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CASTELLA COMPOSITE BEAM TESTING TO BE USED AS A STRUCTURAL ELEMENT OF MULTISTOREY BUILDINGS IN EASTERN INDONESIAN REGION

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ABSTRACT

The purpose of this study was to determine the flexure capasity, resistence, ductility, energy absorption and stiffness of the castela composite beam to be used as a structural element of the multy-storey building frame. This research was carried out through testing castellan composite beams in the form of a portal with cyclic loading. Solid beams steel used is profiles IWF 200 100 5.5 8 fabricated became castella beam. Test beam consists of a solid beam (NB) as a comparison and Castella beams with concrete filler between the flange namely castella composite beams (CCB). The results showed that based on flexure capacity, resistance, ductility which meets the ductility requirements of SNI -1726-2002, energy absorption, and stiffness degradation shows behavior similar to the solid steel beams, then the beam CCB can be used as a structural element in multi-storey buildings for earthquake zone IV, V and VI or Eastern Indonesia Region.

Keywords: steel, castella, composite, cyclic load.

1. INTRODUCTION

Eastern Indonesia Region such as Papua is prone to strong earthquakes, besides that material for the construction of multi-storey buildings to be imported from other regions in Indonesia, thus requiring highest construction costs compared to other regions in Indonesia. The use of steel material is more advantageous in many respects, especially the ability to resist earthquake loads compared to reinforced concrete material. Most of the building structure with steel material uses solid steel profiles as advantageous solution in terms of strength and material usage. Experts are trying to structure how to increase the strength of steel elements without an increase in self-weight of steel in order to obtain some new methods that beams with openings entity known as castella beam. One form of the body opening is hexagon shape. Research on this openings has been done by Wakchaure MR, Sagade AV, Auti V. (2012) and the results showed that the openings with 0.6 of the beam height is the possible maximum openings, or in other words the maximum eligible beam height of the castella beam that can be fabricated. Research on the angle and length of exposure to a high of 0.60 to a high aperture solid beam has been carried out by Parung Herman *et al* (2013) are given monotonic load. Solid steel profiles fabricated into castella beam is IWF 200 100 5.5 8. Research results show the opening angle of 60^0 and aperture length e = 3b = 9 cm gives the best result of the angle and length of openings for openings hexagon. The purpose of this study was to determine the behavior of the castella composite beams through frame structure testing in the laboratory that allows it to be used as a structural element beam on frame of multi-storey building

2. RESEARCH METHODS

2.1 Testing principle

The principle of the test is based on the structure of the framework that burdened earthquake load as in Fig. 1a by taking part beams and columns that are restricted to the joint (s) Figure-1b. Due to horizontal load, the moment at mid beam and column values will be close to zero. Therefore, the position of the zero moment can be modeled as HINGED, column and beam sections tested are considered to represent part with the end as a HINGE (the moment = ZERO).

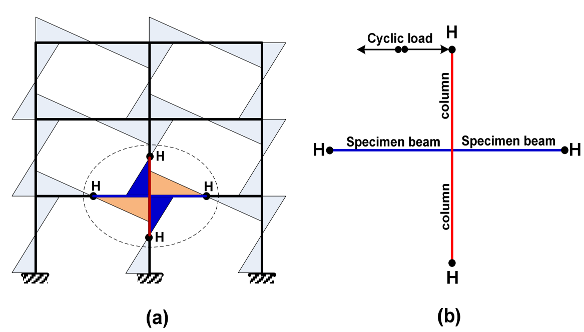

Figure-1. (a) The moment area of a frame due to earthquake loads, (b) Principle of the test beam-column element.

2.2 Test beams

Specimens, a steel beam used is a profile IWF 200 x 100 x 8 x 5.5 with hexagon shaped openings. High

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aperture 0.6 H, a distance of 9 cm and the aperture opening angle 60^0. The cross section of the test beam as in Figure-2. Yield stress (f_y) of steel used is 240 MPa

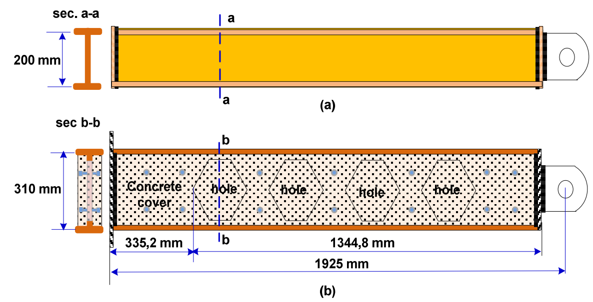
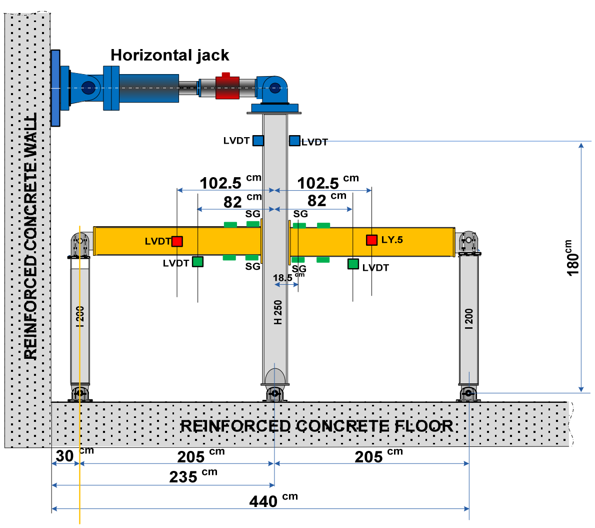


Figure-2. Beam test for the: (a) normal beam (NB), (b) castellan composite beam (CCB).

2.3. Testing frame

The testing requires testing framework. Testing framework is designed based on the principle of test as in Figure-1. Steel beams used are H 250 250 9 14 for the middle column and the IWF 200 100 5.5 8 for the other columns Figure-3. Testing framework laid out on the floor and walls of reinforced concrete. Equipment and testing instruments required are: crane, strain gauge FLK 2.12, LVDT (Linear Variable Displacement Transducer) with a precision of 0.005 and 0.01, actuator (horizontal jack) with a capacity of 1200 KN, logger data and switching box.



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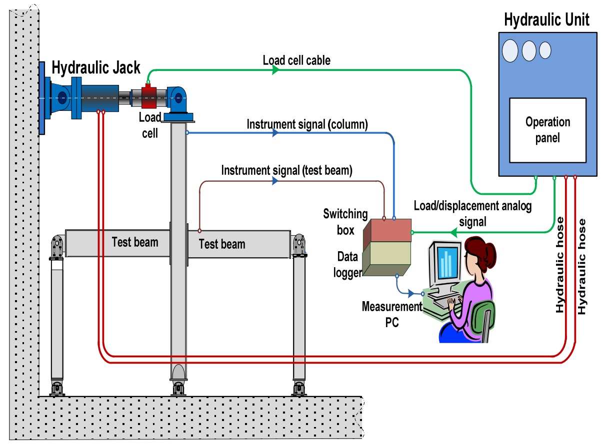
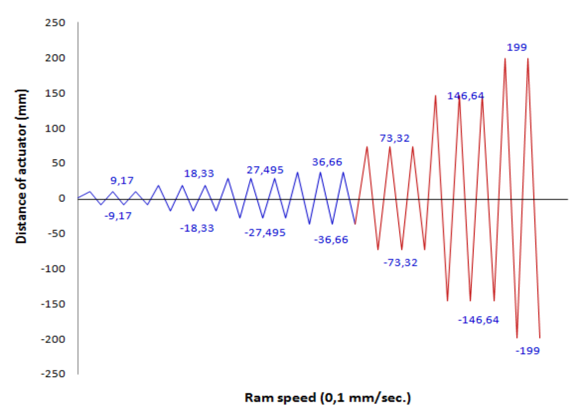


(b)

Figure-3. (a) Framework for testing and placement of testing instruments, (b) testing installation.

2.4. Testing implementation

The cyclic loading is given in the form of displacement-controlled at the upper end of the column. Method of loading each cycle based on the Recommended Testing Procedure for Assessing the Behavior of Structural Elements under Cyclic Loads issued by the European Convention for Constructional Steelwork (ECCS). The testing stopped when loading cycles plans reached $P_{failure} = 0.80\ P_{max}$. (Recommendation by ASTM international, designation: E 2126-02a year 2002). Displacement load-ram speed relationship that has been done as shown in Figure-4. Documentation pictures of the testing are presented in Figure-5



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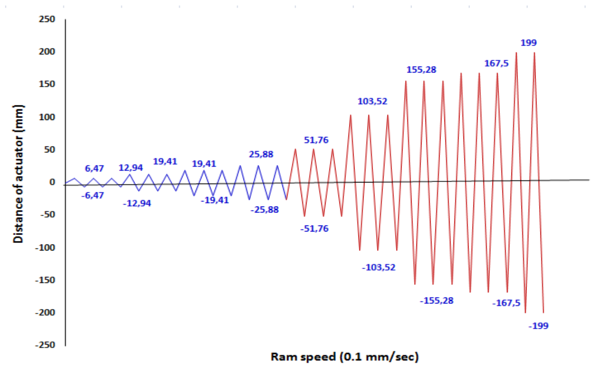

(b)

Figure-4. Displacement-ram speed relationship for the, (a) NB test beam, (b) CCB test beam

(a) (b)

Figure-5. Testing documentation for the, (a) NB test beam, (b) CCB test beam.

3. TEST RESULTS AND DISCUSSIONS

3.1 Sectional characteristics

Table-1 shows the Sectional characteristics of the test beam.

Table-1. Sectional characteristics.

Test beam	**H** (mm)	**Wx** (mm^3) ($x10^3$)	**Ix** (mm^4) ($x10^6$)	**Zx** (mm^3) ($x10^3$)	**Increased Wx to NB** (%)	**Increased Ix to NB** (%)	**Increased Zx to NB** (%)
NB	200	184	18.4	209.47			
CCB	310	453.838	70.35	579.91	146.65	282.31	176.85

Based on data in Table-1; an elastic modulus (W_X), the moment of inertia (Ix) and the plastic modulus (Z_x) beam CCB increased respectively by 146.65%, 282.31% and 176.85% compared to the test beam NB. This conditions shows the ability of the CCB beam to resist loads is greater than the NB beam.

When compared with the normal profile, the CCB test beam equivalent IWF 300 150 5.5 8 profiles with an elastic modulus 424 mm^3 and profile weight 32 kg/m. When compared to the profiles of NB test beam with weight of 21.3 kg / m ', then there is efficiency in the use of steel material by 50.23%.

3.2. Flexural capacity

Data from Table-2 below shows that NB beam design loads is 31.04 KN greater than the actual load is 29.45 KN, with a deviation of 5.13% and for the CCB beam, design load is 87.70 KN greater than the actual load is 84.5 KN with deviation of 3.65%.

Table-2. Design and actual load of the test beam.

Test beam	P_{design} **on top of the column** (KN)	P_{actual} (KN)	**Deviation** (%)
NB	31.04	29.45	5.13
CCB	87.7	84.5	3.65

Table-3, the list of resistance ratio ($\varepsilon = P_{max}/P_y$) for the test beams at yielding and maximum condition. Based on the minimal of $P_{max.}$ at maximum load conditions (cycle 6 and 8), the $P_{max.}$ minimal of NB and CCB test beam respectively 29.45 KN and 84.5 KN. Based on these data, flexural capacity of CCB test beam increased by 186.93 % and ability to resist the load after yielding increased 2.88 % when compared with NB beam. So, with the addition of the beam height without adding steel weight and additional concrete between the flange can improve the flexure capacity and resistance of the CCB beam.

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Table-3. Resistance ratio of the test beam.

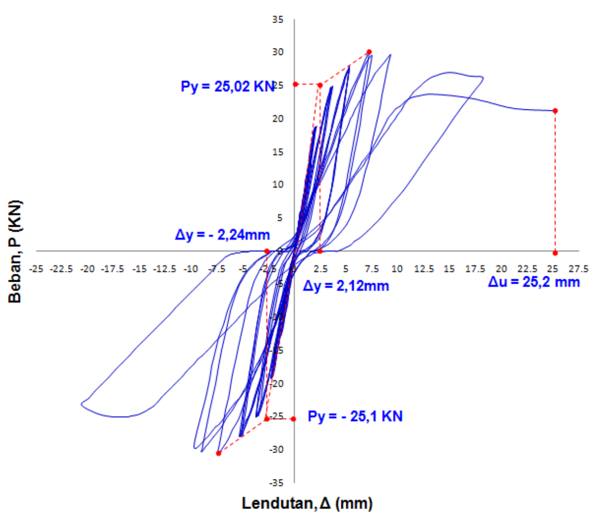
Test beam	P_y (KN)		P_{max} (KN)		Resistance (ϵ)	
	(+)	(-)	(+)	(-)	(+)	(-)
NB	25.02	25.1	29.66	29.45	1.19	1.17
CCB	70	68.45	84.50	85.00	1.21	1.24

Based on the deviation between P_{design} with P_{actual} and resistance, the behaviors of the two beams are almost equal in receiving loading.

3.3 Ductility

The Load-displacement curve relationship (P-Δ) of the test beams NB and CCB are shown in Figure-6. This curve shows the yield load, yield displacement and ultimate displacement of the beam test. Based on the curve's shape of the beam test showed a similar behavior in relationship between load (P) and displacement (Δ)

Table-4 list of full ductility from yield condition to final load. At the ultimate load ($P_{failure}$ = 0.80 $P_{max,}$), full ductility (μ) of NB and CCB test beam respectively 11.89 and 8.8. These data indicate full ductility of CCB test beam smaller 25, 99 % compared with test beam NB. This is caused by the increased rigidity of the beam due to the addition height of the beams and concrete between the flanges of the CCB beam so that minimize displacement value.



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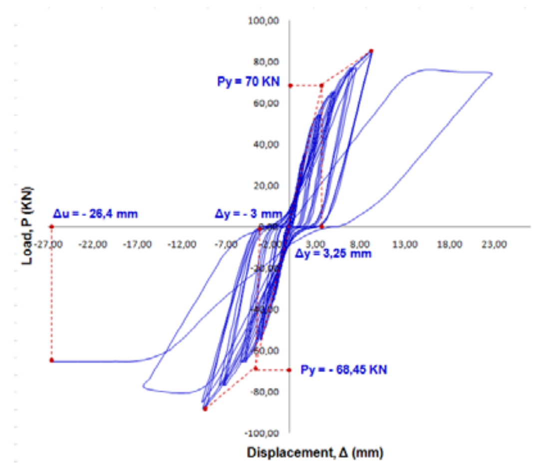

(b)

Figure-6. The load-displacement curve relationship (P-Δ) for, (a) NB test beam, (b) CB test beam.

Table-4. Full ductility of test beam.

Test beam	Yield disp. (Δ_y) (mm)	Ultimit disp. (Δ_u) (mm)	Ductility $\mu = \Delta_u/\Delta_y$
NB	2.12	25.2	11.89
CCB	3	26.2	8.8

Table-5 below shows the performance level of the building structure according to SNI-1726-2002

Table-5. The performance level of the building structure.

The performance level of the building structure	Ductility (μ)	R
Partial ductility	1.5	2.4
	2.0	3.2
	2.5	4.8
	3.0	4.8
	3.5	5.8
	4.0	6.4
	4.5	7.2
	5.0	8.0
Full ductility	5.3	8.5

Source: SNI-1726-2002

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Full ductility in the SNI-1726-2002 Table is planning requirements of earthquake-resistant buildings in a powerful earthquake zone (zone 6) such as of eastern Indonesia region.

Table-4, data for full ductility (μ) is 8.8 of the CCB beam is larger than the full ductility (μ) is 5.3 in Table-5. This data shows, CCB beams can be used as a structural element for multistorey building frame.

3.4. Energy

Table-6, the list of energy absorption (P-Δ) for the test beams at yielding and maximum conditions. At the yielding conditions, the absorption energy of each test beam at the positive moment and negative moment the energy absorption of CCB test beam increased respectively by 108.6% and 92.23% or an average 105.4% when compared with NB test beam. At the maximum conditions, absorption energy for the beam test on the positive moment and negative moment: the energy absorption of CCB test beam increased respectively by 253.2% and 181% or an average 217.1% when compared to the NB test beam. This energy absorption value differences caused by the increased of an inertia moment on the CCB beam.

Table-6. Energy absorption of the test beam.

Test beam	**Energy** (Joule)			
	Yield		**Max.**	
	(+)	**(-)**	**(+)**	**(-)**
NB	1,069.20	1,096.92	5,141.55	6,112.83
CCB	2,230.82	2,108.63	18,158.34	17,176.87

3.5. Stiffness

Value of the stiffness degradation ratio (ξ) on the ultimate load for the test beam as shown in Table-7.

Table-7. Stiffness degradation ratio.

Test beam	Stiffness degradation ratio (ξ) = tg α_u/tg α_y
NB	0,30
CCB	0,32

From the data in Table-5 shows that; stiffness degradation ratio (ξ) of beams NB test beam over 2% faster than the CCB test beam. The difference is not very significant value but this condition shows the behavior of the two beams in stiffness is almost equal

4. CONCLUSIONS

From the discussion above, a number of conclusions as follows:

a) Fabrication normal beam into castella composite beams can save steel material by 50.23% so efficiently used as a structural element.
b) Behavior of the CCB beam in terms of flexural capacity, resistance, energy absorption and stiffness degradation is almost the same as the normal beams behavior.
c) Full ductility value of the CCB beam eligible in accordance with SNI -1726-2002 on Earthquake Planning Procedures for Building Resilience in Indonesia.
d) Based on the conclusions 1, 2 and 3 show the CCB beams can be used as a structural element beam on a multistorey building frame on the strong earthquake region.

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