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Influence of Section Properties of Replaceable Links on Energy Dissipation of Cantilever Steel Beam

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Abstract:

The main principle used in seismic design of structure is capacity design that allows the design of dissipative members, where the energy dissipation will be concentrated during seismic event, while the non-dissipative members are protected from failure by providing them with a level of over strength such that they can resist the maximum force developed by the plasticization in the dissipative zone. The use of bolted connections enables the links to be replaceable. In the current study, a steel beam with replaceable link from a journal paper was modeled and analyzed numerically for evaluating the energy dissipation. Later the steel beams with replaceable links are numerically studied by varying the depths of link c section and angle section and by changing the width of flange. Based on the observations depth of link to depth of beam ratio 0.88 of C- section gives better performance in terms of energy dissipation.

Keywords*:* *Energy Dissipation, Dynamic Loading, Replaceable links*

I. INTRODUCTION

Earthquake is a natural phenomenon, which can occur any+ time anywhere. It is the shaking of the surface of the Earth resulting from a sudden release of energy in the Earth's lithosphere that creates seismic waves. Ground vibrations during earthquake cause deformation and forces in the structures. The earthquake of late 19th and early 20th centuries triggered number of early advancement in science and engineering. The Bhuj earthquake of 2001 was the first instance of an engineering causing collapse of modern multi-storey buildings in India.

The main principle used in seismic design of structure is capacity design. This principle allows the design of dissipative members, where the energy dissipation will be concentrated during seismic event, while the non- dissipative members are protected from failure by providing them with a level of over strength such that they can resist the maximum force developed by the plasticization in the dissipative zone.

Replaceable links was introduced at the beams where the stress concentration is more. By designing the links as the weakest points while the other members are designed to remain elastic. By doing so, only the links need to be replaced while the other members continue to be structurally appropriate to function.

II. MATERIALS AND METHODOLOGY

In this study energy dissipation of replaceable links provided in steel cantilever steel beam was obtained by performing the nonlinear dynamic analysis using ANSYS Workbench. Rolled steel sections are used for the study, replaceable link length and depth has kept constant. Thickness of link plate and position of the link has been varied to study the performance of link under cyclic loading. Location and dimension of the link sections were chosen on the basis of design recommendations for reduced beam section connections. Details of cantilever beam with replaceable link is shown in Figure 1

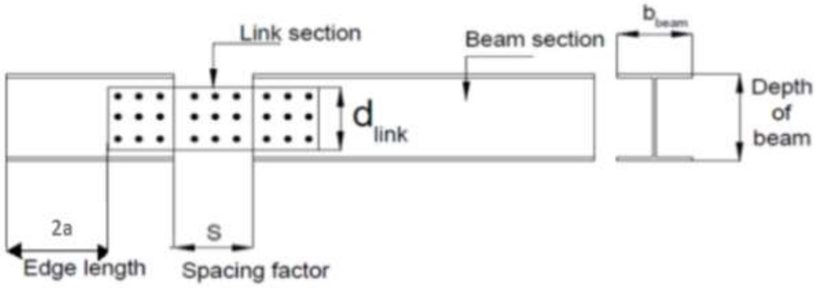


FIGURE 1 Steel beam with replaceable link

III. DATA ANALYSIS AND INTERPRETATION

VALIDATION OF FEM MODEL

Accuracy of modelling, discretization and analysis was verified by comparing the simulation results with experimental results available in literature data, steel beam with a replaceable link model dimension was taken from the paper “Seismic Design and Performance of steel Moment Resisting Frame with Non Linear Replaceable links” which is an experimental study published by Yunlu Shen, Nabil Mansour, Robert Tremblay, M.ASCE and Constantin Christopoulos [9]. Numerical model has been developed using the experimental data. The geometry of the steel beam with a replaceable link was first modeled using the CATIA V5 software shown in Figure 2 and then imported into the finite element analysis program ANSYS Workbench Version 18, to perform discretization and analysis.

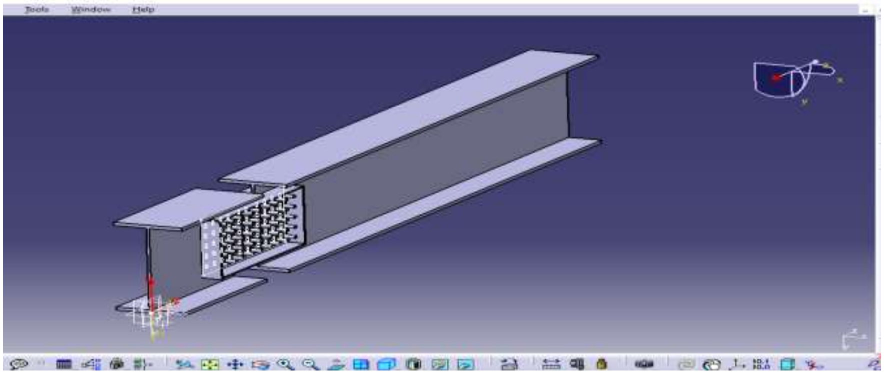


FIGURE 2 Beam modeled using CATIA

Non-linear plastic Analysis of the model with the above material properties is done using ANSYS WORKBENCH software as the cantilever beam subjected to cyclic loading as per AISC-2010 at the free end as shown in Figure 3. Displacement controlled analysis was performed and reaction for the loading is obtained for the applied displacement, Load- Displacement hysteresis curve was plotted to calculate the energy dissipation.

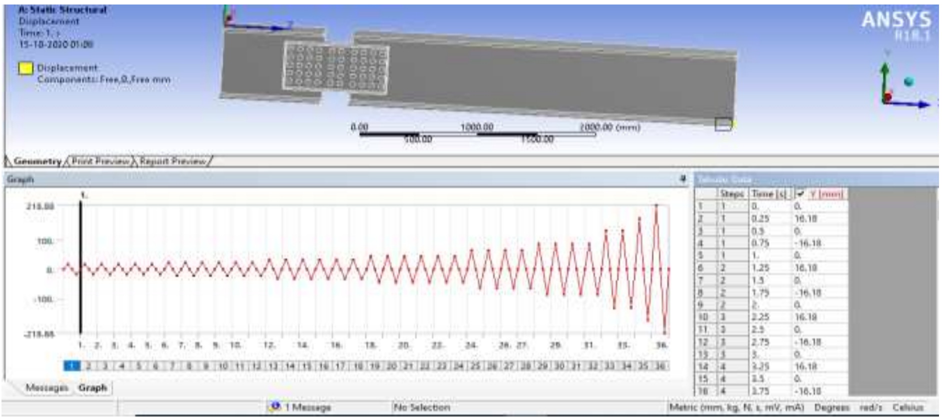


FIGURE 3 AISC Loading protocol

Load displacement hysteresis curve of experimental and numerical study are plotted as shown in Figure 4 and energy dissipation has been compared, it has been observed that there is only 5.43% difference between experimental and numerical value. Hence same methodology of modelling, discretization and analysis was used for further parametric study.

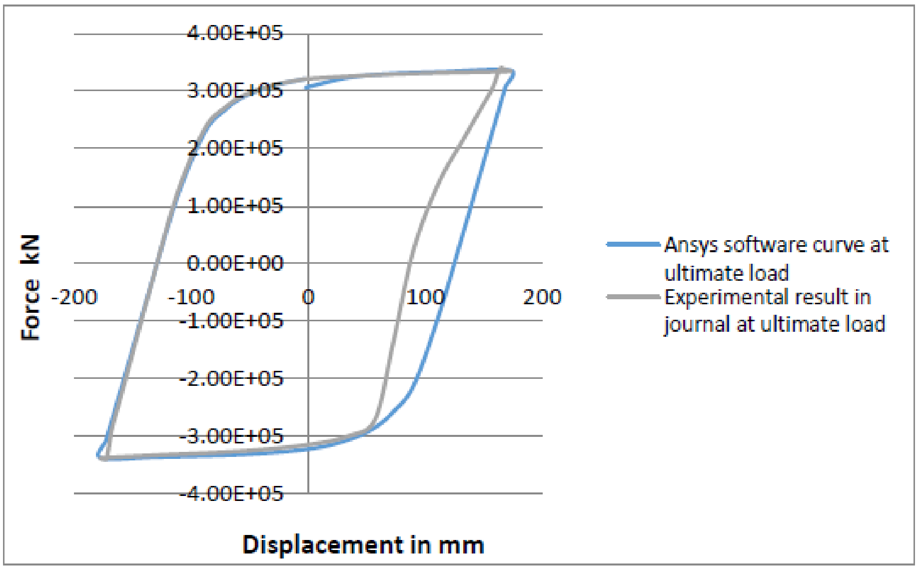


FIGURE 4 Load Displacement hysteresis curve

PARAMETRIC STUDY

For this parametric study. C-section(Channel) and angle section are provided as a replaceable link for the steel beams by varying depth of link being 300mm, 350mm and 400mm. i.e. by keeping depth of link to depth of beam ratio 0.66 ≤ dlink/D ≤ 0.88 for the varying flange width of the link being 40mm,50mm,60mm,70mm.

ISMB450 was considered as beam, with the total length of 3.5m, for replaceable link plate thickness of 7.6 mm was kept constant for entire study and 12mm dia. Bolts are used for the connection. All 24 combinations of cantilever beams were modeled using CATIA V5 and analyzed using ANSYS WORKBENCH by applying the cyclic loading and the hysteresis graphs are plotted to obtain the following results energy dissipation of the link section.

CHANGE IN DEPTH OF LINK AND WIDTH OF FLANGE FOR C-SECTION:

In this study, channel section is used as link. Table 1 gives the details of first stage of parametric study. Analysis was performed for the models and energy dissipation has been calculated from load-displacement hysteresis curve and comparison is shown in Figure 5

Table I Details of C-section link

Dlink/d	DEPTH OF LINK(mm)	FLANGE WIDTH(mm)
0.66	300	40
0.66	300	50
0.66	300	60
0.66	300	70
0.77	350	40
0.77	350	50
0.77	350	60
0.77	350	70
0.88	400	40
0.88	400	50
0.88	400	60
0.88	400	70

Figure 5 shows the variation of energy dissipation of all variations of C-section as replaceable link. It can be observed that C- section with 300mm depth, 40mm flange width shows more energy dissipation ability i.e., 22% to 73% when compared with other flange width. For 350mm depth of C-section, 60 mm flange width shows more energy dissipation ability i.e., 2.5% to 92% when compared with flange width. For 400 mm depth C-section, 70mm flange width shows more energy dissipation ability i.e., 15% to 52.4% when compared with other flange width.

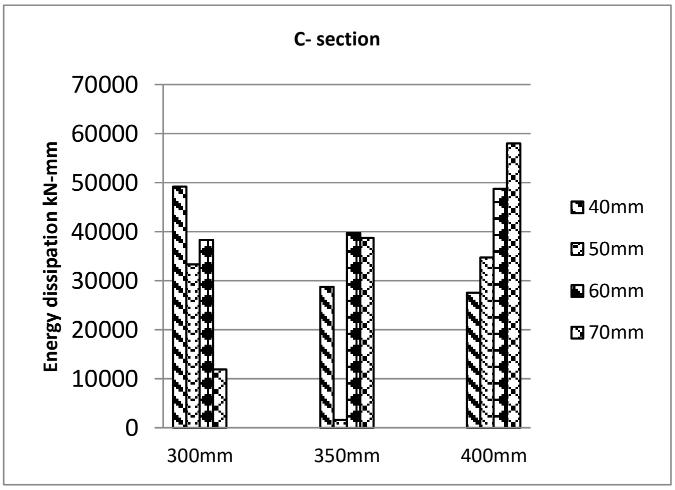


FIGURE 5 Energy dissipation comparison of beams with C-section replaceable links

CHANGE IN DEPTH OF LINK AND WIDTH OF FLANGE FOR ANGLE SECTION:

Figure 6 shows the variation of energy dissipation of all variations of angle section as replaceable link. It can be observed that angle section with 300mm depth, 40mm flange width shows more energy dissipation ability i.e., 38.7% to 63.8% compared with other flange width. For 350mm depth having 60mm flange width shows more energy dissipation ability i.e., 23% to 92% compared with other flange widths.

For 400mm depth section having 70mm flange width shows more energy dissipation ability i.e., 40% to 50.7% when compared with other flange width.

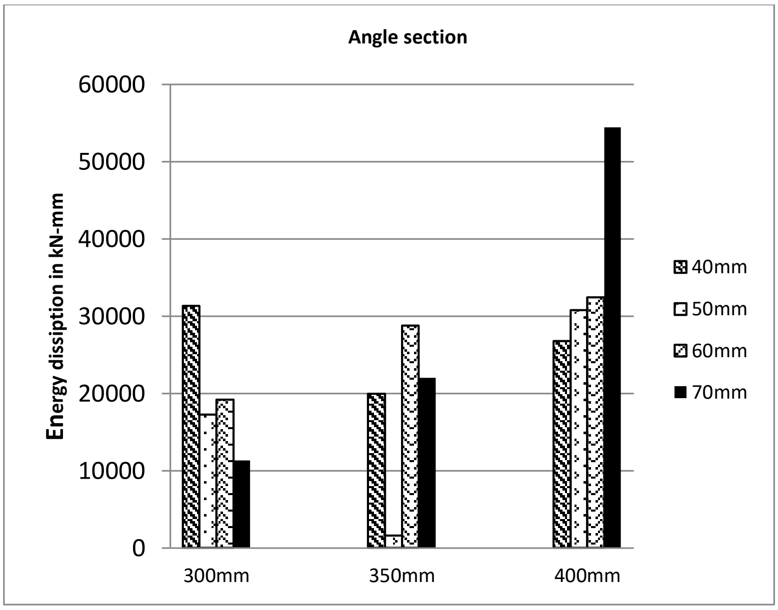


FIGURE 6 Energy dissipation comparison of beams with Angle section-replaceable links

COMPARISON OF ENERGY DISSIPATION OF ALL PARAMETERS:

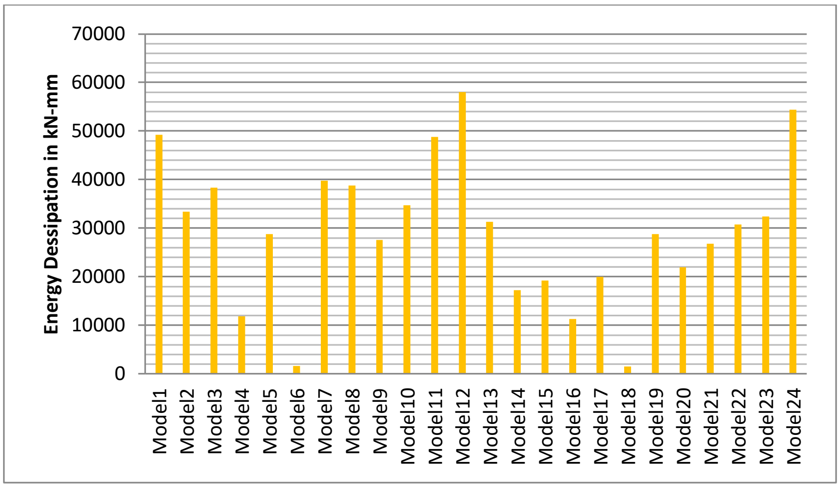
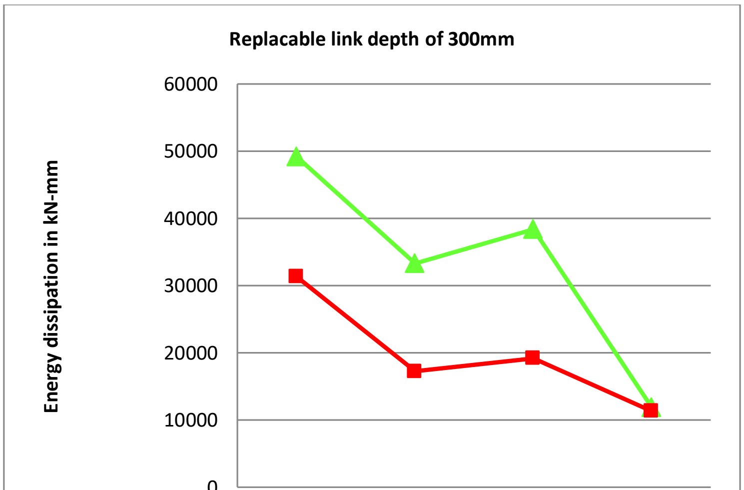


FIGURE 7 Energy dissipation comparison of all parameters

Energy dissipation variation of all combination of replaceable link has been plotted in Figure 7. Following observations were made from Figure 7.

- It can be seen that the load and displacement are decreasing with the increase in width of the flange in both C- section and angle section and then again increases for all depths of plate
- Performance of 12th model number which contains 400mm depth of c- section with 70mm flange width shows better performance by dissipating more energy
- Energy dissipated through the link with the link plate with dlink/ratio of with flange width of 70mm in c section as well as in angle section shows higher values than all other and less stress is observed on the web of the beam
- It is observed that dlink/D ratio of 0.88 shows higher energy dissipation i.e., 15.17% to 95.45% compared to 0.66 and 0.77 ratio for c section replaceable link
- It is observed that dlink/D ratio of 0.88 shows higher energy dissipation i.e., 42.37% to 97.10% compared to 0.66 and 0.77 ratio for c section replaceable link
- It is also observed that c- section with the flange width of 70mm shows higher energy dissipation values when compared with the angle section of flange width 70mm
- C-section of 400mm depth with the flange width of 70mm shows higher energy dissipation i.e., 6.20% when compared with the angle section of depth 400mm with flange width 70mm.



	40mm	50mm	60mm	70mm
C Section	49200	33350	38400	11900
Angle section	31350	17280	19200	11340

FIGURE 7 Energy dissipation comparison of all parameters having replaceable link of depth 300 mm

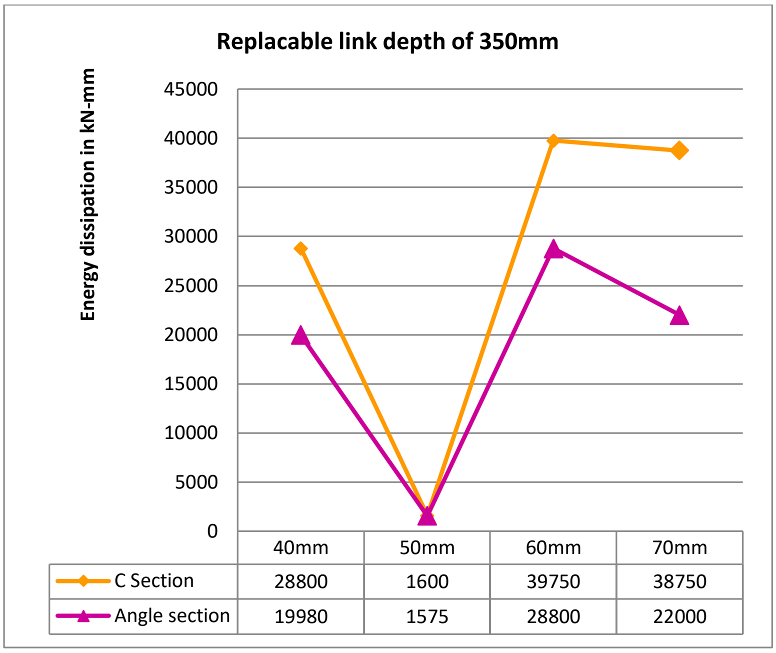


FIGURE 8 Energy dissipation comparison of all parameters having replaceable link of depth 350 mm

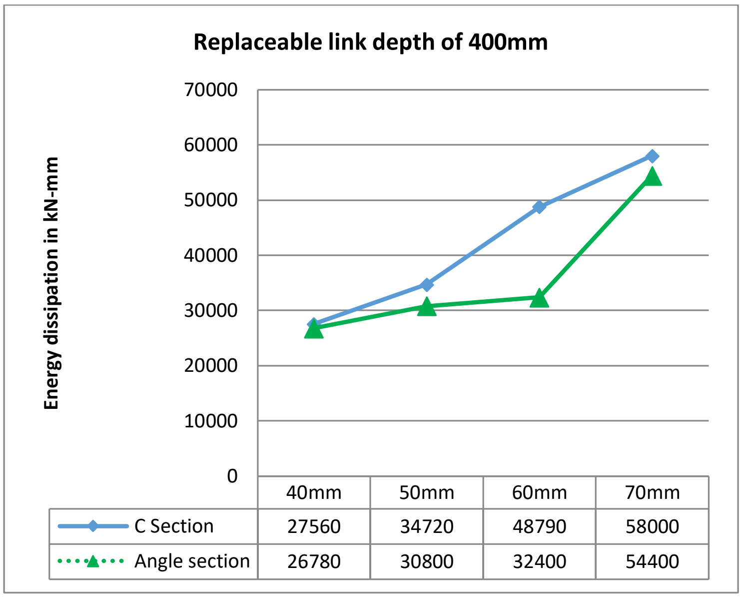


FIGURE 9 Energy dissipation comparison of all parameters having replaceable link of depth 400 mm

From the Figure 7, it is observed that for 300mm ink depth, 40mm flange width shows more energy dissipation for both c section and angle section, in turn c section dissipates more energy i.e., 36.281% when compared with angle section

From the Figure 8, it is observed that for 350mm ink depth, 60 mm flange width shows more energy dissipation for both c section and angle section, in turn c section dissipates more energy i.e., 27.54% when compared with angle section

From the Figure 9, it is observed that for 400mm ink depth, 70mm flange width shows more energy dissipation for both c section and angle section, in turn c section dissipates more energy i.e., 6.62% when compared with angle section

Hence it can be concluded that beams having replaceable links of C-section shows more energy dissipation compare to other parameters. Presence of the flange contributes in additional load carrying capacity.

III. CONCLUSION

The study involves the influence of geometric parameters of steel replaceable links provided in cantilever steel beam on energy dissipation. Based on the observations made it is seen that good results are seen for dlink/D ratio 0.88 i.e for the link depth 400mm. For replaceable link having dlink/D of 0.66 i.e., 300mm, 40mm flange width shows more energy dissipation ability i.e., 22% to 73% for c section and 38.7% to 63.8% for angle section when compared with other flange width with same link depth. Beam with replaceable link plate depth of 300mm of beam web section showcased stress distribution more on the beam rather than the link section. For dlink/D of 0.77 i.e., 350 mm depth, 60mm flange width shows more energy dissipation ability i.e., 2.5% to 92% for c section and 23% to 92% for angle section when compared with other flange width with same link depth. Energy dissipated through the link with the link with dlink/D OF 0.88 ratio of with flange width of 70mm in c section as well as in angle section shows higher values than all other and less stress is observed on the web of the beam. Cantilever beam with c section link depth ratio dlink/D =0.88 dissipates energy 6.24% more energy compare to angle section link with the same depth and same width of the flange

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