International Journal of Engineering and Science Applications
ISSN: 2406-9833 @2015 PPs-UNHAS

IJEScA

Behavior of Castellated Composite Beam-Columns Subjected to Monotonic and Cyclic Loadings

Suryanti Rapang Tonapa[1*], Desi Sandy[1], and Herman Parung[2]
[1] Civil Engineering, Universitas Kristen Indonesia Paulus, Makassar, Indonesia
[2] Civil Engineering Dept., Hasanuddin University, Indonesia
[*]email: tonapa.27rv.bubble@gmail.com

ABSTRACT

The combination of Castellated beam system with composite beam system by adding in-filled concrete between the flanges of steel beam is expected to increase the capacity to accommodate the force and can overcome the shortcomings found in the two systems. Research was conducted to study the behavior of castellated beam with concrete filler in between the flanges due to earthquake loads. Steel beam IWF profile used was 200 x 100 x 8 x 5.5 with hexagonal openings. The opening height of 0.6 H, the opening distance 9 cm and the angle openings of 600. The test objects consist of normal beam and in-filled concrete castellated steel beam. The data were collected using LVDT and the strain gauges recorded by the data logger and switching box. In addition, data retrieval was also done by visually sighting like buckling and cracking. Testing with cyclic load is a continuation of previous research that uses the monotonic load. The initial load of the yielding of the cyclic load on normal beam and castellated composite beam of 16.5 KN and 43.5 KN and for composite beam with a monotonic load was 360 KN. The initial moment of the yielding of composite castellated beam with cyclic loading was 73.52 kN-m, increased from normal beam capacity of 27.89 kN-m compared with a monotonic load of 81.00 kN-m. Castellated composite beam is capable of receiving loads of bigger and smaller deflection than normal beam. The damage shape failure of normal beam on cyclic load was due to local buckling on the flanges while for castellated composite beam both under cyclic load and monotonic load were concrete cracks.

Keywords: buckling; castellated; cyclic load.

Article history: Received 12 May 2015, last received in revised 15 July 2015

1. INTRODUCTION

Composite beam is a combination of concrete and steel profile, the benefits are the ability of steel to withstand tension and concrete to withstand compression. The main consideration of the use of composite materials i.e. steel beams used to have relatively expensive prices so that attempted to cost savings in the implementation of construction works.

Castellated beam has the advantage, namely the ability to withstand a greater bending moment and the value of its own weight, but has a weakness among other sliding capacity reduced and vulnerable local buckling occurs and lateral torsion buckling.

Advantages and disadvantages of both systems can be overcome by combining castellated beam system with composite beam system by adding concrete in-filled between the flanges. It is expected that the system has the capacity to overcome the disadvantages of the two systems.

Previous studies resulted from the application of monotonic loads to castellated beams was insufficient to determine the resistant of the beams to cyclic loads. Therefore it was necessary to conduct research to study the behaviour of castellated composite beam using in-filled concrete between the flanges to resist earthquake loads.

2. A REVIEW OF LITERATURE

A. Castellated Beam

On each castellated profile open can be viewed as two cross-sectional T function is identical to the edge of a frame structure of truss that loading the shear force vertical. Because it's on a cross-section of bending moments (primary moment) in addition T also work the moment secondary. The shear force work in the middle of span beam static load evenly with certain relatively small, so the influence of secondary moment is relatively small.

The greatest shear force is situated on the style object, so that the influence of secondary moment of relatively large enough. The secondary moment happens on the support will occur at a distance of ½ times the distance pieces to the horizontal direction (e/2), on the profile of t. assuming that every work ½ T cross section times the styles of latitude (D/2), then the style and the stress arising at the cross-section of castellated beam can be assumed:

a. Stress fc due to the bending (primary moment M) which occur on the outer fibers meet the equation:

$$\sigma_c = \frac{M}{S_b}$$

(1)

b. The style of the latitude that work on open cross section is supported by two large T the same cross-section, assuming a vertical sliding style of working on the Middle e, then the stress due to the secondary bending can be calculated with the equation:

$$\sigma_v = \frac{V_T \cdot e}{4.S}$$

(2)

With the great moment of secondary bending should be smaller than the primary moment. The total stress of Figure 1 is the result of a combination of primary and secondary stress of stress or is the sum total of the stress from the equation that yields joint 1a 3.a and from joint 1b which produces Equation 3.b. the Combination yields Equation 3.c is:

$$f_{1a} = \frac{M_{1a} h}{I_g} + \frac{V_T\, e}{4\, S_s} \qquad (3.a)$$

$$f_{1b} = \frac{M_{1b} d_g}{2\, I_9} + \frac{V_T\, e}{4.S_f} \qquad (3.b)$$

$$f_1 = \frac{M}{dA} + \frac{V_T\, .e}{4\, .S} \qquad (3.c)$$

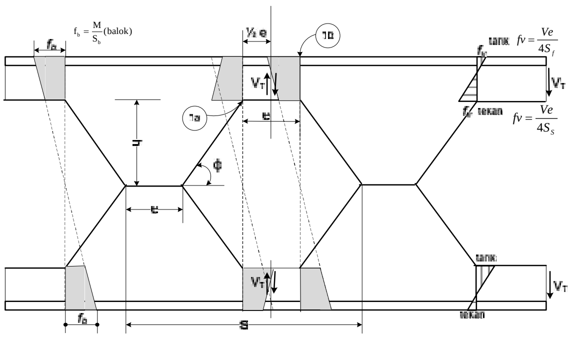

Figure 1. Detail of castellated beam

B. Composite Beam

The strength of a composite beam is generated by the combined strength of concrete and steel, taking into account the characteristics of each material. In conjunction, the composite cross section moment of inertia calculations as well as the capacity of the cross section is based on the comparison of modulus of elasticity of steel and concrete. The higher the quality of the concrete, then comparisons between modulus of steel and concrete is getting smaller so that the combined cross section of both will be higher. In this research, will be retaining castellated beams with concrete filler as a confessor at the Agency to reduce the damage incurred as a result of web buckling.

Herman Parung conducted a study to analyze the influence of concrete against the power of steel profile support, both to the stiffness or resistance against fire. Installation of concrete to wrap the bodies of steel profiles can improve all these parameters so that it can be applied to the structure of fireproof and earthquake resistant. Research results also showed that the strength of a composite beam will be much more improved in all the surface of the steel is wrapped with concrete.

C. Frame with Earthquake Load

a. Diagram of the field the moment

The field moments on a structure that bears the stress of the earthquake is shown in Figure 2. At the point this value of S a moment equal to zero and the greatest moment occurred in the area around the joint.

b. The loads acting on the beam

The shear stress due to earthquake excitation will induce moments in the beams and columns as shown in Figure 2. The moments in the middle span of beams and in the mid-height of columns will be zero.

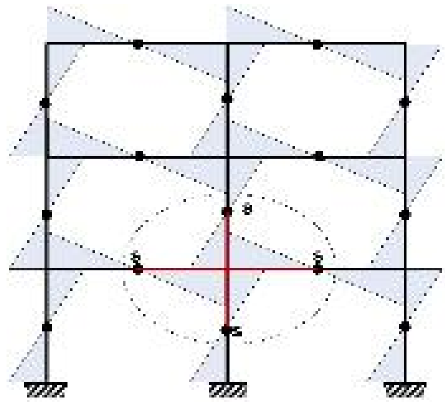

Figure 2. Moment diagram due to earthquake

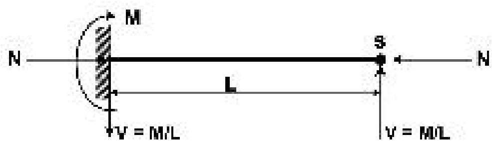

Figure 3. Loads acting on the beam

Assuming the value of positive moments, the normal style of attraction, then a moment of field diagram, normal and shear style can be seen in Figure 4. Figure 4 shows that the most critical moment caused by the combination of the normal style is the area around the object and shear along the span of the beam.

 IJEScA

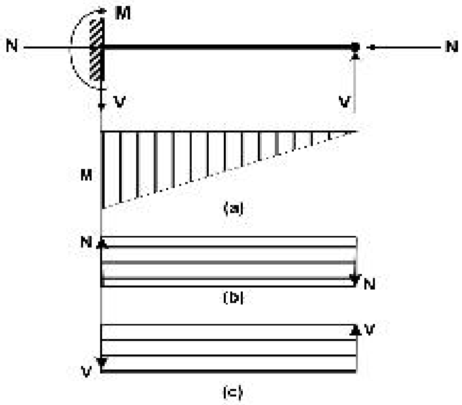

Figure 4. (a) bending moments, (b) normal force, (c) shear

3. RESEARCH METHODOLOGY

Steel beams used in this study were IWF 200 x 100 x 8 x 5.5 with hexagonal openings angles. The opening height was 0.6 H, the opening distance 9 cm and the angle openings of 600. The test objects consist of normal beam and in-filled concrete castellated steel beam. Test objects are presented in Figure 5.

(a)

(b)

Figure 5. (a) normal beam NB, (b) castellated composite beam CCB

Testing structures were laid on top of concrete slabs and reinforced with bolts as shown in Figure 6.

Cyclic load is given in the form of displacement-controlled on the ends of the upper column. Method of introducing a load of each cycle was based on a method that is issued by the European Convention for Constructional Steelwork (ECCS). The magnitude of the deformation was predetermined as well as the number of cycles adjusted to determine the yield displacement. At the time of the testing termination, the maximum displacement was 135 mm.

(a) normal beam

(b) composite castellated beam

Figure 6. Testing Setup

The data were collected using LVDT and the strain gauges record by the data logger and switching box, besides data retrieval is also done by visually sighting like buckling and cracking.

4. Results and Discussions

Testing with cyclic load is a continuation of previous research that uses the load monotonic. So presented with the test results of castellated composite beam has done previously include: capacity load and moment, the relationship of the load – deflection, stiffness and model of damage of castellated composite beam.

Load carrying capacity of the initial yielding of normal beams and castellated composite beam for testing with cyclic loading and monotonic load is shown Table 1.

Table 1. Capacity load and moment of beam test

Beam Code	Initial Yield Load	Moment of Inertia	Initial Yield Moment
	KN	mm²	KNm
NB	16,5	17609322,67	27,89
CCB	43,5	64458362,54	73,52
BCC	360	64458362,54	81,00

Deflections which occur during the cyclic loading excitation was constantly recorded using LVDT. The curve of the hysteretic relationship of the load – deflection normal beams and beam a composite is shown in Figure 7.

Table 2. Types of failure

Beam	Failure position	Failure type
NB	Flange	Local buckling
CCB	In-filled concrete	cracks
BCC	In-filled concrete	cracks

The stiffness of the beam can be known based on relationship of load-deflection, the greater the load and deflection small then the stiffness of the higher and the lower the load and greater then deflection the lower stiffness.

Of table 1 are obtained by yielding the initial load of the cyclic load on normal beam of 16.5 KN. The magnitude of the load of the initial yielding of a composite castellated beam with cyclic load was. 43.5 KN, while the load on composite beam with a monotonic was 360 KN. Based on the results of testing, it can be seen that the load of the initial yielding of composite castellated beam is larger than normal beam.

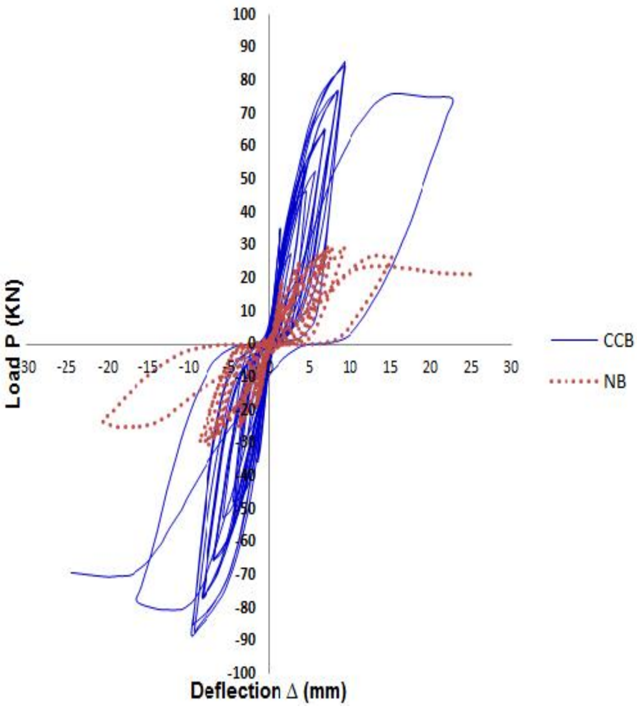

Figure 7. The curve of the histeristik relationship of the load – deflection normal beams and beam a composite castellated.

The magnitude of the initial yielding moment for the composite castellated beam with cyclic loading was 73.52 kNm, while for the normal beam was only 27.89 kNm. Under monotonic load, the initial yielding moment was monotonic 81.00 kNm. A composite castellated beam a is capable of resisting higher loads and smaller deflection.

Table 2 shows that the normal beam failed due to local buckling on the flanges that can be seen with direct observations. Failure on composite beams can be observed from the occurrence of cracks of in-filled concrete. This fact indicates that the concrete between flanges can add stability to the beam and prevent buckling.

5. CONCLUSIONS

The initial capacity of castellated composite beam increased 263% of normal and the maximum load beams increased by 288%. The maximum load that occurs in normal beam was 30.66 kN at the deflection 7.49 mm while on the composite castellated beam, the maximum load was 88.25 KN and deflection 9.65 mm. Beam stiffness of castellated composite beams is higher than the normal beam.

Failures modes for normal beam and composite castellated beam are different. The samples without concrete experienced local buckling while for the castellated composite beam, concrete cracking was found.

6. REFERENCES

[1] Grunbauer, J., (2011). What Makes Castellated Beams So Desirable As a Constructional Element. (http://www.grunbauer.nl/eng/inhoud, diakses Pebruari 2011).
[2] Parung, H., et al., (2006. Fire Resistance of Composite Steel-Concrete Beam, Final Report Hibah Pekerti DP2M, Dikti
[3] Parung, H., et al. (2013). Experimental Study On Castellated Steel Beam Using Monotonic Loading, Prosiding Konferensi Nasional Pascasarjana Teknik Sipil (KNPTS), Bandung
[4] Pribadi, J., (2012). Perilaku Balok Komposit Castellated Bukaan Heksagonal Diselimuti Mortar. Tesis Pascasarjana. Universitas Gajah Mada
[5] Setiawan, A., (2008). Perencanaan Struktur Baja dengan Metode LRFD,, Erlangga , Jakarta