Seismic Evaluation of eccentrically braced frames without diagonal members

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ABSTRACT

Eccentrically braced frames are one type of lateral load bearing systems due to their acceptable ductility and proportional stiffness. However, they have some limitations that need improvement. One limitation is insufficient architectural space creation especially for short spans which leads to using link beams with intermediate and long lengths that have weaker energy absorption compared to links with short lengths. Another limitation is their costly and time-consuming replacement. To address these limitations, this research proposes removing diagonal elements from eccentrically braced frames and increasing beam depth outside links which provides more proportional stiffness and improved architectural space for designers. Additionally, using replaceable connections between links and main beams reduces repair costs after earthquakes. Numerical modeling was used to investigate this idea along with laboratory studies. Finally, the ratio between increased beam depth outside links and frame stiffness was found through numerical modeling samples with gradual increases in beam depth without braces.

KEYWORDS

Eccentrically braced frame; Shear link; short span; experiment; Numerical modeling.

Introduction

In recent years, eccentrically braced frames have been widely used as lateral load-resisting systems in structures. The performance of eccentrically braced frames during earthquakes is such that all structural elements remain intact except for the link, which yields and absorbs energy. The link, depending on its length, can undergo shear yielding, flexural yielding, or a combination of both. As the length of the link increases, the stiffness of the frame decreases. Therefore, designers strive to keep the link short, although the presence of openings in various locations will pose challenges. This research aims to not only preserve the stiffness of such frames but also reduce issues associated with incorporating openings [1–7] . As shown in the figure 1, first, the bracings are removed from the eccentrically braced frames system, and then the depth of the beam outside the joint increases. This way, by solving the problem of accommodating the opening, the stiffness of the beam also increases. Figure 1 illustrates the process of removing the bracings and increasing the depth of the beam outside the joint. This way, both the stiffness of the beam remains constant and a better architectural space is provided for architects.

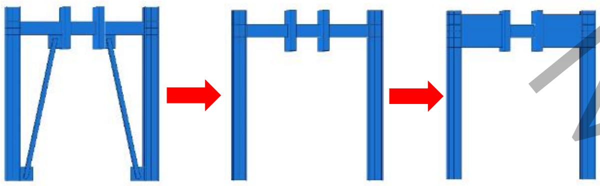

Fig. 1. The shear link frame system.

Methodology

In this research, the concept of a frame with a shear link is investigated and evaluated through experimental and numerical methods. A frame with a shear link is designed and subjected to loading in the middle of it. As shown in Figure 2, this experiment is conducted on a strong floor in the laboratory. The frame placed between two strong frames and on a strong floor. The load is applied to the beam through a jack, and the beam distributes the loads equally to the columns. The connection between the beam and the column is rigid. After validating the experimental work, several numerical models of frames with shear links are created with a gradual increase in the beam's height to establish a relationship between increased stiffness and increased depth of the beam.

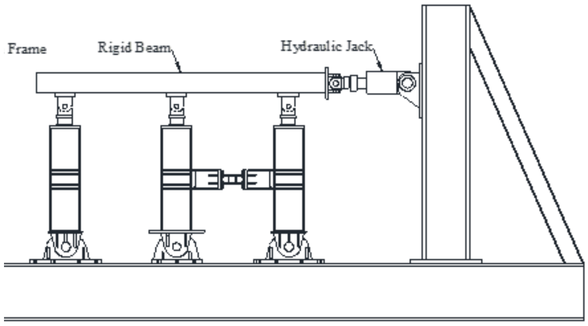

Fig. 2. Test setup.

Results and Discussion

As mentioned, a frame with a shear link was subjected to loading to evaluate this concept experimentally. As shown in Figure 3, the frame underwent a displacement of four percent under loading and experienced cracking in the link during this displacement. As depicted in this figure, the link has completely yielded while the remaining components remain intact. Additionally, Figure 4 illustrates the cyclic energy absorption behavior of this frame, showing a fully stable response.

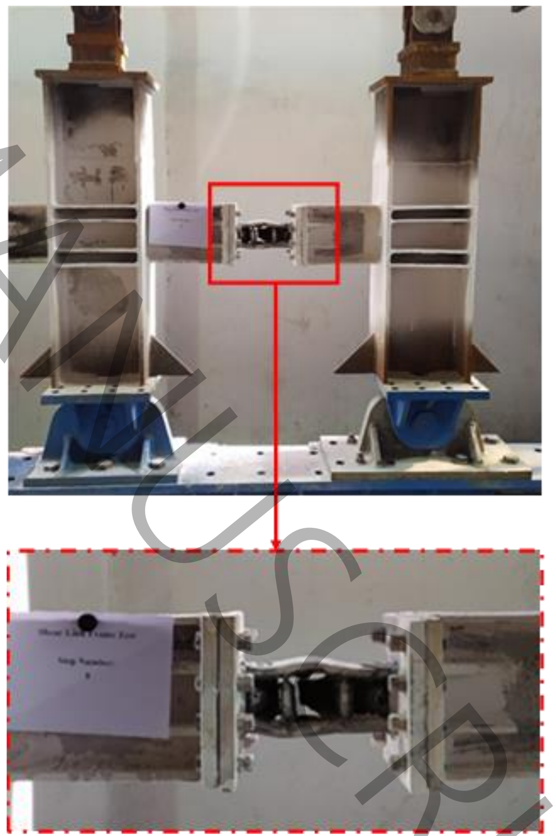

Fig. 3. The condition of the frame with the first shear link in the 8th cycle.

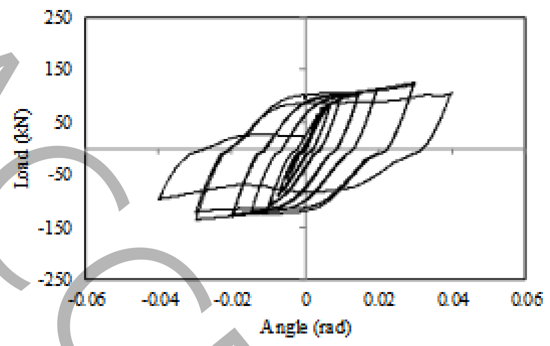

Fig. 4. The cyclic diagram of systems.

In the numerical part of this study, a large number of frames with shear links were designed and modeled using validated numerical models. In this manner, the relationship between the stiffness of these frames based on increasing beam depth is determined. The results indicate that increasing the depth of the frame can lead to increased energy absorption and secondary frame stiffness. Therefore, it can be argued that this frame exhibits satisfactory performance. As shown in Figure 5, a frame with a pinned connection undergoes loading. Additionally, a hinge support has been used to prevent moment yielding at the base of the column.

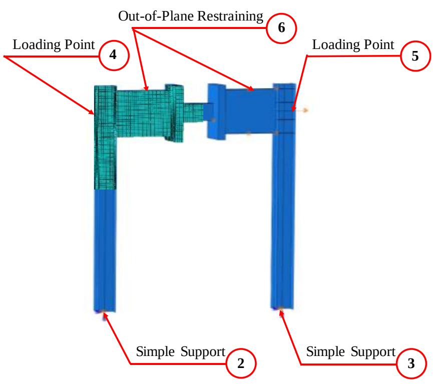

Fig. 5. Boundary conditions.

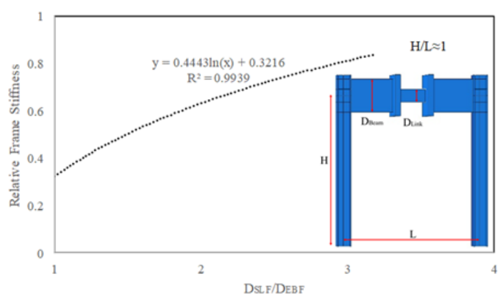

Fig. 6 The relative stiffness change curve of a frame with a link beam to the frame of the bracing system.

Conclusions

Eccentrically braced frames are one type of lateral load bearing systems due to their acceptable ductility and proportional stiffness. However, they have some limitations that need improvement. One limitation is insufficient architectural space creation especially for short spans which leads to using link beams with intermediate and long lengths that have weaker energy absorption compared to links with short lengths. Another limitation is their costly and time-consuming replacement. To address these limitations, in this study, the idea of using link-beam frames to enhance the performance of structures has been evaluated. The conducted experiments have shown that in a link-beam frame, the link beam acts as the yielding member while the rest of the structural elements remain intact. In addition to laboratory experiments, numerical models have also been used to investigate the relationship between frame stiffness and beam depth. The results have indicated that this concept, is practical and effective in terms of structural performance and stiffness. These findings can be utilized to improve the design and construction of structures.

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