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Effect of Length Development on Concrete Jacketing Method with Bamboo Reinforcement of Flexural Capacity Reinforced Concrete Beam

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Abstract**—***Beams are components of building structures that resist bending loads. In this research, the strength of the reinforced concrete beams will be tested with various lengths of bamboo reinforcement using the concrete jacketing (retrofiting) method. The study was conducted at the Structure Laboratory of the Brawijaya University, Malang, Indonesia. Existing reinforced concrete beams with dimensions of 15x20 cm span 120cm, stirrup reinforcement installed D10 at a distance of 10cm, for the main reinforcement D13. Mix mortar with a thickness of 3 cm and four bamboo reinforcement with dimension 1x1 cm as a layer of repair (retrofiting). The first loading is carried out until the existing reinforced concrete beam reaches the peak load condition, and is continued with the second loading (retrofit) until it reaches collapse. From the results of the study showed the length development of bamboo reinforcement will increase the flexural capacity of concrete beams.*

Keyword**—***Length development, bamboo reinforcement, retrofit method (concrete jacketing), flexural capacity*.

I. INTRODUCTION

Lately the discussion about strengthening structures with various methods has become a very interesting subject. Exceeds load the planned capacity (overloading) both in terms of service loads and earthquake loads can cause structural failure. In addition, errors in working procedures that result in defects in the structure and environmental factors such as acid attack also cause structural failure. Therefore, efforts to strengthen the structure become a way out in order to meet the safety and servicebility of a structure.

Many methods have been carried out to damaged provide reinforcement to structures either internal reinforcement, external reinforcement, to reinforcement by adding other elements. The selection of this method is based on the form of damage to the structure, the structural elements that are reinforced, to the cost and impact on the environment. This is done in order to be able to increase the strength of the structure and have a long life.

Some reinforcement of bending in particular has been carried out. Fahreza, (2018) suggested that the improvements made by the addition of 700 mm staple steel reinforcement in the maximum moment area of reinforced concrete beams increase capacity between 22-32% when compared to beams with repairs using straight reinforcement. In that study, using steel reinforcement as a repair material with reinforcement lengths only along the maximum moment area and adding bending steel staples.

Research on beam bending capacity was also carried out by Nahar et al. (2016) with the method of reinforcement bamboo reinforced beams along the span of the beam able to increase the beam capacity by up to 50%. Research conducted by Nahar et al. (2016) bamboo reinforcement is used as reinforcement of reinforced beams, but according to the authors bamboo reinforcement material can also be used as repairs. Analisys from Fahreza's research (2018) which provides bending of staple steel reinforcement. But it is difficult if applied to bamboo reinforcement so that the length development is needed instead of the contribution of bending to the steel reinforcement of staple. It aims to obtain the most effective length of the bending capacity of the reinforced beam.

II. EXPERIMENTAL DETAILS

A. Beam Description

In this research three groups of specimens were used consisting of 9 reinforced beams with dimensions of 15 x 20 cm with a length of 100 cm. The reinforcement dimension is used 2D13 for compressive and tensile reinforcement. Stirrup reinforcement using Ø10 with a distance of 100 mm. Of the nine test specimens given the first loading to the condition of the peak load, and after that will be repaired using the concrete jacketing method. Repairs were made using a mortar and installed four bamboo rebars with three distribution length distribution groups of 80, 60 and 40 cm. Reinforcement details can be seen in Figure 1.

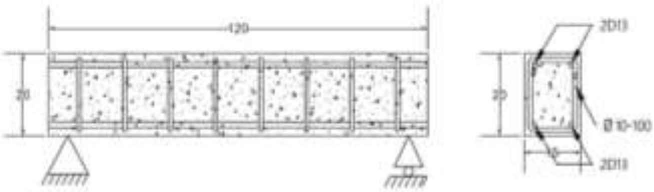

Fig. 1. Detail of existing reinforced concrete beam specimen

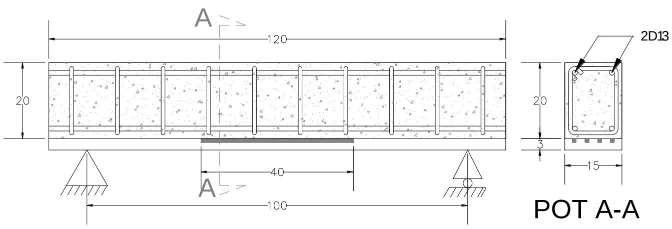

Fig. 2. Detail of retrofit reinforced concrete beam specimen with 40 cm bamboo reinforcement

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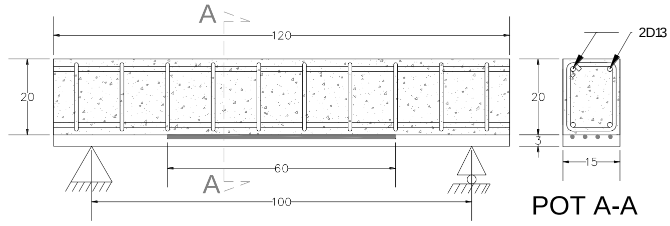

Fig. 3. Detail of retrofit reinforced concrete beam specimen with 80 cm bamboo reinforcement

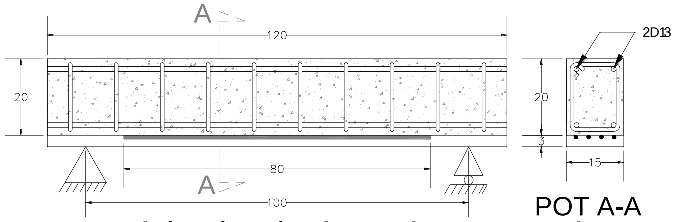

Fig. 4. Detail of retrofit reinforced concrete beam specimen with 60 cm bamboo reinforcement

B. *Material Properties*

The average compressive strength of concrete obtained from testing cylinders with dimension 150 mm of diameter and 300 mm of height is 26.63 MPa. For the average compressive strength the mortar obtained from the test cube size of 50 x 50 x 50 mm is 32.48 MPa. Tensile strength of 10 mm and 13 mm diameter reinforcement are 407 MPa and 424 MPa respectively. Bamboo reinforcement used is a type of bamboo Petung with ages between 3 until 5 years. Bamboo reinforcement is given a treatment in the form of layer with Sikadur and sand. The tensile strength of bamboo reinforcement is 221.73 MPa.

C. *Test Setup*

The test is carried out into two stages, namely initial loading on the existing beam and testing the beam after being given a retrofit. All types of reinforced concrete beam specimens were tested with three-point bending with a span distance of 1.0 m. Beam test specimens are carried out in the loading frame. For reading load using a load cell and for reading deflection using a LVDT. Both of which are placed in the center of the beam specimen spans (Figure 3).

III. TEST RESULT

The second test of reinforced concrete beams with initial damage to reach the peak load with repairs using a repair mortar and four bamboo rebars with a length of 80 cm obtained the results of the load and deflection in Table 2. From the test results obtained an increase in peak load on the BRB-4-80-1 beam by 0.95%. For the other two beams the peak load decreases when compared to the peak load on the existing beam. The magnitude of decrease in peak load is between 8.71% and 12.67%.

From the results of retrofit beam testing with a length of 60 cm, an increase in peak load on the BRB-4-60-3 beam was 0.59%. For the other two beams the peak load decreases when compared to the peak load on the existing beam. The magnitude of decrease in peak load is between 5.06% and 0.12%. For the results of retrofit beam testing with a length of 40 cm obtained an increase in peak load on the BRB-4-40-3 beam by 10.59%. For the other two beams the peak load decreases when compared to the peak load on the existing beam. The magnitude of decrease in peak load is between 8.71% and 12.67%.

TABLE 1 Specification of specimen

Specimen		Initial Loading	Dimension (cm)	Repair Reinforcement	Amount specimen
First Group	BRB-4-80-1 BRB-4-80-2 BRB-4-80-3	Peak Load	15 x 23	Four bamboo reinforcement with length of 80 cm	3 specimen
Second Group	BRB-4-60-1 BRB-4-60-2 BRB-4-60-3	Peak Load	15 x 23	Four bamboo reinforcement with length of 60 cm	3 specimen
Third Group	BRB-4-40-1 BRB-4-40-2 BRB-4-40-3	Peak Load	15 x 23	Four bamboo reinforcement with length of 40 cm	3 specimen

TABLE 2 Load and deflection of retrofit beams with four bamboo reinforcement with variation long reinforcement.

Spesimen	First Loading (Kg)	Second Loading *(Retrofit)* (Kg)	Percentage of Retrofit Beam Load to Existing Beam Load (%)	Deflection (mm)	
				First	Second
BRB-4-80-1	8959	9809	109.49	32.33	63.02
BRB-4-80-2	9388	8570	91.29	48.00	40.81
BRB-4-80-3	9299	8121	87.33	38.73	33.65
BRB-4-60-1	8970	8516	94.94	41.93	33.01
BRB-4-60-2	8298	8288	99.88	48.60	39.6
BRB-4-60-3	8248	8739	105.95	28.08	47.25
BRB-4-40-1	9104	6034	66.28	55.00	30.17
BRB-4-40-2	9256	7576	81.85	58.51	27.6
BRB-4-40-3	8797	9729	110.59	20.08	57.16

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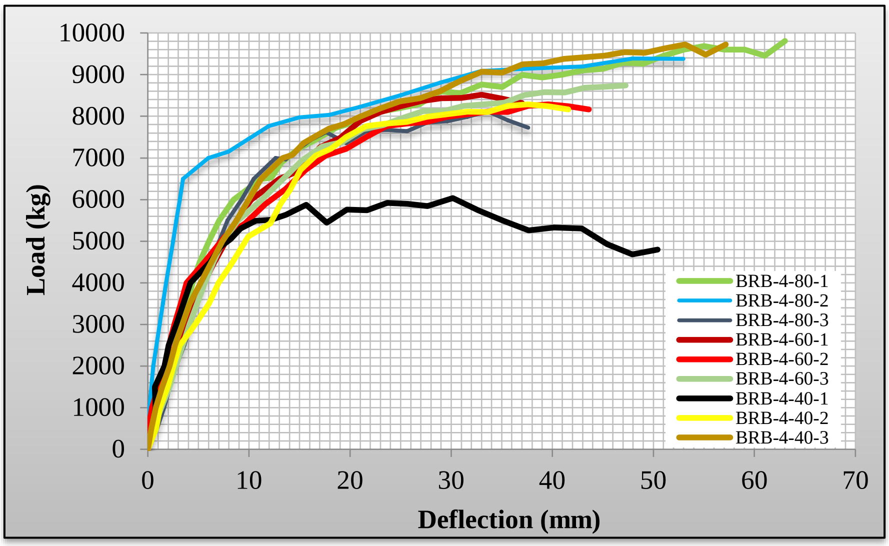

Fig. 5. Combined load and deflection curve of retrofit beams with variation long reinforcement.

TABLE 3 Flexural strength of retrofit beams with variation long reinforcement.

Specimen	Peak Load (Kg)		Flexural Strength (Mpa)		Percentage of Retrofit Beam Flexural Strength to Existing Beam (%)
	Existing	*Retrofit*	Existing	*Retrofit*	
BRB-4-80-1	8959	9809	21.96	24.05	109.49
BRB-4-80-2	9388	8570	23.02	21.01	91.29
BRB-4-80-3	9299	8121	22.80	19.91	87.33
BRB-4-60-1	8970	8516	21.99	20.88	94.94
BRB-4-60-2	8298	8288	20.34	20.32	99.88
BRB-4-60-3	8248	8739	20.22	21.43	105.95
BRB-4-40-1	9104	6034	22.32	14.79	66.28
BRB-4-40-2	9256	7576	22.69	18.57	81.85
BRB-4-40-3	8797	9729	21.57	23.85	110.59

Flexural strength for the first beam group with an average of 22.59 MPa, the average flexural strength for the second and third beam groups is 20.85 and 22.19 MPa. The flexural strength of the first case beam group is greater when compared to the flexural strength of the second and third beam groups, although the difference between the two conditions is not so significant.

Flexural strength in the first case beam group with code BRB-4-60-1 has the greatest flexural strength compared to the average flexural strength of the two beam groups BRB-4-60-2 and BRB-4-60-3 which is 9.49 %. As for the BRB-4-40-3 beam, the flexural strength is higher than the second group, which is 5.95%. In general, the first beam group (reinforcement length 80 cm) has a retrofit beam flexural strength greater than the flexural strength of the existing beam, although the difference is not so significant.

IV. Conclusion

Based on the results of the research that has been done, the following conclusions can be drawn:

1. The beam with the first loading reaching the peak condition is repaired with a reinforcement length variation of 80 cm can provide an increase in the flexural capacity of 9.49%. The second group of beams with loading reaching the peak condition was repaired with a reinforcement length of 60 cm capable of increasing the flexural capacity by 5.95%. While the third beam group is able to increase the flexural capacity by 10.59% to the existing beam.
2. Beams with a length development of 80 cm have the highest value of flexural capacity when compared to beams with a length of 60 and 40 cm, namely 3.75% and 13.54%, respectively. Beams with a distribution length of 60 cm have a value of flexural capacity higher than the flexural capacity of beams with a distribution length of 40 cm with a difference of 9.44%. From the results above, it can be concluded that the longer distribution of bamboo reinforcement will increase the flexural capacity of the beam using the concrete jacketing method.
3. The beam crack pattern after retrofitting is almost similar to the existing crack beam pattern. The difference between crack patterns in existing beams and retrofit beams is the displacement of the main flexural cracks where the main cracks in the existing beam occur in the center of the beam span and the main flexural cracks on the retrofit beams occur in the part of the beam which is de-bonding between the old concrete and mortar.

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