

In EBF, absorbance of earthquake energy is carried out through a mechanism of plastic joint formation on link elements. Link elements are part of the beam which is assigned to dissipate energy in the event of a large earthquake. Plastic hinges occurring on link elements can be in a form of shear or flexural yielding. The type of yielding is dependent on link length.

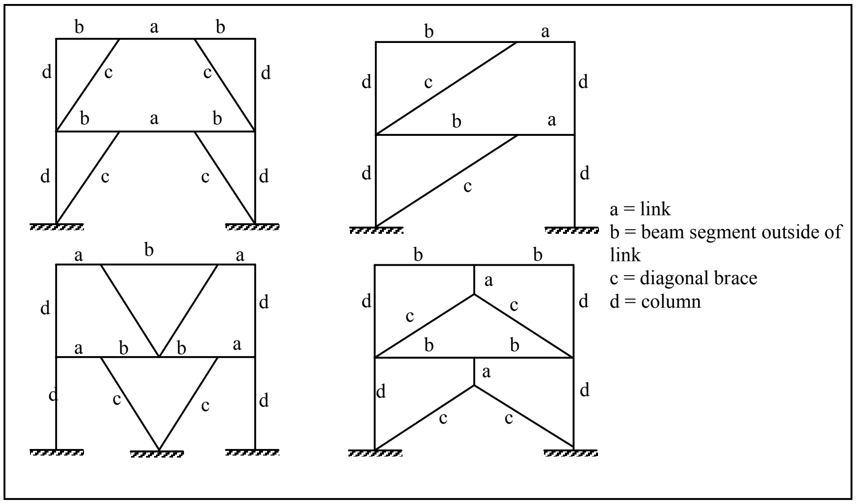

Figure 2 Eccentrically Braced Frame Configurations [3].

3.2 Link Element Characteristic in EBF System

Link is an element inside EBF system which behaves as a short (deep) beam and on both sides apply shear forces with opposite directions along with the corresponding flexures (see Figure 3).

Plastification occurring on link element is caused by both forces above; therefore link element behavior in overall can be classified into two types namely; 1) Moment (flexural) link and 2) Shear link. Link is classified as shear link if yielding is caused primarily by shear, and is classified as moment link if the yielding is caused by flexural moment.

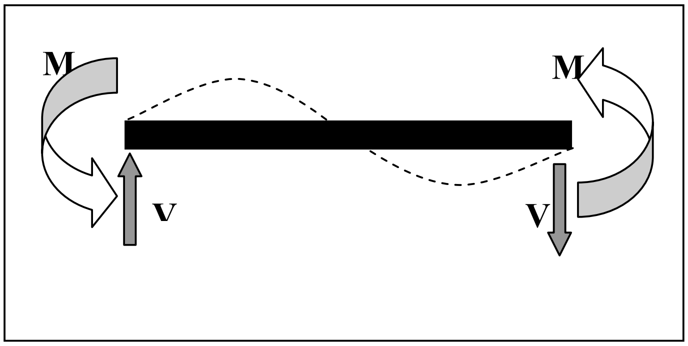

Figure 3 Shear Forces on Link Element [4-5].

Deformation after yielding occurred of a link beam is caused by either shear yielding or flexural yielding or combination of both. By applying a simple analytical model, it can be determined the exact limit between flexural and shear mechanisms. This limit can be described by using a shear span which simultaneously yields in both flexure and shear condition [6].

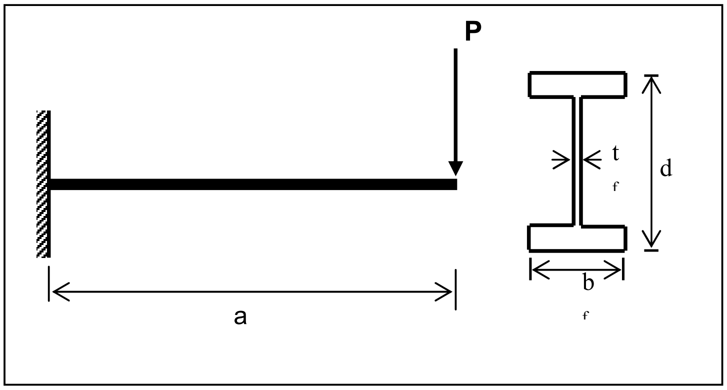

Figure 4 Shear Span and Surface of A Simple Cantilever Beam [7-8].

Shear span is a comparison between moment with shear on a point or spacing between point M=0 (inflection point) with a maximum moment point with no increase in load between both points. Shear span in its simplest form is described as a cantilever beam loaded on its end, as seen in Figure 4. Behavior of link in EBF system during mechanism situation is described with the same concept, which is a simple shear span as in Figure 4. A balance strength ratio is achieved when shear span experiences both flexural and shear yielding simultaneously.

$$a = \frac{M}{V} \tag{1}$$

Where a = length of cantilever beam shear span, M = moment working on beam, V = shear force working on beam. Meanwhile length of cantilever in balanced plastic condition can be translated in the formula:

$$a_b = \frac{M_p}{V_p} \tag{2}$$

where: $M_p = Z_x.F_y$, $V_p = 0{,}6.F_y.d.t_w$

a_b = Comparison of balance strength ratio

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