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Effect of Repairing with Retrofit Method (Concrete Jacketing) Using Bamboo Reinforcement on Flexural Capacity of Reinforced Concrete Beam with Initial Damage Variation

Achmad Rivaldy Rizal[1], Ari Wibowo[2], Indradi Wijatmiko[3], Christin Remayanti N[4]
[1]Structural Engineering Student Department of Civil Engineering, Brawijaya University, Malang, East Java, Indonesia
[2,3,4]Department of Civil Engineering, Brawijaya University, Malang, East Java, Indonesia
Email address: achmadrivaldy[DOT]r[AT]gmail[DOT]com

Abstract**—** *The flexural capacity of the reinforced concrete beam was given initial damage variation and do the retrofit with repair mortar and four bamboo reinforcement with 60 cm of length. The study was conducted at the Laboratory of Structure and Construction Materials, Brawijaya University, Malang, Indonesia. Existing reinforced concrete beams with dimensions of 15 x 20 x 100 cm using 2D13 for compressive and tensile bars and stirrup bars Ø10-100. In the retrofit process, the height of reinforced concrete beams increased to 23 cm and use four bamboo reinforcements with dimensions 10 mm x 10 mm. Reinforced concrete beams were tested for flexural in initial and after loading retrofitting with three-point loaded. From the research conducted, it can be found that the beam with low initial damage has a large flexural capacity comparing to the beam with high initial damage.*

Keyword**—***Initial damage variation, bamboo reinforcement, retrofit method, concrete jacketing, flexural capacity*.

I. INTRODUCTION

The failure of the beam structure is caused by corrosion on the steel reinforcement, overloaded conditions, poor of construction methods, age of construction which causes the concrete experiences fatigue, until due to earthquake loads which occur suddenly. The level of damage that occurs in the reinforced concrete beams is varied. Damage occurs can be in conditions where the beam reaches the first crack, the tensile reinforcement reaches yield, the beam reaches the peak load and the beam reaches failure. This depends on the amount of the load that acting on reinforced concrete beams. The collapse that occurs in the beam is not expected to occur in the building structure. However, if that happens, then there must be further treatment.

There are many methods have been carried out to provide strengthening for the structures damaged by using internal reinforcement, external reinforcement, and strengthening by adding other elements. This study is using the retrofitting method (concrete jacketing). The choice of this method is based on the level of damage of the structure, the kind of structural element, the cost and the impact on the environment. This is done to increase the strength and age of the structure.

The reinforced concrete beams with repairs using concrete jackets and steel reinforcement with initial damage that high initial damage has a smaller increase peak load when compared to low initial damage (Soliman and Bashandy, 2013). Then the beam with repairs using CFRP also results that reinforced concrete beams with high damage give a smaller increase in peak load comparing to low damage (Morsy, 2015). In another study conducted by (Akbar, 2018) found that retrofit made by the addition of 700 mm and 400 mm staple steel reinforcement in the reinforced concrete beams has increased capacities respectively between 22-32% and 4-8%. It has obtained the beams with low initial damage provide a greater increase in peak load comparing to high initial damage.

The reinforced concrete beams strengthening by bamboo reinforcement at the bottom can increase the capacity of carrying the load until 65%. Besides that, the reinforced concrete beam with bamboo reinforcement at the bottom and both sides of the beam can increase the capacity to carry the load until 84% (Nahar and Rahmat, 2015). The increasing of carrying load capacity resulting from Nahar and Rahmat's study was very large but did not use bamboo as a repairing. Besides, bamboo as a strengthening in the study was also used along the beam and loaded until the beam failed. According to the author, bamboo reinforcement can be used as the repairing to the reinforced concrete beam which has suffered initial damage and can still be reduced not along the span of the reinforced concrete beam. Therefore, the authors are interested in conducting a retrofit study of the reinforced concrete beam with bamboo reinforcement in the largest moment area in the middle of the reinforced concrete beam span with initial damage variations.

II. EXPERIMENTAL DETAILS

A. Beam Description

Nine reinforced concrete beam specimens with dimensions of 15 x 20 cm and a 100 cm span of length were used in this study. The reinforced concrete beam specimens use 2D13 for compressive and tensile reinforcement. Stirrup used Ø10 with 100 mm of distance (Figure 1). The specimens were divided into three groups namely control beams (BC), yield beams (BL), and peak beams (BP). The repaired beams undergo thickening until 3 cm. The repairing process used a mortar while the repairing reinforcement using four bamboos with

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dimensions of 10 mm x 10 mm and 60 cm of length (Figure 2). The details of grouping specimens are shown in Table 1.

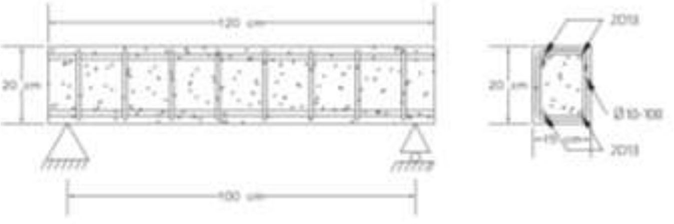

Fig. 1. Detail of the existing reinforced concrete beam specimen

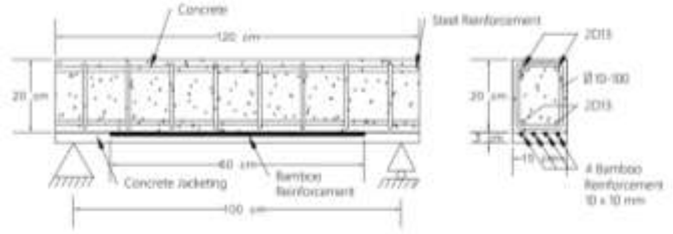

Fig. 2. Detail of retrofit reinforced concrete beam specimen with four bamboo reinforcement

B. *The Variation of Initial Damage*

The variations of initial damage in this test are the beam has reached yield and peak load conditions. The amount of initial loading for each condition given to the specimens is obtained from the analytical calculation of the relationship between moment and curvature (Figure 3). From that calculation, the magnitude of loading for yield and peak load conditions was obtained.

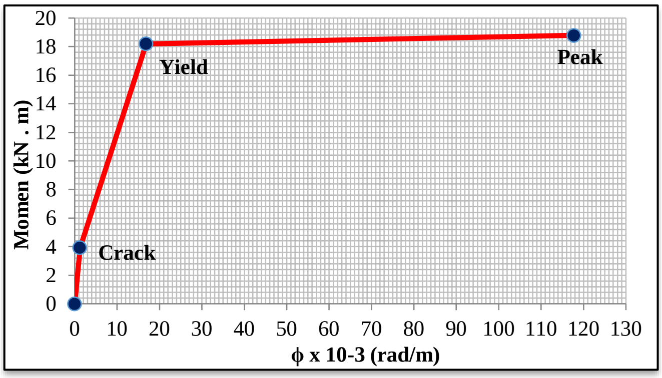

Fig. 3. The moment-curvature relationship of reinforced concrete beam specimen for determining the initial loading

C. *Material Properties*

The average compressive strength of concrete was obtained from the testing of cylinders with 150 mm of diameter and 300 mm of height was 26.63 MPa. The average compressive strength of the mortar obtained from the test cube size of 50 x 50 x 50 mm was 32.48 MPa. Tensile strength of 10 mm and 13 mm diameter reinforcements were 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 treatment with layering by Sikadur 31 CF Normal and sand. The tensile strength of bamboo reinforcement was 221.73 MPa.

D. *Setup of Test*

The test is carried out into two stages, namely first loading on the existing beam and second loading on the retrofitted beam. All types of reinforced concrete beam specimens were tested with three-point bending with a span distance of 1.0 m. The testing process of beam specimens is carried out in the loading frame. For load reading used a load cell while deflection reading used an LVDT. Both of them were placed in the center of the beam specimen spans (Fig. 4).

Fig. 4. Setting up frame load

III. THE RESULT OF TEST

The second loading on the group of reinforced concrete beam specimens with initial damage variations after repairing (retrofit) process was carried out until it collapsed and showed the magnitude of deflection occurred. In this case, an observation of the ability of reinforced concrete beam specimens was carried out after retrofitting with mortar and bamboo reinforcement. The data has obtained is the maximum load on repaired specimen, deflection, and ductility.

The peak load of the first case beam group (initial loading reaches the yield load) compared to the peak load average of control beam group because in the first case beam group, the researchers only gave initial loading until it reaches the yield load. So, to get the peak load value it must refer to the control beam group. Although it does not fully describe the actual situation in the existing beam of the first case beam group, it is needed to find out how much the increasing or the decreasing occurs in the first case beam group. The second case beam group still compares the flexural capacity between the existing and the retrofit beam.

From the results of retrofit beam testing (Table 2), the first case obtained an increase in yield load as much as 6.42% until 15.38% from the yield load of the existing beam. The peak loads of the R4-60-BL-1 beam increased by 3.63% and the other two beams decreased peak loads up to 15.73% from the peak load average of the control beam. The results of retrofit beam testing in the second case showed a decrease in the yield load as 1.74% until 33.33% from the yield load of the existing beam. For peak loads of R4-60-BP-3 beam increased by

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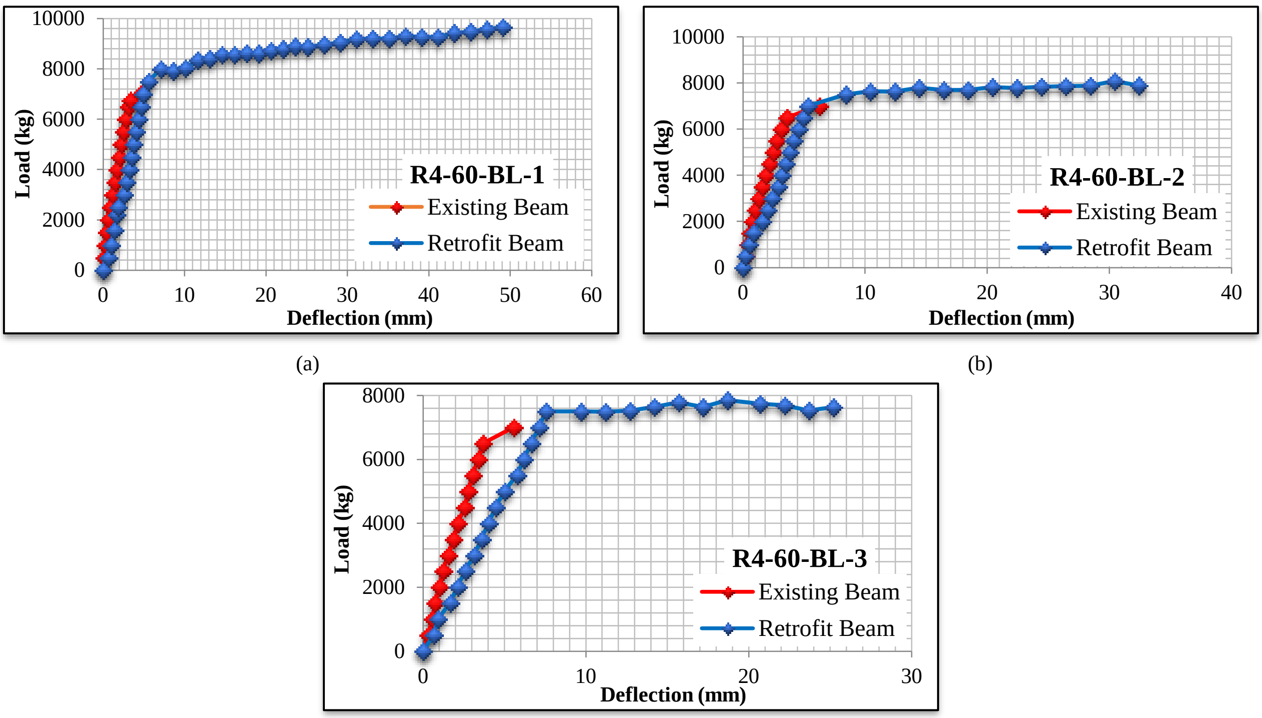
5.95% and the other two beams decreased peak load up to 5.06% from the peak load of existing beam.

TABLE I. Specification of specimen

Specimen		Initial Loading	Dimension (cm)	Repair Reinforcement	Amount of Specimen
Control Beam	BC – 1 BC – 2 BC – 3	Maximum	15 x 20	-	3 Specimen
First Case	R4-60-BL-1 R4-60-BL-2 R4-60-BL-3	Yield Load	15 x 23	Four bamboo reinforcement with length of 60 cm	3 Specimen
Second Case	R4-60-BP-1 R4-60-BP-2 R4-60-BP-3	Peak Load	15 x 23	Four bamboo reinforcement with length of 60 cm	3 Specimen

TABLE II. Load and deflection of retrofit beams with four bamboo reinforcement with initial damage variations

Specimen		Existing Beam (kg)		Retrofit Beam (kg)		Percentage of Retrofit Beam Load to Existing Beam Load (%)		Deflection at Retrofit Beam (mm)	
		Yield Load	Peak Load	Yield Load	Peak Load	Yield Load	Peak Load	Yield	Peak
Control Beam	BC 1	6883,5	9178	-	-	-	-	-	-
	BC 2	7192,5	9590 9319	-	-	-	-	-	-
	BC 3	6891,8	9189	-	-	-	-	-	-
First Case	R4-60-BL-1	6750	-	7183,5	9657	106,42	103,63	5,17	49,09
	R4-60-BL-2	6500	-	7000	8081	107,69	86,72	5,32	30,41
	R4-60-BL-3	6500	-	7500	7853	115,38	84,27	7,55	18,69
Second Case	R4-60-BP-1	6500	8970	6387	8516	98,26	94,94	12,38	33,01
	R4-60-BP-2	6000	8298	4000	8288	66,67	99,88	3,83	39,60
	R4-60-BP-3	6000	8248	5000	8739	83,33	105,95	7,42	47,25



(c)

Fig. 5. Curve of the relationship between the load and deflection of retrofit beams with initial loading reaching the yield load: (a) R4-60-BL-1, (b) R4-60-BL-2 and (c) R4-60- BL-3

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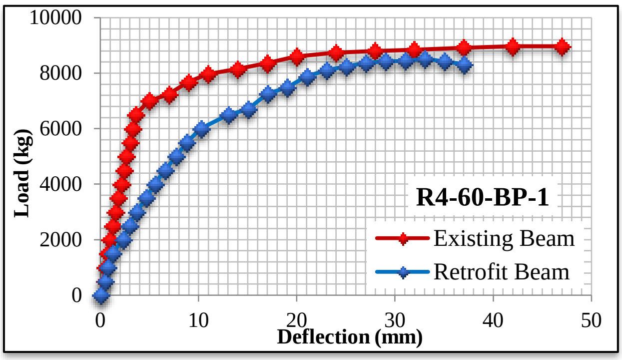
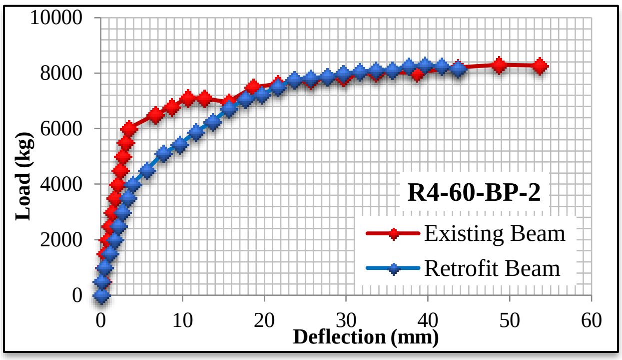


(a)



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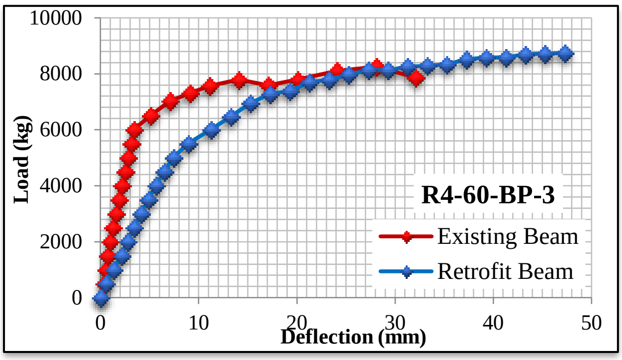

(c)

Fig. 6. Curve of the relationship between the load and deflection of retrofit beams with initial loading reaching the peak load: (a) R4-60-BP-1, (b) R4-60-BP-2 and (c) R4-60- BP-3

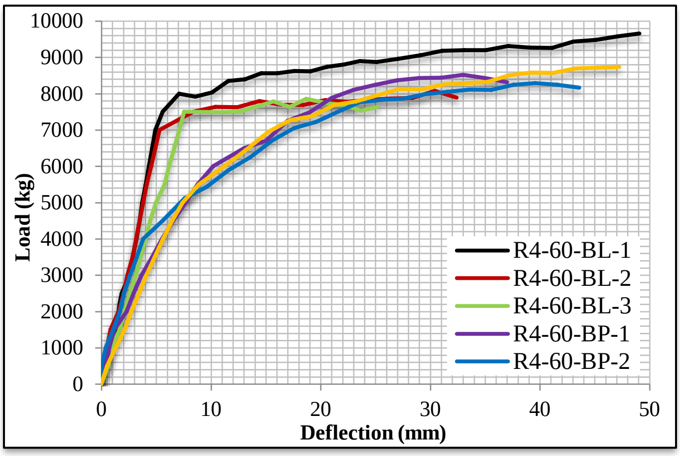

Fig. 7. Combined load and deflection curve of retrofit beams with initial damage variations

TABLE III. Flexural strength, stiffness and ductility of retrofit beams with initial damage variations

Specimen		Flexural Strength (MPa)		Stiffness (kg/mm)		Ductility	
First Case	**R4-60-BL-1**	23,68	20,91	1391	1233,24	9,50	5,90
	R4-60-BL-2	19,81		1316		5,72	
	R4-60-BL-3	19,25		993		2,48	
Second Case	**R4-60-BP-1**	20,88	20,87	516	744,73	2,67	6,46
	R4-60-BP-2	20,32		1044		10,34	
	R4-60-BP-3	21,43		674		6,37	

From Table 3, it can be seen that the flexural strength of the retrofit beam in the first case is higher than the flexural strength of the retrofit beam in the second case, although the difference is not too significant that 0.19%. The stiffness of the retrofit beam of the first case is higher than the second case with a difference as much as 65.60%. For ductility, the retrofit beam of the second case has a greater ductility than the first case with a difference until 9.49%.

IV. CONCLUSION

Based on the results of the research, the following conclusions can be drawn:

1. Beams with initial damage which reached the yield load, given repair with four bamboo reinforcement of 60 cm length have the flexural capacity as much as -15.73% to 3.63% from the control beam flexural capacity. While beams with initial damage reached the peak load, given repair with four bamboo reinforcement with length 60 cm have flexural capacity by -5.06% to 5.95% from the existing beams flexural capacity.
2. The first case beam group (initial damage which reached the yield load given repair with four bamboo reinforcement of length 60 cm) has a higher yield and peak load than the second case beam group (initial damage reaching the peak load given repair with four long bamboo reinforcement 60 cm) respectively 40.90% and 0.19%.
3. The first case beam group has greater flexural strength and stiffness than the second case beam group with a difference of 0.19% and 65.60%, respectively. For ductility, the first case beam group is lower than the second case group with a difference of 9.49%.

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