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Reduced stiffness as structure acceptance criteria on cyclical loading in castellated beams

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Abstract. The performance of RBS (Reduced Beam Section) on the exterior connection structure of castellated beam-column with cyclic loading method was tested on three specimens, which were the steel castellated beam without RBS (WRBSC), castellated steel beam with the RBS-1 (RBSC-1), and castellated steel beams with the RBS-2 model (RBSC-2). The three specimens were designed in an assumption of the strong column-weak beam and other assumptions based on seismic regulations as a condition for earthquake resistant building planning. This study presents the results of each specimen when given a certain structural response. The results also provide a detailed description of the test results starting from lateral axial loads. The lateral force was assumed to be the most dominant force acting in this experimental test, while the gravitational force was considered insignificant. Thus, this test only obtained structural performance when alternating lateral forces (cyclic test) was applied to the column frame structure and castellated steel beams. The values of life safety (LS) for the three specimens were 2.1 while the CP (Collapse Prevention) values of WRBSC, RBSC-1, RBSC-2 reached 4.3, 4.1, and 3.6, respectively.

1. Introduction

The experimental study of the cyclic lateral load aimed to analyze load performance and drift ratio of a structure. The study was conducted to determine the behavior of the reduced beam section (RBS) design applied to the test specimens. The system was considered semi-rigid; thus, the connection using an end plate joint [1]. Therefore, the set-up of the test object is shown in Figure 3 [2]. The cyclic load was then applied, then global displacement was measured using an actuator during the test to determine the deformation component and deflection in the beam [3].

The results of an experimental study using castellated beams, as illustrated in Table 1, as well as the images of the test object failure, explain the causes and effects of the failure that are classified based on what happened to each specimen.

These results indicate that the specimen without RBS (WRBS) had 4% greater load resistance than specimens with RBS [1]. The strength of RBS beams also decreased by 4% compared to the WRBS beam. [4] explains that the RBS on castellated beams decreased the strength slightly compared to a beam without RBS (WRBSC), which is caused by a coefficient (reduction) of flange parts [5].

The RBS is one method to reduce earthquake energy so that the structure is more elastic. Using this method, parts of the beam flange were cut based on the AISC 358-10 standard article 5.8 to ensure the plastic joints in the area [6]. Aswad et al. [5] using numerical studies Abaqus and found that the damage positions of RBS specimens were concentrated in the cut area (RBS). The results then followed by



experimental tests to confirm the behaviour and performance of the joints between columns and beams with RBS. The results show that the displacement occurred at a peak load of 104.25 mm, the flange in the RBS beam was bent. The ductility of the castellated beam with RBS is higher than the beam without RBS [3].

Performance-based seismic design in figure 1 shows the new buildings and reinforcement of existing buildings with aspects of safety risk (life), readiness to use (occupancy), and risk of losses due to earthquakes (economic loss). Strategies in planning, implementation, and maintenance or reinforcement are essential so that the buildings can function on an earthquake. Structural failure of 25% in immediate occupancy means that there is no significant damage. Then, the LS (Life Safety) value should range from 25 – 50% where non-structural components are still in place and functioning, not having structural damages that require repairs. Meanwhile, the CP (Collapse Prevention) value is used to assess damage to structural and non-structural components, where the strength and stiffness decreases a lot until the building collapses.

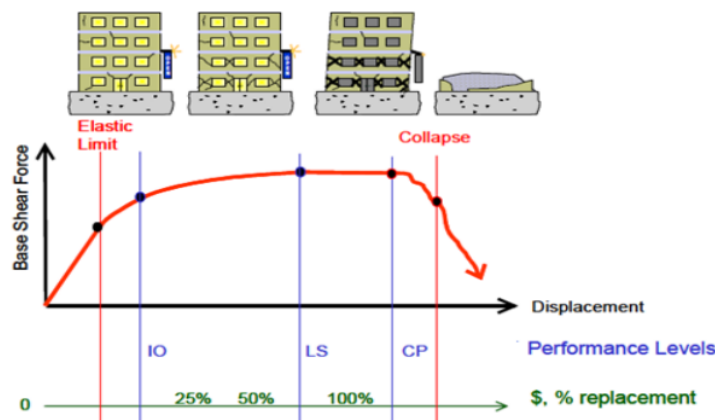


Figure 1. The plastic elastic curve of performance-based planning.

The following equation was used to calculate the drift ratio:

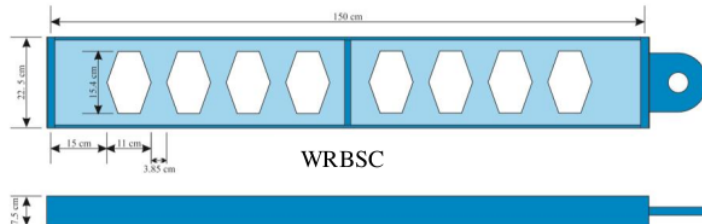
$$Drift\ ratio = \frac{\Delta}{L} (\%) \tag{1}$$

With:

- Δ : deflection due to lateral load (displacement), mm.
- L : lateral load height (column height), mm

2. Design and experimental testing

Figure 2 shows the dimension of specimens and figure 3 shows the loading setup.



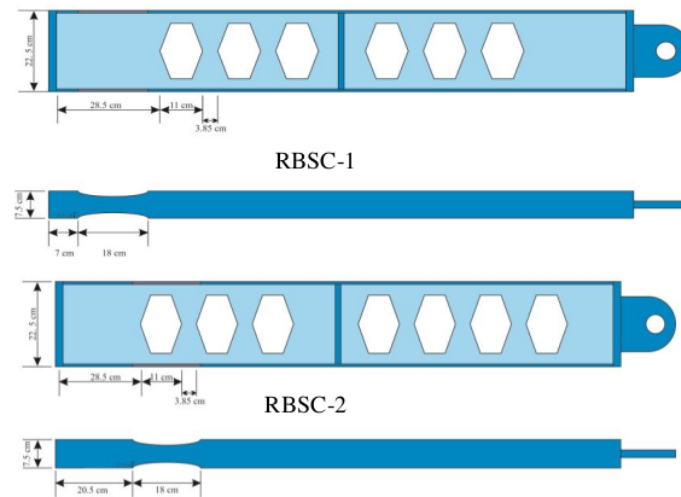


Figure 2. The dimension of specimens.



Figure 3. Method and instruments of beam testing.

3. Results and discussion

Table 1 shows the load capacity of each specimen, where the CP/LS ratio shows the performance of the structure. When the collapse occurred, the WRBSC specimen can resist 87% of the load while the RBSC-1 and 2 only can resist 84.6% and 55.8% of the load, respectively. This means that the RBSC-2 design has the lowest strength and cannot be recommended for structure. Openings on castellated beams parallel to RBS reduced the strength to 55.8%. Meanwhile, similar to the results of [7], the drift ratio of the RBSC-1 specimen shows that it had the yielding point at a load of 8 kN, 9 kN, and 12 kN with a drift ratio of 1.05%, 2.1%, and 3.20%, respectively. The necking phase occurred at a load of 10.53 kN with a drift of 4.17%. Aswad et al. [8] explain that RBSC-1 had 12.25% reduced strength.

Table 1. Testing results of each specimen.

Test results	WRBSC	RBSC-1	RBSC-2
Maximum push load (P ⁺),kN	12.5	12.05	12
Maximum push load before collapsing (P ⁺), kN	10.9	10.2	6.7
Structure performance during the collapse (%)	87.2	84.6	55.8
The ratio of CP/LS	0.87	0.85	0.56

Table 2 shows the drift ratio of each specimen with a cyclic load performance level on 1% IO, 2.1% LS and on Collapse Prevention (CP). The specimen without RBS shows the highest yield of 4.37%, followed by RBSC-1 with 4.17%, and RBSC-2 with 3.57%. This is caused by hexagonal openings on castellated beams and RBS cut weakens the capacity to withstand lateral loads. Thus, the RBS design is not recommended in this scenario.

Table 2. Structural performance of each specimen in various drift ratio.

Specimen	Structural Performance Level	Drift (%)	Note
WRBSC	Immediate Occupancy (IO)	1.06	Transient
RBSC-1		1.06	
RBSC-2		1.03	
WRBSC	Life-Safety (LS)	2.10	Permanent
RBSC-1		2.10	
RBSC-2		2.10	
WRBSC	Collapse Prevention (CP)	4.37	Permanent
RBSC-1		4.17	
RBSC-2		3.57	

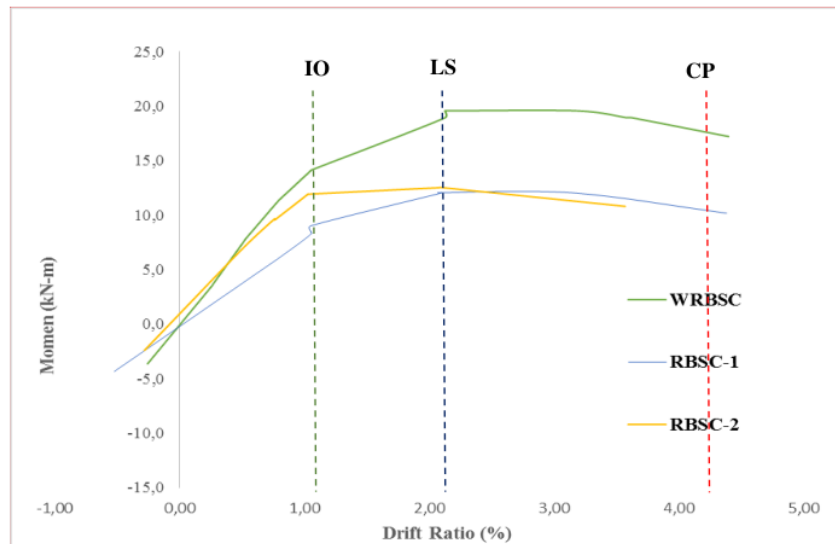
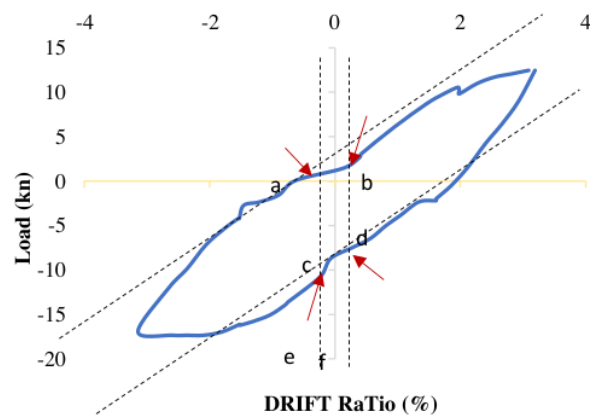


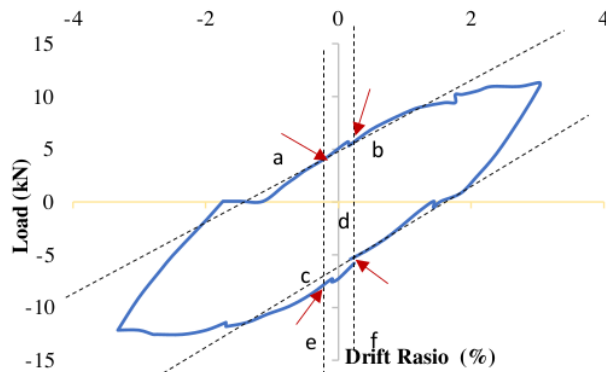
Figure 4. The curve of drift ratio and moment.

At this point, the structure was expected to have still the integrity to maintain the gravity load even if only by relying on residual strength. Under the AISC Code [9], the degradation evaluation of stiffness in the specimen is also related to the stiffness slope. The specimens were considered to have acceptable stiffness degradation if the stiffness ratio of the drift ratio was $\pm 3.5\%$ from the initial ratio of $\pm 0.35\%$ that was equal to or exceeded the value of 0.05 [10]. The stiffness in the 3.5% drift ratio was calculated by referring to the illustration from figure 5. In general, the stiffness in the loading direction was described as the slope from points a to b while the stiffness in reverse loading direction was described as the slope from points c to d in figure 5.

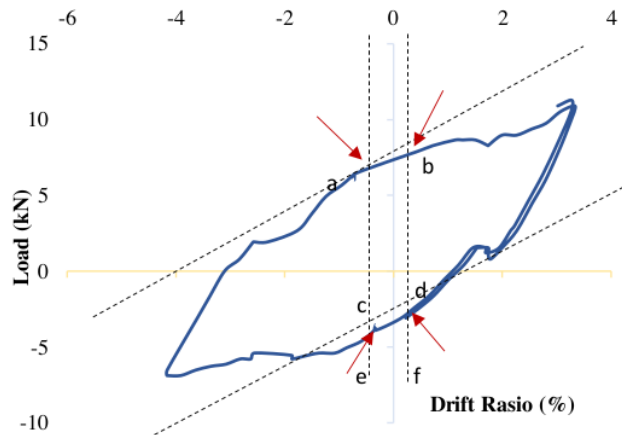
Points e and f respectively show the initial drift ratio that meets the requirement, which ranges from -0.35% and +0.35%. The initial drift ratios for WRBSC, RBSC-1, and RBSC-2, were in the range of -0.27% to 0.29%, -0.25% to 0.34%, and -0.33% to 0.26%. All specimens had an initial drift ratio of -0.35% and +0.35%. Figure 5 illustrates the position where the initially reduced stiffness points based on the initial drift ratio.



(a). WRBSC



(b). RBSC-1



(c). RBSC-2

Figure 5. Reduced stiffness curve.

As can be seen in figure 5, the slope from the initial reduced drift ratio point met the requirements as point a to b had loading in the positive and negative direction. Meanwhile, the reduced stiffness value of the reverse loading was illustrated as the slope from point c to d. Points e and f respectively show initial drift ratios at intervals of -0.35% and +0.35%. Figure 5 shows that the leaf shape curve of the RBSC-2 was the smallest when compared to the curves of the RBSC-1 and WRBSC specimens. Both the initial and final drift ratios illustrate that the specimen without RBS had the highest drift values as shown in table 1.

4. Conclusions

The castellated beam on RBSC-1 and WRBSC specimens met earthquake planning requirements with a drift ratio value at the initially reduced stiffness and when it collapsed. Meanwhile, the RBSC-2 specimen did not reach the structural response for CP with a drift ratio that reached 3.57% when it collapsed, which means that the RBSC-2 model is not recommended for designing earthquake-resistant buildings.

5. References

- [1] Aswad N, Parung H, Irmawaty R and Amiruddin A A 2017 Evaluasi posisi jarak bukaan balok kastella terhadap daktilitas, *KONTEKS 11*, SK-91–99
- [2] Aswad N, Parung H, Irmawaty R and Amiruddin A A 2018 Performance of reduced beam section in castellated beam subjected to a cyclic loading. *J. Eng. Sci. Technol.* **13** 2870–80
- [3] Aswad N, Parung H, Irmawaty R and Amiruddin A A 2016 Performa RBS Balok Kastella Terkoneksi Kolom Pada Beban Siklik, *Publikasi Ilmiah Proposal penelitian*, **XXXVIII** 85–92
- [4] Kim T, Whittaker A S, Gilani A S, Bertero V V and Takhirov S M 2002 Experimental evaluation of plate-reinforced steel moment-resisting connections. *J. Struct. Eng.* **128** 483–91
- [5] Aswad N, Parung H, Irmawaty R and Amiruddin A A 2017 The effect of reduced beam section on castellated beam. *MATEC Web of Conferences* **138**
- [6] American Institute of Steel Construction 2010 *Specification for steel building (AISC 360-10)* aisc, Inc Chicago, IL
- [7] Aswad N, Parung H, Irmawaty R and Amiruddin A A 2017 Pengaruh posisi RBS balok kastella terhadap daktilitas, *Publikasi Ilmiah Hasil penelitian* **XLIV** 1–9
- [8] Aswad N, Parung, H, Irmawaty R and Amiruddin A A 2019 Evaluation of reduced beam

section (RBS) on castellated beam subjected to a seismic load. *IOP conference series: Earth and Environmental science* **235**

- [9] American Institute of Steel Construction. (2010). Prequalified connections for special and intermediate moment frames for seismic applications. *ANSI/AISC 358-16 Standard*
- [10] American Society of Civil Engineers 2010 *Minimum design load for buildings and other Structures* (ASCE 7-10) Reston VA

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