THE BEHAVIOR OF SELF COMPACTING CONCRETE BEAMS REINFORCED STEEL ROUND HOLLOW PIPE IN Fc' 25 MPa CONCRETE

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Abstract: This research examines the behavior of Self Compacting Concrete beams reinforced with round hollow steel pipes on fc' 25 MPa concrete which aims to determine the effect of both types of reinforcement characteristics on flexural capacity, deflection, and crack patterns in self-compacting concrete beams reinforced with round hollow steel pipes size 1.8 x 16 x 1000 mm and plain steel reinforcement Ø10 which is used as longitudinal reinforcement. The specimen of a reinforced concrete beam with a dimension was 12 cm x 18 cm x 100 cm used 2 types of longitudinal reinforcement. BTH beams use longitudinal reinforcement from round hollow pipe steel reinforcement measuring 1.8 x 16 x 1000 mm and BTK beams use longitudinal reinforcement from steel reinforcement plain Ø10 while the stirrup reinforcement used steel reinforcement Ø6. Based on the research results, the average flexural capacity of BTK beams is 16.50 MPa and the average flexural capacity of BTH beams is 16.41 MPa. The test results of the maximum deflection of the BTK beam are 9.83 mm and the average maximum deflection of the BTH beam is 7.84 mm. The flexural capacity between the two types of beams does not have a significant difference. The maximum deflection that occurs from the BTK beam and the BTH beam does not have a significant difference. The crack pattern of all beam specimens is categorized as a flexural crack.

Keywords: beam behavior, self-compacting concrete beams, round hollow pipe, steel reinforcement, concrete fc' 25 MPa

1. INTRODUCTION

Reinforced concrete is a combined material between concrete and reinforcing steel where the concrete functions to receive compressive forces while the reinforcement functions to receive tensile forces (Asroni, 2010). One of the reinforced concrete structures, namely beams, reinforced concrete beams are long horizontal or inclined structural elements with limited width and height and function to transmit loads from floor slabs to columns (Setiawan, 2016). Because reinforced concrete beams play an important role in carrying lateral loads, this research is interesting to do.

Research on reinforcement in reinforced concrete beam structures has been carried out a lot. Some of them are Hastono (2013) who researched the use of hollow-type mild steel (cold-formed) as reinforcement in reinforced concrete beams. This study aims to determine the effect of using D13 deformed steel reinforcement on hollow-type mild steel reinforcement from two variations of concrete covers, namely, 4 cm and 7 cm. This study concluded that the value of flexural strength using mild steel reinforcement, especially the hollow type, was 23.2% greater when compared to the use of D13 deformed steel reinforcement in reinforced concrete beams.

Based on research conducted by Nuralinah (2016) on test specimens of knitted bamboo reinforced concrete beams with a planned concrete quality of 20 MPa. The results of this study indicate that the bending capacity of the beam increases linearly with the increase in the amount of bamboo knitted reinforcement. In addition, an increase in the amount of knitted bamboo reinforcement in the tension area can affect the load capacity of 4567 Kg for 2D13 tensile reinforcement, 5517 Kg for 3D13 tensile reinforcement, 6367 Kg for 4D13 tensile reinforcement, and 7342 Kg for 5D13 tensile reinforcement. Research by Sudarsana et al (2015) regarding petung bamboo reinforced concrete beams with variations in the area of tension reinforcement and the area of compression reinforcement is fixed. It shows that the results of this study can increase the serviceability of the beam which includes an increase in the first crack load as well as the width of the crack that occurs and a decrease in the deflection of the beam structure.

While research from Prayitno (2019) on beam structures given rectangular steel plate torsion reinforcement measuring 4 x 25 x 1000 mm between 3, 4, 5, and 6 twists with a design concrete quality of 20 MPa. Resulting in the conclusion that the moment capacity that occurs in the beam has an effect of 85.9% on the number of plate twists and 67.4% of the beam deflection statistical tests.

The research above uses normal concrete material, while in this study SCC concrete will be used. Self Compacting Concrete (SCC) is a concrete mixture that can flow and compact itself without using a vibrator to compact the concrete (As'ad, 2017). This study aims to determine the flexural capacity, deflection, and crack patterns of self-compacting concrete blocks with beams measuring 100 cm x 18 cm x 12 cm from BTH beams with steel reinforcement of round hollow pipes measuring 1.8 x 16 x 1000 mm as longitudinal reinforcement with beams BTK which is a control beam of plain steel reinforcement with a diameter of 10 mm. The decision to use round hollow pipe steel reinforcement measuring 1.8 x 16 x 1000 mm was based on the calculation of the area of reinforcement which was close to the area of plain steel reinforcement Ø10. So the two types of reinforcement will be researched.

The benefits to be achieved from using round hollow pipe steel reinforcement measuring 1.8 x 16 x 1000 mm as longitudinal reinforcement in BTH beams results in better structural strength than using plain steel reinforcement with a diameter of 10 mm as longitudinal reinforcement in BTK beams. However, if this is not fulfilled in this study, there is a possibility that the use of round hollow pipe steel reinforcement measuring 1.8 x 16 x 1000 mm can be used as an alternative solution to the use of reinforcement in other building structures, one of which is a column structure. In addition, the use of hollow reinforcement in building structures can be used as a medium for plumbing channel systems and electrical cable channels without neglecting the safety factor of the structure.

2. METHOD

The research that will be carried out uses an experimental design and the data obtained is the result of the test that will be described. The purpose of this study was to determine the behavior of self-compacting concrete beams with longitudinal reinforcement of steel reinforcement round hollow pipes measuring 1.8 x 16 x 1000 mm for BTH beams and to compare them to the control beams of BTK beams with plain steel reinforcement Ø10 as longitudinal reinforcement. The parameters measured in this study included the flexural strength test of the beam, the maximum deflection of the beam, the difference in the flexural capacity of the beam, the difference in the maximum deflection of the beam, and the pattern of cracks that occur in reinforced concrete beams. The reinforced concrete beam test object used is a block mold with dimensions of a length of 100 cm, a height of 18 cm, and a width of 12 cm using a design concrete quality of fc' 25 MPa. There are 3 concrete cylindrical specimens for each beam specimen and 3 beam specimens for each type of reinforcement used, so a total of 12 specimens were made and 3 mortar cylinder specimens. Testing of beams refers to the regulations of SNI 4154: 2014 where the beams tested are one-span beams that are placed on roller joints and given a load P at one point of loading while the manufacture of reinforced concrete beam test specimens is based on SNI 2847: 2019 concerning structural concrete requirements for buildings building.

Data analysis in this study used descriptive statistics based on data obtained from laboratory testing and statistical analysis of independent sample T-tests with the help of the Microsoft Excel application and SPSS v.25.0 software to find out whether there is a significant difference or average between the two objects. beam test. The results of the analysis will be displayed in the form of load graphic data (P) and tables from the results of the calculation of the flexural capacity of reinforced concrete beams as well as differences in the results of testing the flexural capacity of the beams and differences in the maximum deflection results that occur in the beams. The analysis used to analyze the crack pattern after the beam test is carried out is to describe the condition of the beam with the support of beam images after the flexural strength test of the beam has been carried out.

To get the appropriate data and results, for the research that will be carried out the author makes a research procedure. The research procedure to be carried out is divided into several stages, namely: preparation of tools and materials, material testing, manufacture and compressive strength test of mortar cylinders, tensile strength test of steel reinforcement, concrete mix design test, manufacture of concrete cylinder and beam test objects, maintenance of test objects concrete cylinders and beams, testing the compressive strength of cylindrical concrete and testing the flexural capacity of the beams, the last analysis of the data results. The research implementation procedure is described in the form of a research flow scheme which can be seen in Figure 1 as follows.

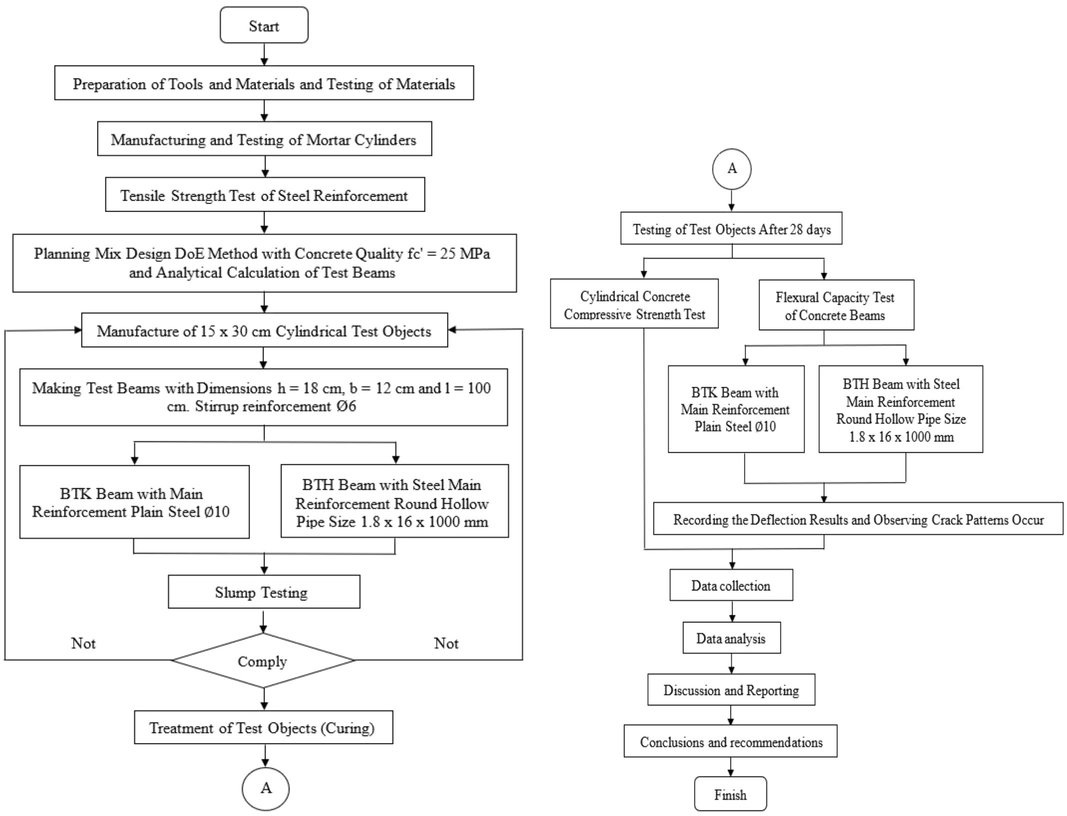


Figure 1. Research Flow

3. RESULT

Flexural Capacity of Reinforced Concrete Beams

Testing the flexural capacity of the beam on the specimen aged 28 days was carried out to determine the value of the flexural strength of the beam when it reaches the maximum load. The loading result data is obtained from the reading of the UTM (Universal Testing Machine) machine which is given a continuous load with an additional load of 500 N up to the maximum load. The results of the flexural strength test of the beam can be seen in Table 1. Loading is done by giving a concentrated load in the middle of the span based on SNI 4154:2014. The placement of the load P and the distance of the supports on the beam test object can be seen in Figure 2.

Table 1. Recapitulation of Flexural Strength Test Results for Beams

Beam	P Maximum (UTM) (N)	P Maximum (Crosscheck) (N)	Flexural (MPa)	Average Flexural (MPa)
1	**2**	**3**	**4**	**5**
		BTK BEAM		
BTK-A	66.300	53.300	16,45	16,50
BTK-B	67.900	54.900	16,94	
BTK-C	65.200	52.200	16,11	
1	**2**	**3**	**4**	**5**
		BTH BEAM		
BTH-A	67.600	54.600	16,85	16,41
BTH-B	64.400	51.400	15,86	
BTH-C	66.500	53.500	16,51	

Calculation of the flexural strength of the beam

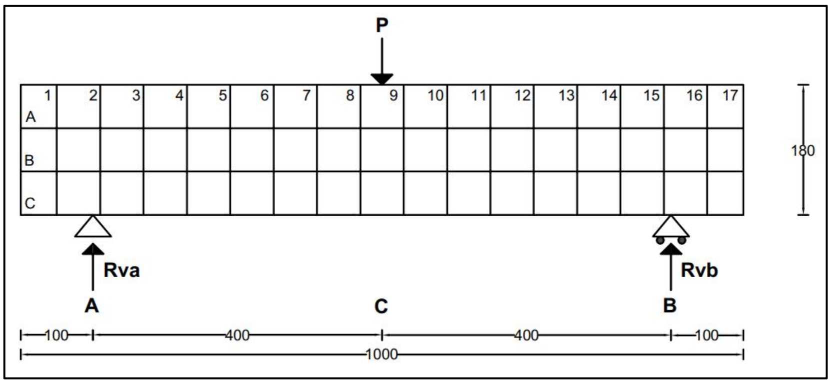


Figure 2. Points of Placement of Load P and Loading Distance on the Beam Test Object

Calculation of the flexural strength of beams can be calculated using the formula equation based on SNI 4154:2014 as follows:

$$\sigma_1 = \frac{3\,PL}{2\,bd^2} = \frac{3\,x\,53.300\ x\ 800}{2\,x\,120\,x\,180^2} = \frac{127.920.000}{7.776.000} = 16{,}45 \text{ MPa}$$

Deflection (Δ) of Reinforced Concrete Beams

The deflection that occurs in the beam is obtained from the results of the beam bending test using a UTM (Universal Testing Machine) machine which is read by a dial gauge when the additional load reaches 500 N up to the maximum load that can be accepted by the beam test object. This test aims to determine the magnitude of the test object deflection due to the load (P) acting on the beam. The following is a recapitulation of the deflection results from the flexural testing of BTK beams and BTH beams for each specimen of the beam test object.

Based on the calculation, the theoretical deflection of the beam produces a deflection of 0.61 mm. whereas based on the calculation of the allowable deflection of the beam based on SNI 2847: 2019, the value of the resulting allowable deflection is 3.33 mm. The deflection observed in this study is the deflection when the beam test object experiences maximum flexural strength. The results of the deflection when experiencing peak loads are shown in Table 2 as follows.

Table 2. Recapitulation of beam deflection test results

Beam	P Maximum (UTM) (N)	P Maximum (Crosscheck) (N)	Deflection (mm)	Average Deflection (mm)
		BTK BEAM		
BTK-A	66.300	53.300	11,03	9,83
BTK-B	67.900	54.900	9,25	
BTK-C	65.200	52.200	9,21	
		BTH BEAM		
BTH-A	67.600	54.600	9,18	7,84
BTH-B	64.400	51.400	6,03	
BTH-C	66.500	53.500	8,32	

Based on the deflection that occurs when the beam experiences a peak load that is greater than the theoretical deflection and allowable deflection, the deflection that occurs on the beam does not meet the requirements.

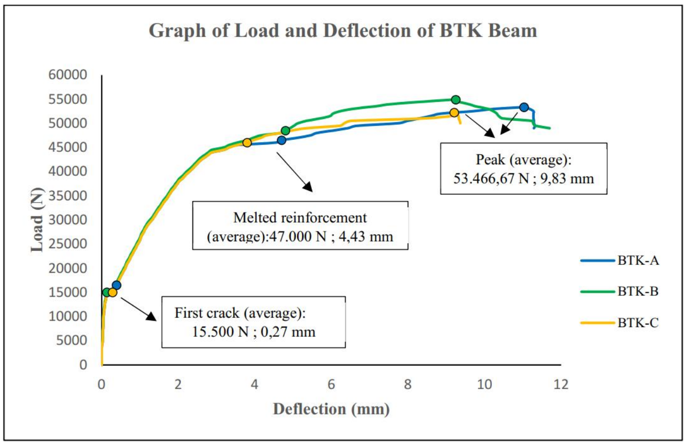


Figure 3. Graph of Load and Deflection Relationships on BTK Beams

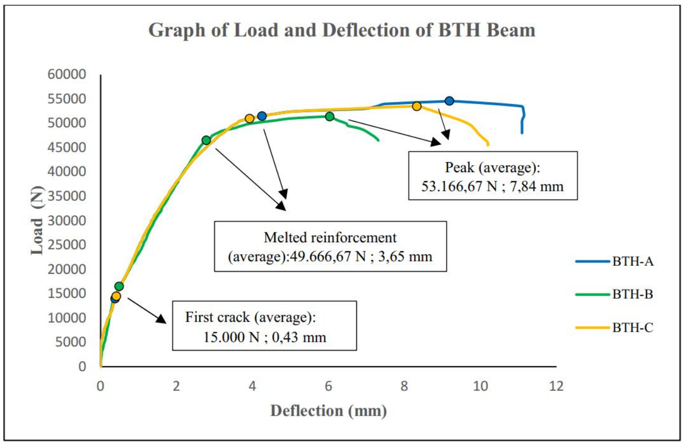


Figure 4. Graph of Load and Deflection Relationships on BTH Beams

Data analysis

Analysis of the Bending Capacity of the Beam

The results of the data obtained from the flexural strength value of each beam are homogeneous data. The value of the T count is 0.247. The value of T table = t_(1/2α(4)) is 2.78. The value of the t count is less than the t table, so Ho fails to be rejected or Ho is rejected not significant. The conclusion is that Ho failed to be rejected or Ho was accepted because there was no supporting data for rejection. The conclusion from the statistical analysis is that there is no significant difference regarding the differences in the bending capacity of the beams between the BTK beams and the BTH beams.

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Kapasitas Lentur Balok	Equal variances assumed	.153	.715	.247	4	.817	.09333	.37733	-.95430	1.14097
	Equal variances not assumed			.247	3.868	.817	.09333	.37733	-.96856	1.15523

Figure 5. Results of Statistical Analysis of Bending Capacity of a Beam from SPSS v.25.0 Software

Maximum Deflection Analysis that Occurs in the Beam

The results of the data obtained from the maximum deflection value of each beam are homogeneous data. The value of the T count is 1.781. The value of T table = t_(1/2α(4)) is 2.78. The value of the t count is less than the t table, so Ho fails to be rejected or Ho is rejected not significant. The conclusion is that Ho failed to be rejected or Ho was accepted because there was no supporting data for rejection. The conclusion from the statistical analysis is that there is no significant difference regarding the difference in maximum deflection that occurs in the beam between the BTK beam and the BTH beam.

Independent Samples Test

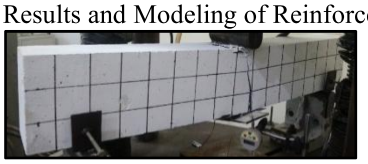
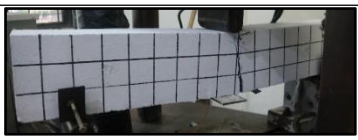
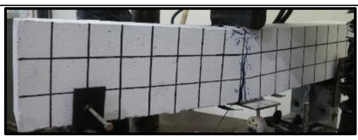
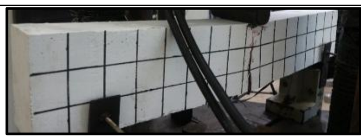
		Levene's Test for Equality of Variances		t-test for Equality of Means					95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Lendutan Balok	Equal variances assumed	.866	.405	1.781	4	.149	1.98667	1.11526	-1.10980	5.08313
	Equal variances not assumed			1.781	3.398	.162	1.98667	1.11526	-1.33864	5.31197

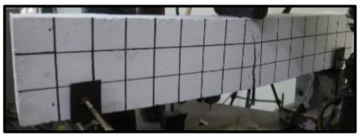
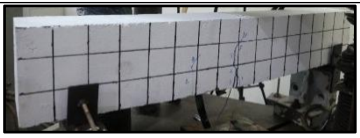
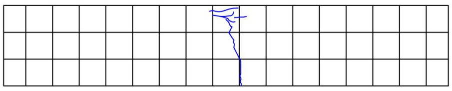
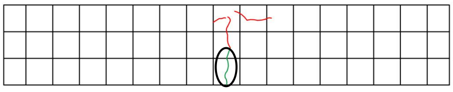
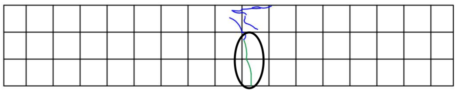
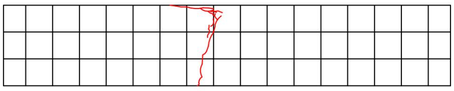
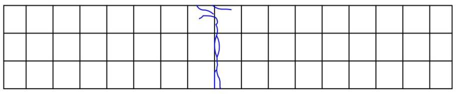
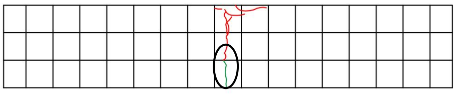
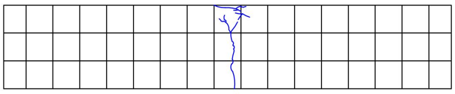
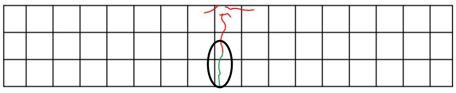
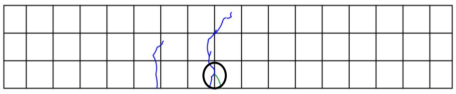
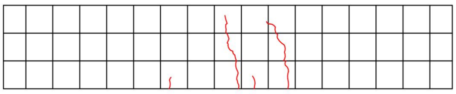
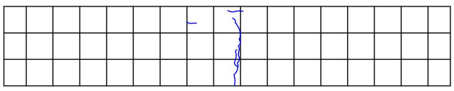
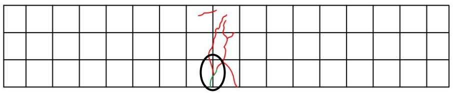
Figure 6. Statistical Analysis Results of Beam Deflection Test from SPSS v.25.0 Software

Reinforced Concrete Beam Crack Pattern

The crack pattern observed in this study is the crack pattern that occurs in Ø10 plain steel reinforced BTK beams with 1.8 x 16 x 1000 mm round hollow pipe steel reinforced BTH beams as the main reinforcement. In one beam test object, there are two observation sides of the crack pattern, namely on the front of the BTK and BTH beams and the back of the BTK and BTH beams. The following is an illustration of the crack pattern and the position of the cracks in the six beams. The results and modeling of the crack pattern data are presented in the following table.

Table 3. Results and Modeling of Reinforced Concrete Beam Crack Patterns

BTK-A	 front	flexural crack	 hind	flexural crack
BTK-B	 front	flexural crack	 hind	flexural crack
BTK-C	 front	flexural crack	 hind	flexural crack

BTH- A	 front	flexural crack	 hind	flexural crack
BTH- B	 front	flexural crack	 hind	flexural crack
BTH- C	 front	flexural crack	 hind	flexural crack
BTK- A	 front		 hind	
BTK- B	 front		 hind	
BTK- C	 front		 hind	
BTH- A	 front		 hind	
BTH- B	 front		 hind	
BTH- C	 front		 hind	

4. DISCUSSION

Flexural Capacity of Reinforced Concrete Beams

A comparison of the flexural capacity test of the BTK beam against the BTH beam shows that the beam's ability to withstand a load decrease by 0.56% when it receives the maximum P load. Based on the results of the study, the flexural strength of BTK beams reinforced with plain steel Ø10 used as longitudinal reinforcement has a strong bending of 16.50 MPa, while the BTH beams reinforced with round hollow pipe measuring 1.8 x 16 x 1000 mm used as longitudinal reinforcement have strong bending. 16.41 MPa. The maximum load value achieved by the BTK beam is 53,466.67 N while the BTH beam is 53,166.67 N. The calculation of the design flexural strength is 12.06 MPa from the design maximum P load of 39,080 N. The results of the flexural strength test of the beam at peak load that occurs are greater than those with a strong flexible beam package. Figure 7 presents the strength values of the BTK flexural beams and BTH beams as follows.

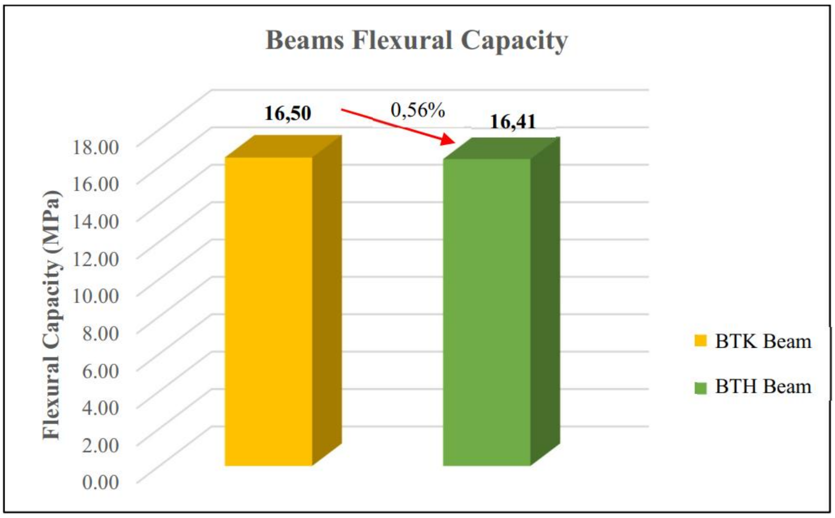


Figure 7. Graph of Flexural Strength of a Beam when Experiencing a Maximum P Load

Based on the results of the research that has been done, concluded that the decrease in the flexural strength of the beam is due to the difference in the tensile strength of the reinforcement resulting from the results of the tensile strength test of the reinforcement. In BTK beams reinforced with plain steel Ø10 used as longitudinal reinforcement the value of the tensile strength of the resulting reinforcement is greater than in BTH beams reinforced with round hollow pipe steel measuring 1.8 x 16 x 1000 mm used as longitudinal reinforcement. Therefore, the use of a relatively large diameter of reinforcement but the value of the tensile strength of the resulting reinforcement is lower causing the bending strength of the beam to decrease. Similar to Chandra's statement (2016) if the tensile strength of the resulting reinforcement is lower, it can affect the stiffness and behavior of reinforced concrete beams.

Deflection (∆) of Reinforced Concrete Beams

The flexural strength test of the beam resulted in the maximum deflection of the beam as follows, the deflection of the BTK beam using longitudinal reinforcement of Ø10 plain steel reinforcement of 9.83 mm with an average maximum loading of 53,466.67 N and BTH beams reinforced with steel round hollow pipe size 1.8 x 16 x 1000 mm used as longitudinal reinforcement of 7.84 mm with an average maximum loading of 53,166.67 N. In Figures 8 and 9, the deflection values that occur when subjected to the maximum P load and the average value of the maximum load are presented. on BTK beams and BTH beams as follows.

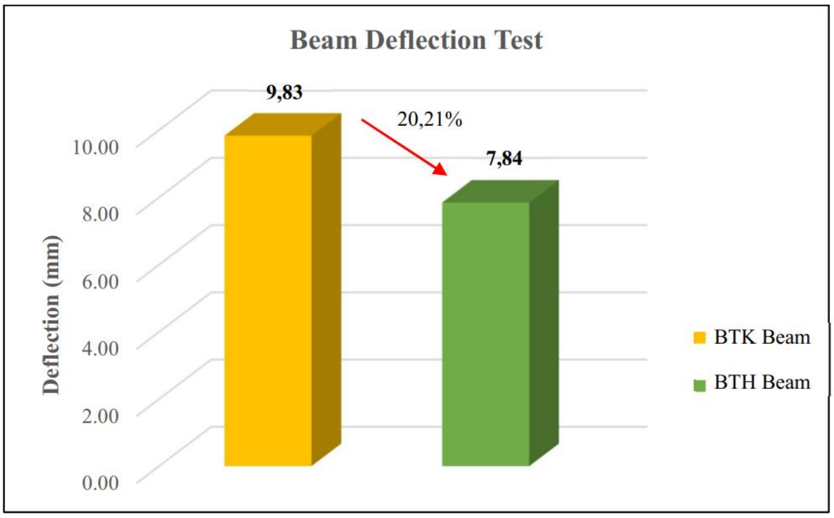


Figure 8. Graph of Block Deflection when Experiencing Maximum P Load

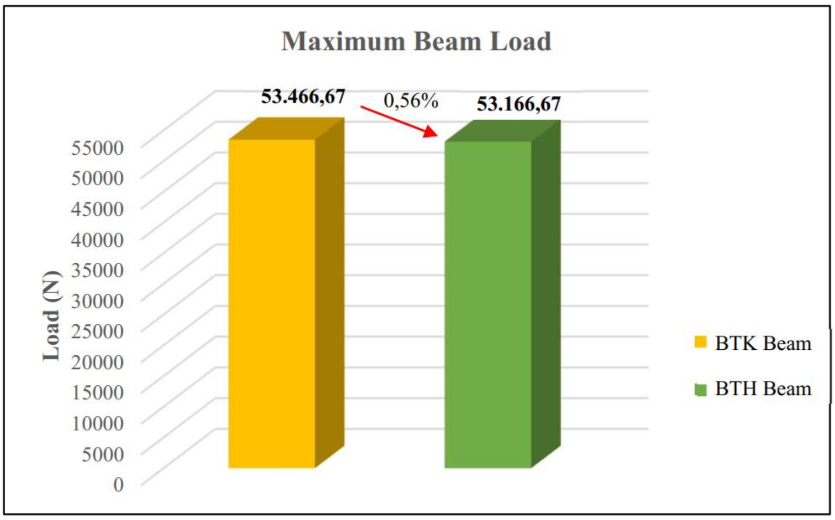


Figure 9. Graph of Maximum Beam Load

The theoretical deflection value based on SNI 2847:2019 obtained that the allowable deflection of the beam is L/240 or 3.33 mm. The largest deflection test results occurred in BTK beams using longitudinal reinforcement of Ø10 plain steel reinforcement, namely 9.83 mm, and having the ability to withstand greater deflection, namely 20.21% of BTH beams reinforced with steel round hollow pipes measuring 1.8 x 16 x 1000 mm used as longitudinal reinforcement. The factor that causes the amount of deflection that exceeds the allowable limit is the amount of bending load that the beam can withstand has exceeded the plan, increasing beam deflection. The deflection that occurs in BTH beams reinforced with steel round hollow pipes measuring 1.8 x 16 x 1000 mm is also affected by the relatively small values of yield stress (fy) and modulus of elasticity (E) when compared to the yield stress and modulus of elasticity in reinforced BTK beams. plain steel Ø10. According to Chandra (2016) relatively small yield stress (fy) and modulus of elasticity (E) can affect the bond strength between reinforcement and concrete. These conditions can cause very large cracks, and cause deflection in the beam structure.

This research concluded that the greater the diameter used in hollow reinforcement which has hollow reinforcement characteristics in it, the smaller the resulting deflection will be. The smaller the diameter used in conventional reinforcement which has solid reinforcement characteristics, the greater the resulting deflection will be. Therefore, the use of a reinforcement diameter that is large enough causes the beam's ability to withstand smaller deflections. In addition, the deflection is also influenced by the type of loading and the type of support used in the test. The pedestal (roller-joint) will provide a greater deflection when compared to the pin-pin and roll-pin types. This is because there is no moment of resistance against the action of the force due to the given load on the roller joint support. In this study, the loading was carried out by providing a concentrated load in the middle of the beam span according to the test plan to be carried out, while the supports used simple supports (roller joints) so that the deflection that could occur could be greater than the results of theoretical deflection calculations (Rosalia, 2017).

According to Hartoyo (2020), the magnitude of the experimental deflection that occurs is greater when compared to the results of the calculation of the allowable (theoretical) deflection. The theory is by the results of experiments that have been carried out in this study. Based on the analysis, the deflection that occurs when the beam specimen experiences a peak load is greater than the theoretical calculation and allowable deflection. So it can be concluded that the deflection that occurs when experiencing peak loads does not meet the applicable requirements. From the theoretical calculation of the deflection, it is obtained that the beam deflection is 0.61 mm, and the allowable deflection of the beam structure based on SNI 2847: 2019 obtained the allowable deflection of the beam test object is 3.33 mm.

The difference in the bending capacity of the beam

Testing the analysis of differences in beam flexural capacity using the Independent Sample T-Test analysis to determine whether there is a significant difference from each data group. Analysis of test data obtained from the T-test using Microsoft Excel and the help of SPSS v.25.0 software with a significant level used is 5% or the test of each variable must have a big value. < 0.05. In testing the analysis of the bending capacity of the beam, the significant difference is that the BTK beam reinforced with plain steel Ø10 was used as longitudinal reinforcement and the BTH beam reinforced with round hollow pipe measuring 1.8 x 16 x 1000 mm was used as longitudinal reinforcement is 16.50 MPa > 16 .41 MPa. The resulting significant level is 0.715 > 0.05. The results of the analysis test can be concluded that there is no significant difference regarding the differences in beam flexural capacity between Ø10 plain steel reinforced BTK beams and 1.8 x 16 x 1000 mm circular hollow pipe steel reinforced BTH beams used as longitudinal reinforcement.

Maximum Deflection Difference of Beam

Analysis of test data obtained from the Independent Sample T-Test test to find out whether there is a significant difference from each group of data using Microsoft Excel and the help of SPSS v.25.0 software with a significant level used is 5% or the test of each variable must be worth sig. < 0.05. In testing the beam deflection analysis, the value of significant difference was the BTK beam reinforced with plain steel Ø10 which was used as longitudinal reinforcement and the BTH beam reinforced with round hollow pipe steel measuring 1.8 x 16 x 1000 mm which was used as longitudinal reinforcement, namely 9.83 mm > 7 .84mm. The resulting significant level is 0.405 > 0.05. The results of this analysis can be concluded that there is no significant difference regarding the difference in beam deflection test between Ø10 plain steel reinforced BTK beams and 1.8 x 16 x 1000 mm circular hollow pipe steel reinforced BTH beams used as longitudinal reinforcement.

Reinforced Concrete Beam Crack Pattern

The first crack of the BTK beam reinforced with plain steel Ø10 which is used as longitudinal reinforcement begins with a vertical crack in the tension area of the beam from the bottom, with increasing loading the cracks that occur increase in length and width beyond the neutral line of the beam cross-section, causing cracks along the side of the beam approaching the loading area. Beam failure is characterized by flexural cracks that occur at the bottom of the beam and are damaged around the working load. The beam experiences the first crack when the average load is 15,500 N and the average deflection that occurs is 0.27 mm. The reinforcement undergoes a yielding phase when the load reaches an average of 47,000 N and the deflection achieved by the beam is 4.43 mm. The failure of the beam is marked by the widening of the crack in the tension area and the reading of the load P on the UTM machine stops or has reached its peak, the average maximum load of the BTK beam is 53,466.67 N with a deflection of 9.83 mm. The loading is stopped when the load reading on the UTM machine decreases. In beams that use longitudinal reinforcement of Ø10 plain steel reinforcement (BTK beams) a crack pattern occurs, namely a flexural crack.

The first crack of the BTH beams reinforced with round hollow pipe steel measuring 1.8 x 16 x 1000 mm which is used as longitudinal reinforcement begins with a vertical crack in the beam tension area from the bottom, with increasing loading of the cracks that occur are getting longer and the width exceeds the neutral line of the beam section causing new cracks along the side of the beam approaching the loading area. Beam failure is characterized by flexural cracks that occur at the bottom of the beam and are damaged around the working load. The beam experiences the first crack when the average load is 15,000 N and the average deflection that occurs is 0.43 mm. The reinforcement undergoes a yielding phase when the load reaches an average of 49,666.67 N and the deflection achieved by the beam is 3.65 mm. The failure of the beam is marked by the widening of the crack in the tension area and the reading of the load P on the UTM machine stops or has reached its peak, the average maximum load of the BTH beam is 53,166.67 N with a deflection of 7.84 mm. The loading is stopped when the load reading on the UTM machine decreases. In beams that use longitudinal reinforcement from round hollow pipe steel reinforcement measuring 1.8 x 16 x 1000 mm (BTH beams) a crack pattern occurs, namely a flexural crack.

5. CONCLUSION

The average value of the flexural capacity of BTK beams reinforced with plain steel Ø10 used as longitudinal reinforcement has a flexural strength of 16.50 MPa while BTH beams reinforced with round hollow pipe steel measuring 1.8 x 16 x 1000 mm used as longitudinal reinforcement have flexural strength. 16.41 MPa. The comparison of the flexural strength of the BTK beam and the BTH beam is 1.01 : 1.00. From these results it can be concluded that the BTK beam has a greater flexural strength value than the BTH beam.

In this research, the average deflection of beams using longitudinal reinforcement from Ø10 plain steel reinforcement (BTK beams) is 9.83 mm and the average deflection value of beams using longitudinal reinforcement from steel reinforcement round hollow pipes measuring 1.8 x 16 x 1000 mm (BTH beam) is 7.84 mm. The deflection that occurs in the BTK beam can withstand greater deflection, namely 20.21% than the BTH beam, but the deflection from the test results exceeds the allowable deflection required by SNI 2847:2019, which is 3.33 mm.

The flexural capacity between the two types of beams in this study did not have a significant difference or it could be said to be the same. Based on the Independent Sample T-Test test, the resulting significant level is 0.715 > 0.05, and the value of t count = 0.247 < t table = 2.78. So that it can be concluded that BTK beams reinforced with plain steel Ø10 used as longitudinal reinforcement and steel-reinforced BTH beams with round hollow pipes measuring 1.8 x 16 x 1000 mm used as longitudinal reinforcement do not affect the flexural capacity of reinforced concrete beams.

The maximum deflection of the two types of beams has no significant difference. Based on the Independent Sample T-Test test, the resulting significant level is 0.405 > 0.05, and the value of t_count = 1.781 <t_table = 2.78. In other words, beams using longitudinal reinforcement from Ø10 plain steel reinforcement (BTK beams) and beams using longitudinal reinforcement from steel reinforcement round hollow pipes measuring 1.8 x 16 x 1000 mm (BTH beams) do not affect the deflection of the concrete beams.

The beam crack pattern that occurred in this study was the flexural crack pattern on all test objects for BTK beams reinforced with plain steel Ø10 used as longitudinal reinforcement and BTH beams with steel reinforcement with round hollow pipes measuring 1.8 x 16 x 1000 mm used as longitudinal reinforcement. This is evidenced by the vertical cracks found in the field area on the beam test specimens which are almost perpendicular to the center of the load.

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