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Evaluation of reduced beam section (RBS) on castellated beam subjected to a seismic load

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Abstract. The ability of the beam to receive a seismic load can be explained in the experimental study of a castellated beam using RBS (reduced beam section) as a damping factor on earthquake resistant building structure. Evaluation of the structure of the exterior connections was done by subjecting cyclic loads gradually until collapsed to evaluate castellated beam test specimens with and without RBS. The experimental test conducted by cyclic test aimed to determine the ability of deformation and the force that worked due to the influence of RBS placement from the column face on the castellated beam. Investment of RBS positions on the columns in the column face shows that failures occurred due to the bending on the shaft. The results obtained by each load to the drift ratio were as follows. On the test specimens with RBS, the melting point was at 8 kN loading with a 1.05% drift ratio, 2.1% drift load at a 9 kN load, 3.20% drift at a peak load of 12 kN, and necking phase at 10.53 kN load with 4.17% drift.

1. Introduction

Explanation of structural strength of seismic design on steel structure is aimed to make structure elastic during small to medium seismic events. In the 1994 Northridge Earthquake, fractures occurred on the connections, which some of them often started at the bottom flange weld and spread to the column flange and the beam web. Miller reported that the crack model on the Northridge Earthquake began at the point of intersection between the weld access hole and the beam bottom flange.

In tests using RBS connections, one way to lessen earthquake energy for a more elastic structure is by cutting a part of the beam flange by SNI 03-1729-2015 or using AISC standard 358-10 as a reference in RBS design [1]. RBS design procedure is based on AISC 358-10 section 5.8 of column face to ensure the plastic joints in the area. RBS is a very strategic type of connection in the flexing mechanism at the desired location on the beam.

In a study conducted by using numerical Abaqus studies, the position of damage was concentrated in the cutting area (RBS), then the specimens were tested to confirm the behavior and performance of the connection between columns and beams with reduced beam section (RBS), which produced displacement at 104.25 mm peak load, where flange bending on RBS beam occurred [2].

Meanwhile, examined the performance of skeletal beam joints with RBS against fires by numerical methods. The results showed that the strength of axial forces and deflections was generated in beam joints by the RBS method. The first meeting in the RBS region was well exposed to fires locally and global [3].

Eliminating the continuous plate reduces the cost of materials and labor; thus, it is more economical to be implemented in a steel frame construction. Compared the behavior of buildings with RBS and conventional buildings and found that there were 23% deflection increase and the drift ratio improvement on the upper level of the buildings [4]. Many experimental studies and literature reviews of castellated beam and RBS have been conducted to analyze the exterior connection of beam-column joint subjected to cyclic loads. Meanwhile, this study presented the results of the test design of the strength and value of the drift ratio on the castellated beam connection by cutting the beam flange.

2. Experimental design and testing

The experimental testing used to analyze the effect of the lateral cyclic load on the structure of the exterior column beam using RBS on the castellated beam, which resulted in the load performance and the drift ratio.

The study was conducted to analyze the behavior of RBS castellated column on the specimens. The welding procedure was done on the system considered as a semi-rigid connection using an end plate connection. The testing set-up is displayed in figure 1 [5]. Loading was exerted by applying a cyclic load.

In the tests, lateral support near the actuator was provided to prevent lateral deformation of the beam and damage of the actuator. The global deformation of the specimen was measured during the test to determine the deformation and deflection components of the beam. The global displacement of the samples was measured using the actuator to identify the deformation and deflection components of the beam.

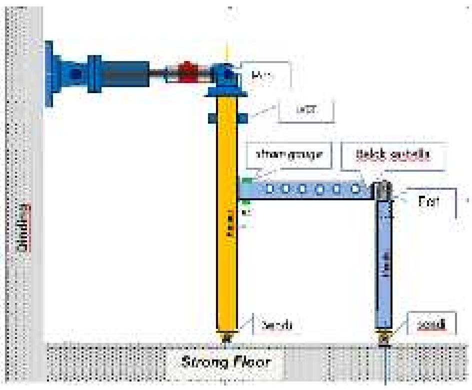

Figure1. Experiment set-up the castellated beam column.

The study to obtain records of a structure experiencing a force due to cyclic loading to reach the melting or plastic limit was done in four phases; namely, the design using the principle of strong column-weak beam, the tested structure design was modeled by the exterior column beam with cyclic load, the test results of the structure was read using LVDT and recorded into the computer. The cyclic loading was applied gradually with hydraulic jack and load cell according to the value of displacement at the first melting point (Δy), which was 20 mm based on the analysis results. The movement (melting point) was determined for each cycle in 0.25Δy, 0.5Δy, 0.75Δy, Δy, 2Δy, 3Δy and so on until the load termination in case of decreased load value from the previous peak (collapse) [6]. The gravitational load remained constant, and the lateral cyclic load was then provided with an initial displacement rate of 0.05 mm/sec.

Table 1. The dimension of the tested beam [7].

Tested beam	Castellated opening distance from the column face (mm)	The distance of trim (RBS) from the column face (mm)
RBSC - 1	285	70

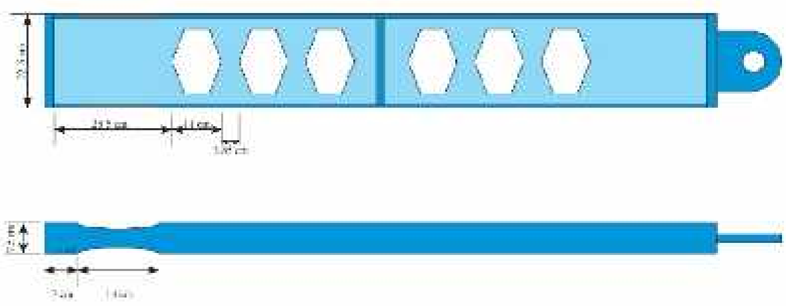

Figure 2. The dimension of the castellated beam and RBS.

Figure3. The testing instrument of castellated beam and RBS.

3. Results and discussion

Figure 3 illustrates the relationship between the loads received at each phase starting from the elastic region to the inelastic, and continuing in the necking phase (collapsing). The result shows that the melting first occurred in the flange section of the beam. An experimental test of the RBS castellated beam is displayed in tables, graphs/curves, and figures. The detail of the failure on the beams explained the failure effect and caused classified by each phase of structural failure.

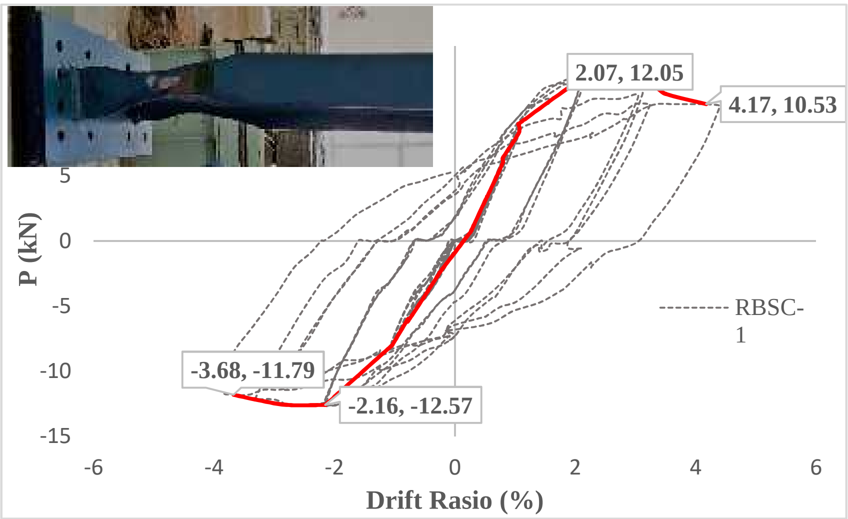

Figure 4. Graph of the load against drift ratio at each phase

As can be seen in figure 4, the lateral load capacity increased as the lateral displacement rose. The difference between positive and negative maximum loads was possible due to the different movement of load cell pads to each side that affected the lateral deflection of the beam. Figure 3 also displays the four phases of the RBSC-1 test specimen. In the first phase, the load and the initial drift ratio were 0 – 8 kN. The response was the linear region called elastic phase that generated a 1.05% drift ratio. The second phase occurred at a load rate of approximately 8 – 9 kN, namely the plastic stage. In this phase, the specimen was plastic or inelastic with a drift ratio of 2.07%. The third phase occurred on the load and the drift ratio at the load rate of approximately 9 kN to the peak of 12 kN at 3.20% drift ratio, which the specimen had an inelastic response called the strain hardening. Furthermore, in the fourth phase, the curve decreased when the load capacity was reduced to 10.53 kN, at 4.17% drift ratio, which was called the necking phase. On the lower area of the curve, the drift ratio was -3.68% obtained at 11.79 kN load. Each of the flange surfaces showed a failure pattern (bending) located in the RBS area in the beam, where new bending moments were formed on the upper and lower surfaces on both sides at the same time. As the cyclic lateral load continued to increase, the formation of a new bending yield was visible on the surface of the paint undergoing shedding along with the area of RBS seen on the outside with a bent pattern. In addition, when the load exceeded the capacity of 12.05 kN as in the post-peak response with a 4.17% drift level, it is interesting to note that the load had exceeded the maximum capacity and the capability decreased to 16.7% on average in both directions, which indicates that the specimen tended to achieve its bending capacity.

4. Conclusion

The performance of the RBS castellated beam was as follows. The maximum lateral load capacity value of each drift ratio during the collapse phase showed the drift ratio at the peak load of 12.0 kN, which indicated that the structure met the seismic design requirements with a drift ratio of 3.2%. The strength decreased by 12.25%, which was caused by the addition of load to reach the necking phase at a drift ratio of 4.17%.

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