International Journal of Civil Engineering and Technology (IJCIET)
Volume 9, Issue 4, April 2018, pp. 534–543, Article ID: IJCIET_09_04_058
Available online at http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=9&IType=4
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

FLEXURAL BEHAVIOR OF T SHAPED REINFORCED CONCRETE HOLLOW BEAM WITH PLASTIC BOTTLE WASTE

Syahrul Sariman
Civil Engineering Department, Bosowa University, Makassar, Indonesia

Abd. Rahim Nurdin
Civil Engineering Department, Bosowa University, Makassar, Indonesia

ABSTRACT

Reinforced concrete girder with T shaped beam is a widely used bridge construction in Indonesia. Principal calculation of bridge structure is based on the simply supported beam which is the concrete will be experienced compression and the reinforcing steel will experienced tension. Due to that reason, concrete region under the neutral axis will not be calculated as strength contribution. Because of this assumptions, T shaped beam with plastic bottle waste was considered. There are several advantages using this material such as reducing of structural weight, reducing cement as concrete base material which realted to the environment issue, the reduction of cement means reducing the potential of CO_2 pollution and utilizing the plastic bottle waste means reducing the environment pollution by plastic material which is difficult to be decomposed. The beams were in two conditions which were apparent T shaped beam and the neutral T shaped beam with the cross section taken from the cross section of reinforced concrete girder bridge with 1:3 scale. The aim of this study is to compare the ultimate load of normal beam and beam with plastic waste. The result showed that there is not significantly different between two sample. It means that their ability to retain the loads is not significantly different.

Keywords: Plated T Shaped Beam, Plastic Bottle Cavity, Static Monotonic Load

Cite this Article: Syahrul Sariman and Abd. Rahim Nurdin, Flexural Behavior of T Shaped Reinforced Concrete Hollow Beam with Plastic Bottle Waste, International Journal of Civil Engineering and Technology, 9(4), 2018, pp. 534–543.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=9&IType=4

1. INTRODUCTION

T shaped beam type reinforced concrete girder bridge is a widely used bridge construction in Indonesia. Its main structure is a beam on two supports. The calculation principle of a structure of reinforced concrete beam simply supported like this in bearing the bending moment is that the compression is born by the concrete cross section while on the tension area, the tension is born by the reinforcing steel so that there is a part of the concrete cross section on the tension area below the neutral line that is not bearing loads. Many researchs have been done related to the bending behaviour including by user plated concrete beam with variation of the concrete strength on the compression section and tension section [1], [2], [4], [10], [17], and using hollow with PVC pipe by employing different diameters and neutral line position [3], [5], [11], [13], and [16]. Another study have been done relation with the environment pollution reduction using plastic waste from the recycled plastic and mixed with the concrete [7] and [14].

The other action of using plastic waste is by using it as the cavity material like the study of Rahadyanto [12], (2013), with its special objective to obtain an easy way to construct beams by using plastic bottles so that they can be used as the landfill of plastic bottle waste. The other research about using plastic bottle as the cavity filling was done by Sari [13], 2013 its objective to know the effect of cavity on the reinforced concrete plate on the bending strength, deflection, and crack pattern. It was concluded that the maximum load capacity of the plate with cavity was lower than the solid plate. The difference between the bending strength of those two types of plates was because of the plastic bottle was not so stiff and made it easy to change its form to be oval when casting.

In relation with those previous studies, this research used T shaped beam at the structure of girder bridge that has been standardized by Indonesia. There were 2 types of beams made in different advantages, then plated with plastic bottle cavity on the tension cress section. The objectives are:

1. formulating the difference of the ability to bear loads as a result of the variation in using plastic bottle cavity on the tension cross section,
2. analyzing the bending behavior of the cross section of the reinforced concrete girder bridge as a result of the variation in the plastic bottle cavity.

2. BASIC THEORY

2.1. Reinforced concrete characteristics with T shaped beam bending capacity

The mechanism of T shaped reinforced concrete beam bending capacity is obtained by taking neutral line precisely on the bottom side of the flange.

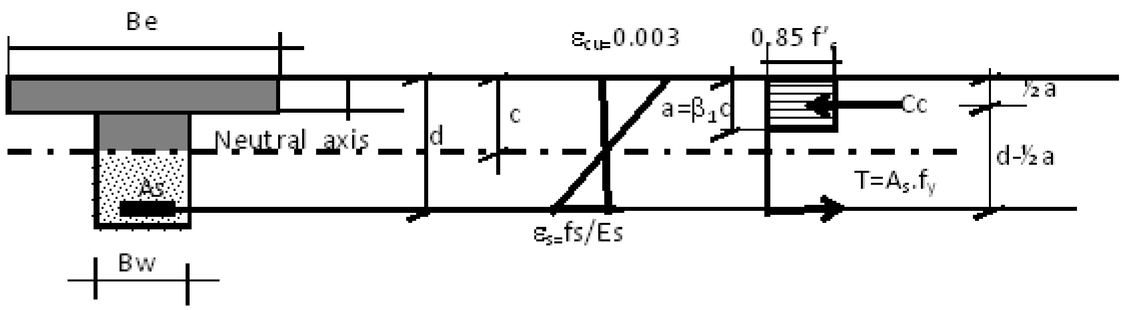

Figure 1 The neutral line below the flange

$Cc = T \rightarrow 0.85\, f'c.\ Be.\ a = As.\ fy$

And it is obtained: $$a = \frac{As.fy}{0.85\ f'c.Be} \quad (1)$$

If $a < t \rightarrow$ apparent T shaped beam

$a > t \rightarrow$ neutral T shaped beam

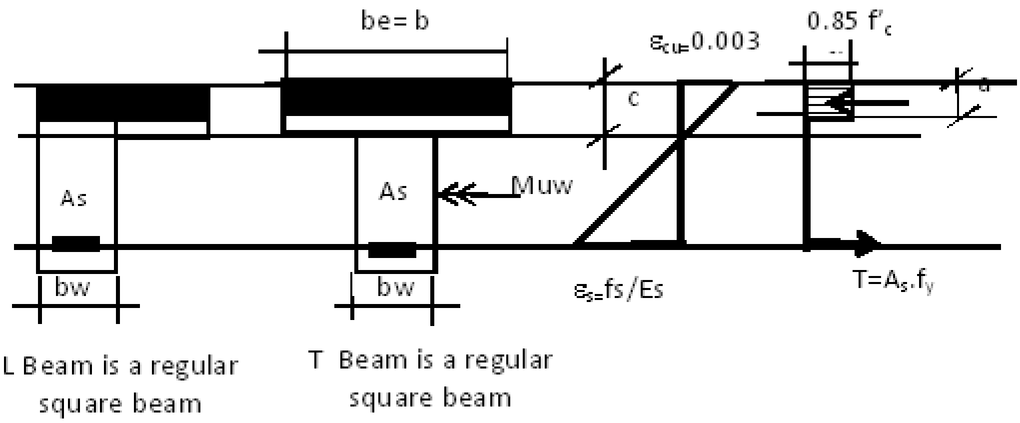

Figure 2 Stress and strain diagram of apparent T shaped beam

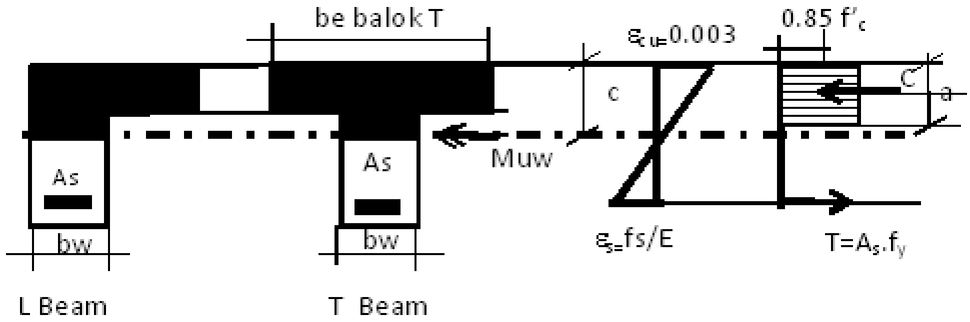

Figure 3 Stress and strain diagram of neutral T shaped beam

In the diagram of neutral T shaped beam, the balance of the force:

$T = Cc_1 + Cc_2$

As.fy = 0.85.f'c (Be-bw).t + 0.85f'c.bw. a

$$a = \frac{As.fy}{0.85 f'c.bw} - \frac{.(Be - bw).t}{bw} \qquad (2)$$

And the nominal moment $Mn = Mn_{req}$

$$Mn_{req} = Cc_1.(d - \frac{t}{2}) + Cc_2(d - \frac{a}{2}] \qquad (4)$$

$$Mn_{req} = 0.85.f'c.t.Be.(d - \frac{t}{2}) + 0.85 f'c.(a - t).bw.(d - \frac{a}{2}) \qquad (5)$$

There are three failure conditions of the reinforced concrete structure, including:

a) Tension failure

Tension failure will occur if the percentage of reinforcing steel of a beam yield cross section is relatively small (under reinforced) so that the reinforcement will yield first before the compression strain reaches its maximum. At this stage, reinforcing steel strain is $\varepsilon_{\sigma} = \varepsilon_{\sigma\psi}$ and concrete strain is $\varepsilon_{\chi} < \varepsilon_{\chi\upsilon}$, and will continue until $\varepsilon_{\chi} = \varepsilon_{\chi\upsilon}$.

b) Balance failure

Balance failure will occur if both the concrete or the reinforcing beam reaches the maximum strain and stress at the same time. The failure occurs simultaneously.

c) Compression failure

Compression failure occurs if the percentage of the reinforcing steel of a beam section is relatively big (over reinforced) so that the concrete stress reaches its maximum before the yield stress of the reinforcing steel is reached. At this stage, the strain of the reinforcing steel $\varepsilon_{\sigma} < \varepsilon_{\sigma\psi}$ and the concrete strain $\varepsilon_{\chi} = \varepsilon_{\chi\upsilon}$. The failure occurs on the compression area of the concrete. It occurs suddenly and is often accompanied by the explosion of the crushed concrete and without large deformation.

Based on three conditions and due to the safety reason, tension failure is chosen for designing the reinforced concrete beam.

2.2. Reinforced Concrete Hollow Beam

Because of the bending moment, the top fiber will be in compression and the bottom fiber will be in tension. In the equilibrium condition, the tension provided by the reinforcing steel is equivalent with the compression provided by the concrete cross section above the neutral line. Therefore, there is a part of concrete section below the neutral line that is calculated as not bearing the compression force so that this part can be removed or made into hollow.

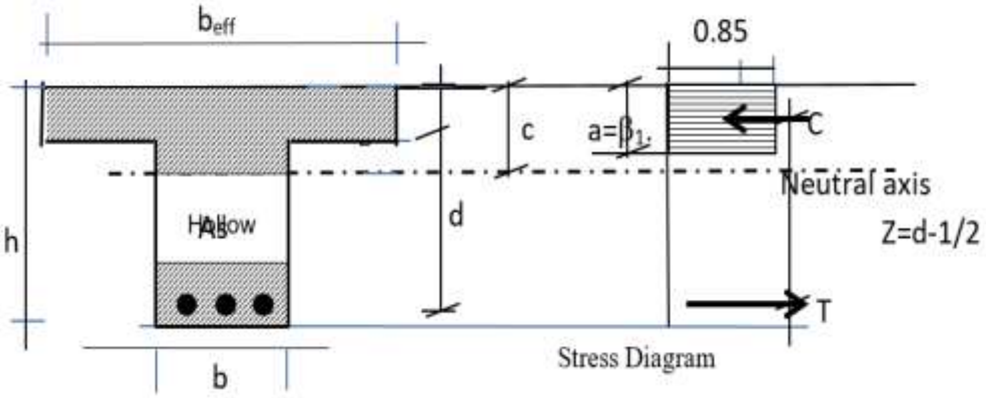

Figure 4 Hollow T shaped beam

There are some advantages using hollow in the tension section:

a) The structure will be lighter.
b) The production of cement as the main material to make concrete will be reduced.
c) Providing place for utility facility
d) It can be used to accommodate waste.

2.3. Previous Studies

Varghese, N, et al,2016, conducted an experimental test on the bending behavior of reinforced concrete beams with 50 mm diameter PVC pipe cavity at various depths. Ten beams of 200 x 300 x 2000 mm consisted of two solid reinforced concrete beams as the controlling beams (CB), two reinforced concrete beams with 160 mm depth of cavity (B1) two reinforced concrete beams with 160 mm depth of cavity (B2), two reinforced concrete beams with 200 mm depth of cavity (B3), and two reinforced beams with 240 mm depth of cavity (B4). All of the beams were bending tested with the loads at two points. Three main aspects tested were the bending capacity, deflection on the middle of the section and the beams' strain behavior.

The result of the test was that the bending behavior of reinforced concrete beams with cavity is similar with the conventional reinforced concrete beams. The optimum depth of the cavity that give optimum beam capacity was 160 mm which was right at the beam's geometrical line.

Dhinesh, et al, 2017, conducted a bending test on cavity reinforced beams. Eight tested beams of 150 x 150 x 1000mm consisted of two tested beams with top PVC pipe depth of 34 mm from the compression fiber, two beams with 75 mm depth PVC pipe axis position (the pipe axis coincided with the cross-section axis), two beams with the bottom part of the PVC pipe at 116 mm from the compression fiber (34 mm from the tension fiber) and two beams with the PVC pipe at 75 mm depth and 116 mm from the compression fiber. The beams were designed with weak reinforcement with bottom reinforcement of 2 ϕ 8mm and the top reinforcement of 2 ϕ 8mm. The shear reinforcement used cross bar of ϕ 6 - 150 mm. The relation between the loads and the deflection showed various values. The beams with 34 mm of pipe depth showed 22 KN maximum load value and 3.4mm deflection. The 75 mm of pipe depth showed 22 KN maximum load value and 5.8 mm deflection. Then, the 166 mm of pipe depth showed the highest value of load which was 26 kN with 5.7 mm deflection. The last, for the pipes at two points which were at 75 mm and 116 mm of depth showed 24 kN maximum load and 5.5 mm deflection.

Kumar, et al, 2015, conducted a research by replacing some part of the concrete below the neutral line, which was 4% and 8%, with air cavity made from polyethylene ball with 3.5 mm of diameter. The dimension of the tested beam was 200 mm x 300 mm x 1000 mm and the effective range was 800 mm. Class M30 concrete was used. The zone below the neutral line was divided into three zones and two zones adjacent to the neutral line were replaced by air cavity. The value of load and deflection which was suitable from the beams and the solid controlling beams with the replacement at the neutral line until the load was 220 kN. The solid beam's deflection was 30.73 mm and the beams with 4% and 8% air void created polyethylene ball of 35.16 mm and 37.85 mm.

Rahardyanto, 2013, the previous research on hollow core slab found a problem in the casting process caused by the buoyancy of the bottle which made it difficult to be performed. The experimental study to search an easier method and learn the hollow beam's bending strength with PET bottle had been done by using tested object of 200 x 400x 3850 mm. There were 6 hollow beams with K-300 and K-400 concrete quality, and three solid K-400 reinforced concrete beam specimens of the same sizes which were also tested as the comparison. The result was obtained from the analysis based on the graph of relation between the load and the deflection, and between the moment and the round angle on the middle of the section, crack pattern which occurred on each specimen and failure mode. The comparison between the theoretical and experimental ultimate capacity.

3. RESEARCH METHODE

3.1. Section and material properties of tested beam

The dimension of the beam used in the research used the T shaped beam cross section of Bina Marga standard bridge. The scale was 1:3.

- Beam's width: bw = 150 mm
- The flange thickness: t = 66.7 mm
- The height of the beam: h = 350 mm; effective height: d = 275 mm
- Tension reinforcement 2 D 25; tension reinforcement: 4 ϕ 8
- Reinforced steel on the support is ϕ 8–100 while on the middle length is ϕ8– 150 mm,

- The beam's length: L = 3300 mm (free section: 3000 mm)
- Compressive strength, f'_c: 25 MPa,
- Yield stress of reinforcing steel, f'_y = 400 Mpa

Tested objects' variables and notations

- Variation of effective width of flange: 200 mm, 500 mm

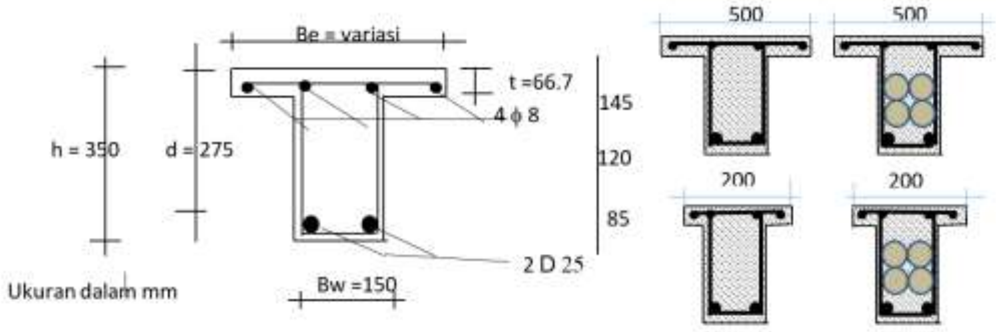

Figure 5 Dimension and variation of plated reinforced T beam

Table 1 Notation and the amount of tested objects

No	Effective Length	T Shaped beam concrete	Specimen Notations	Amount of Specimen
1	200	Normal	TMNS	1
2	200	Hollow	TMBS	1
3	500	Normal	TSNS	1
4	500	Hollow	TSBS	1

Figure 6 Dimension and variation of plated reinforced T beam

3.2. Theoretical Calculation of Bending Capacity of T Shaped Beam

Table 2 Neutral and apparent T shaped beam capacity

DESCRIPTION		UNIT	T BEAM'S CONDITION		
f'c		Mpa	25	25	25
fy		Mpa	400	400	400
t		mm	70	70	70.00
b		mm	150	150	150
be		mm	264.0	200.0	500.0
C = 0,85 f;c. Be. t		N	392,700.00	297,500.00	743,750.00
Reinforcement			2 D 25	2 D 25	2 D 25
As		mm^2	981.75	981.75	981.75
T = As x fy		N	392,699.08	392,699.08	392,699.08
a		mm	70.0	92.40	36.96
a ? t			a = t	a > t	a < t
T Beam Behaviour			T Beam = Square Beam	Neutral T Beam	Apparent T Beam
a	at Flens	mm	70.00	70.00	36.96
a'	at Web	mm	-	29.87	
Hollow Height		mm	195.00	165.13	228.04

3.3. Loading frame test instrument

The test instruments of loading frame and the loading frame instruments are:

1. Actuator with maximum load capacity of 1500 kN
2. Load Cell, to measure the applied loads, with 200kN capacity.
3. Data logger, to automatically record the data measured by the strain gauge LVDT and Load Cell
4. Strain gauges, to measure the reinforcing steel strain and concrete strain.
5. LVDT (*Linier Variable Displacement Transducer*), to measure deflection of tested beam.

Test setup can be seen on Fig.6.

Figure 6 Set up of the test instruments

4. RESULT AND DISCUSSION

4.1. The Ability of T Shaped Beam to Bear Loads

4.1.1. The Ultimate Load Capacity of Apparent T Beam (TS) and Neutral T Beam (TM)

Fig 7 shows the ultimate load capacity of apparent T beam and neutral T beam. The comparison of apparent and neutral T beam's ability to bear the load on the normal cross section was 99.25% and on the plated cross section was 99.41%. there values show that the difference of apparent and neutral T beam's ability to bear the loads is not significant and it was only caused by the longer moment of the apparent T beam than of the neutral T beam.

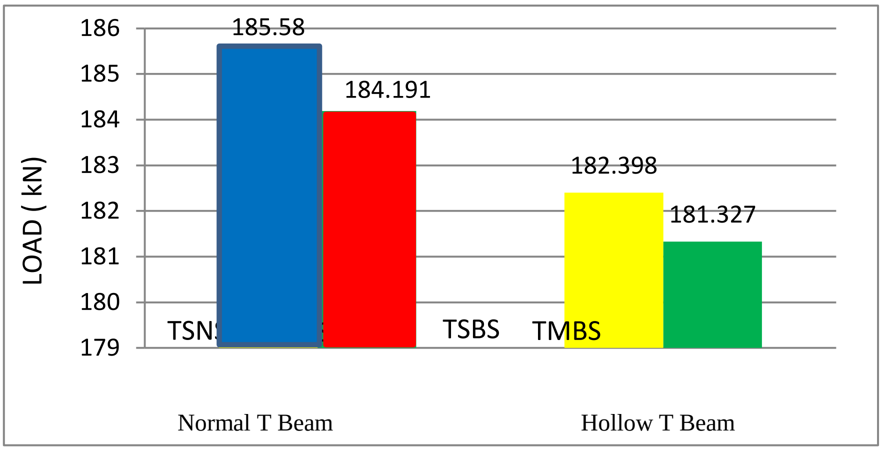

Figure 7 The ultimate load capacity of apparent and neutral T beam

4.1.2. The Ultimate Load Capacity of normal beam (TN) and the hollow beam (TB)

Figure 8 shows the ultimate load capacity of the normal beam and the cavity T beam. The comparison of the ability to bear the loads of the cavity beam and the normal beam of the apparent T beam was 98.29% and of the neutral T beam was 98.45%. It shows that the ability to bear the loads of the cavity beam was not significantly different from the normal beam. This is because the cavity which was made from the plastic bottle was placed on the tension cross section which was theoretically calculated to not bear the loads

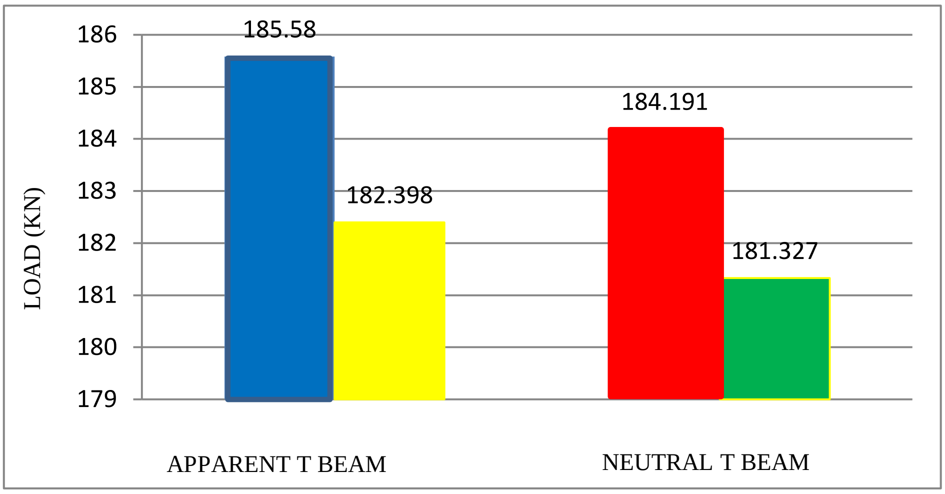

Figure 8 The ultimate load capacity of normal beam and hollow T beam

4.2. Load-deflection relationship of each tested beams.

Figure 9 shows the relationship of the load-deflection curve. Based on that figure, it can be seen that either normal or cavity beam of the neutral T beam was stiffer than the apparent T beam. The result also show that stiffness of normal beam is better than the hollow beam although the value is not significantly different.

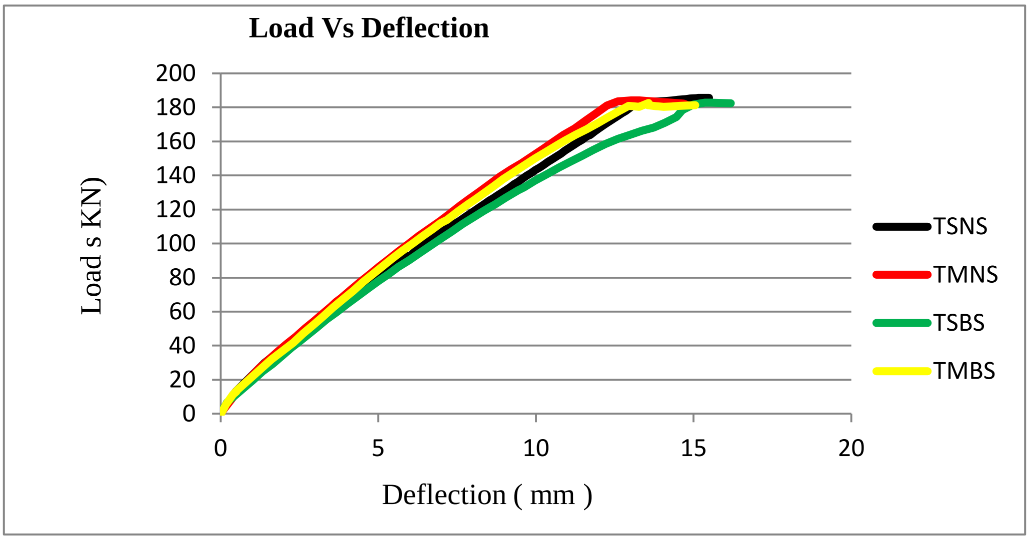

Figure 9 The ultimate load capacity of normal beam and cavity T beam

5. CONCLUSIONS

Based on the experimental test, it can be concluded that:

a. The ultimate load of each tested beam did not give any significant difference. The capacities of all tested beams were determined by using under reinforced principle, which means that the bending failure of the beam was started by the yield reinforcing steel.
b. The stiffness of the neutral T beam is better than the apparent T beam although the value is not significantly different. The stiffness of the cavity apparent T beam is better that the normal neutral T beam.

ACKNOWLEDGEMENT

1. Kemenristek-Dikti Republic of Indonesia for having supported the fee of the research
2. The chairperson of LPPM of Bosowa University
3. The head of the Structure Research and Development Laboratorium of Civil Engineering Department, Faculty of Engineering, Hasanuddin University
4. The head of Structure and Material Laboratorium of Civil Department, Faculty of Engineering, Bosowa University.

REFERENCES

[1] Besari,M.S, Lauw, CGS 1999, Behaviour of hybrid concrete T-Beams under monotonic and cyclic Loading, 24thconference on our world in concrete & structures, 1999, Singapore.

[2] Chandra, Yovi, 2011, Karakteristik Beton Dalam Web Dan Flens Balok T Pada Kombinasi Beton Normal Dan Beton Non Pasir, Teras Jurnal Vol. I No.2 Juni 2011

[3] Dhinesh.N.P, Satheesh.V.S, Flexural Behaviour of Hollow Square Beam, International Journal (IJSEAS) – Vol.3, March 2017, ISSN: 2395-3470

[4] Irmawaty, R., Djamaluddin, R, Malim, Wa O. A. R (2016), Flexural Behavior Of Styrofoam-Filled Concrete, Ijesca, ISSN: 2406-9833 @2016 PPs-UNHAS

[5] Joy, Jain , Rajeev, R, 2014, Effect of Reinforced Concrete Beam with Hollow Neutral Axis, Int.Journal for Scientific Research & Development, Vol.2, 2014, ISSN : 2321-0613

[6] Lisantono, Ade ,Besari, MS, Suhud, R , Soemardi, BW (2004), Experimental Investigation on the effect of Web Opening Dimension on the Behaviour of R/C hybrid Deep T-Beam subjected to Pure Torsion, Jurnal Teknik Sipil, Vol. 11 No. 1 Jan. 2004.

[7] Kumar, Aswathy S Joy, Anup (2013), Experimental Investigation on Partial Replacement of Concrete Below Neutral Axis of Beam, IJSR, Vol. 4 Issue 8, Aug. 2015

[8] Kunal Jadhav, S. S. Angalekar, A. A. Taware, 2017, Study on Influence of Polyethylene Teraphthalate (PET) Bottles in Concrete Section, International Journal of Science, Engineering and Technology Research, Volume 06, Issue 7, July 2017

[9] Manuhua, Yacob Yonadab, Wallah, Steenie E, Dapas , Servie O. 2015, Analisis kapasitas balok beton bertulang dengan lubang pada badan balok, Jurnal sipil statik Volume 3 No. 7 Juli 2015 ISSN 2337-6732, hal 456 – 465.

[10] Olmedo, F.I, Valivonis, J and Cobo,A, 2016, Experimental Study of Multilayer beams of lightweight concrete and normal concrete, Modern Building Materials, Structures and Techniques, MBMST 2016, Procedia Engineering 172 (2017), p. 808 – 815.

[11] Parthiban, N, Neelamegam, M 2017, Flexural Behavior Of Reinforced Concrete Beam With Hollow Core In Shear Section, IRJET, Vol. 04 Issue: 04 , Apr -2017.

[12] Rahardyanto, 2013, Studi eksperimental balok berongga dengan pemanfatan limbah botol PET, Jurnal Penelitian FT UI

[13] Satheesh V.S, Nyosu, Bomrik, 2017, Flexural Behavior of Hollow RC beam using Glass Fiber, Int. Journal of Science Technology & Eng, Vol. 3, March 2017 ISSN 2349-784X

[14] Sivaneshan, P and Harishankar, S, 2017, Experimental Study on Voided Reinforced Concrete Beams with Polythene Balls, IOP Conf. Series: Earth and Environmental Science 80 (2017) 012031

[15] Tanijaya, Jonie , Besari, MS , Suhud, Ridwan , 2001, An experimental investigation of the mechanical behavior of hybrid R/C T-Beams with web Openings, The eight East Asia-Pasific conference on structural Engineering and constructions, 5-7 December 2001, Nanyang Technology University, Singapore

[16] Varghese, Nibin , Joy, Anup, 2016, Flexural Behaviour of Reinforced Concrete Beam with Hollow Core at Various Depth, International Journal of Science and Research (IJSR), Vol. 5 Issue 5, May 2016, ISSN (Online): 2319-7064

[17] Yasser, Parung,H, Tjaronge, MW and Djamaluddin, R. 2014, Flexural Characteristics of Reinforced Concrete Beam Using Styrofoam Filled Concrete (SFC) in Tension Zone.