Stiffness of Reinforced Concrete Beams after Retrofit with External Steel Reinforcement Method

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Abstract - *How many inovations to retrofitting of building structures are important topics. Failure in structures such as beams dan columns due to time, refunctions of a building, even initial design errors that are weak or lack the safety factor of a building structure. External reinforced concrete beams are one of the beams currently being developed, concrete blocks with reinforcement of steel reinforcement on the outer (external) of beam. This study aims to determine the stiffness of RC beams before and after retrofit with external stell reinforcement, dimension of beams 15 x 15 x 100 cm repeat 12 pcs, with external reinforcement each 6 pcs 2Ø6 and 3Ø6. The results from this research are stiffness pre-crack and after crack. Where beams pre-crack in term of load P = 1000 kg, have an average decrease stiffness of 31.11%, 28.32%, 0.58%, and increase stiffness 17.09%. And after crack in term of load P = 3000 kg, have an average increase stiffness of 1.8%, 2.8%, while increase significant until 41.88% and 59.72%.*

Key Words: retrofit, external steel reinforcement, stiffness, pre-crack, after crack,

1.INTRODUCTION

Reinforced concrete is a combination of concrete and reinforcing steel which functions as reinforcement in fibers/ tensile parts which are not owned by concrete. One of the structural elements in the building is concrete blocks [4]. Concrete beams as structural elements are designed to hold loads perpendicular to the axis [4]. Increasing the strength of building structures has become an important topic lately. Transfer of functions of a building, failure of structures such as beams and columns due to time serviceability, environment that affects the decrease in structural strength and even initial design errors that are weak or lacking or disaster such as earthquakes. In the research of Suhad Susanto, et al. "External Reinforced Concrete Beams" where Steel Lips Channel is used as reinforcement. The results showed that after being strengthened with steel Lips Channel there was an increase in strength.

Kothandaraman et al (In Zhang., 2012) "Flexural Retrofitting of RC Beams Using External Bars at Soffit Level-An Experimental Study". The method of retrofitting RC beams with external reinforcement at the soffit level. This retrofit method is cost effective, and easy to apply. All specimens are under two-point loading until they collapse. Middle-range and quarter deflections are shown in Figure 2.2 and the tests are presented in Table 2.1. The results showed that external reinforcement retrofitting at the soffit level in this way significantly reduced crack width, deflection, and increased moment capacity compared to without retrofit. [1]

Alanwar, A and Elbatal (2015) "A Smart Reinforced Steel Wire Mesh U-Shape Jacketing Technique in Strengthening and Retrofitting RC Beams". This method uses external steel reinforcement for reinforcement and is covered with U-shaped wiremesh. The difference in the number of variations of external steel reinforcement is used in the repair method. The results show that the reinforcement method significantly increases the flexural and shear strength and performance of reinforced concrete beams. With the addition of variations in the number of reinforcement from 2Ø8 to 5Ø8, it shows the results of increasing load carrying capacity from 108% to 136%. [2]

Hamza Salim Mohammed Al Saadi, et al (2017) Research "An Experimental Study on Strengthening of Reinforced Concrete Flexural Members using Steel Wire Mesh". In this method, wiremesh is used to increase the flexural capacity of the beam, but the installation of wiremesh is only on the flexible side, so that when a lot of testing is done shear crack occurs. [3]

n this research case is retrofit with external steel reoinforcement method and add confinement external reinforcement to hold the shear strength of beam.

2. EXPERIMENTAL PROCEDURES

2.1 Test Specimen

The specimens for reinforced concrete beams dimension of 15 x 15 x 100 cm, while the beam of the specimen after retrofitting remains with a size of 15 x 15 x 100 add external steel reinforcement at the bottom and sides of the beam, with cross section right-left 6 pieces of confinement. The following is the detail of the test object to be made in the study, namely as follows:

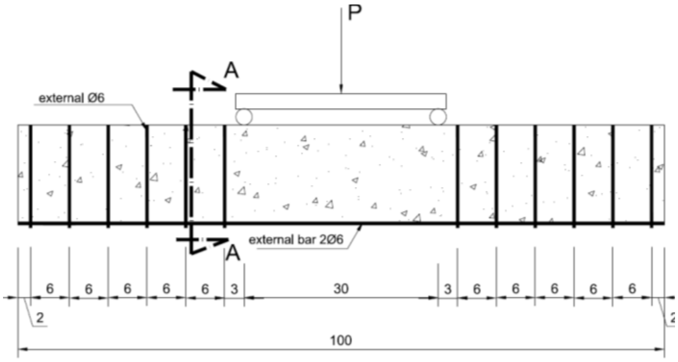

Fig -1: Specimen of beams with external bar 2Ø6

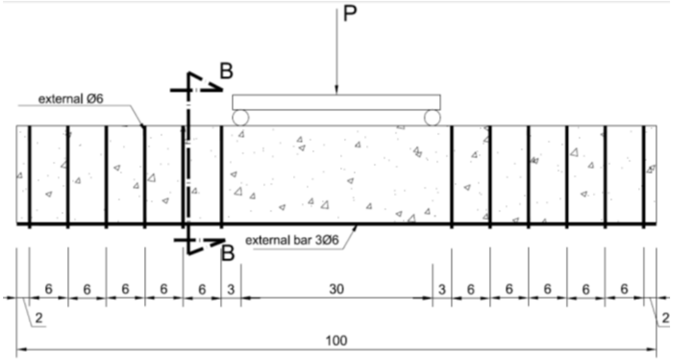

Fig -2: Specimen of beams with external bar 3Ø6

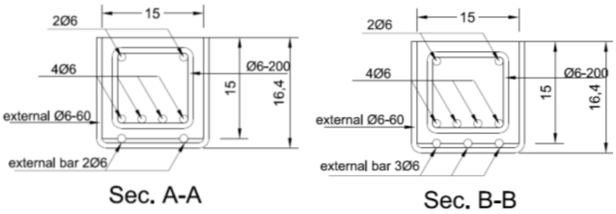

Fig -3: Section of specimen

Table -1: Quantity and Variation of Beams Specimen

A (Beams, dimension 15 x 15 x 100 cm before retrofit)			
No	**Code**	**Annotation**	**Q**
1	**A1B1C2D1**	Beams (4Ø6, confinement Ø6-200)	3 pcs
2	**A1B1C2D1 (FA)**	Beams + fly ash 20% (4Ø6, confinement Ø6-200)	3 pcs
3	**A3B1C2D1**	Beams with slag cement 40% (4Ø6, confinement Ø6-200)	3 pcs
4	**A3B1C2D1 (FA)**	Beams with slag cement 40% + fly ash 20% (4Ø6, confinement Ø6-200)	3 pcs
B (Beams, dimension 15 x 15 x 100 cm after retrofit)			
1	**B1**	Beams with add external reinforcement bar and external confinement (2Ø6, confinement Ø6-60)	6 pcs
2	**B2**	Beams with add external reinforcement bar and external confinement (3Ø6, confinement Ø6-60)	6 pcs

2.2 Procedures

Beams specimen were repaired after loading up to failure (Fig.4), the reinforced surface of the beam was cleaned, and prepared before the installation of external steel reinforcement, in the following order:

1. Provide all necessary materials and equipment; Upholding the position of the beam which slides to the zero deflection position;
2. Flatten the surface of the beam to be reinforced with external steel reinforcement and clean it from any dirt that might reduce;
3. Ensure that the concrete surface is dry so that the sika grout adheres well;
4. Preparing to make formwork for grouting;
5. Grouting or do all parts of the beam that have been damaged, for damage to the concrete that is wide enough to need to be given coarse aggregate in the mixture.
6. Keep the entire surface of the damaged concrete block closed properly, and do curing for approximately 72 hours.
7. Prepare a mixture of adhesive materials between external steel reinforcement and concrete that has been repaired, which uses sikadur adhesive.
8. Add grid hole on the concrete surface as the base for placing external steel reinforcement. Both longitudinal and vertical directions.
9. Apply sikadur adhesive on the surface of the beam to be installed with external steel reinforcement.
10. Attach steel reinforcement reinforcement material longitudinally to the beam and reinforced again with external stirrup reinforcement as a sliding barrier.
11. After the external steel reinforcement is installed, then testing is continued.

The graph of the beams after retrofit can be shown in Figure 5 and Figure 6 below.

Fig -4: The condition of flexural beam testing after loading up to failure

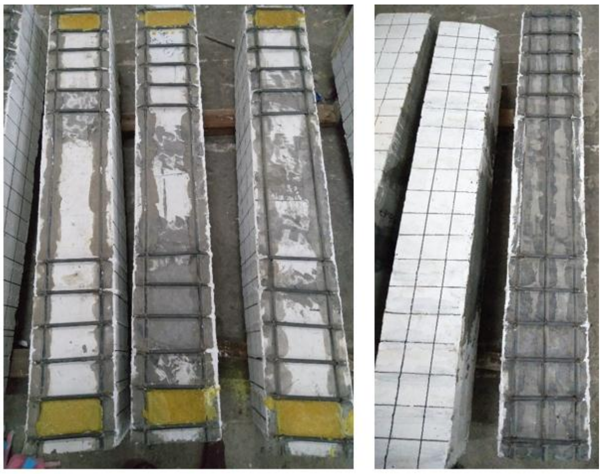

Fig -5: Beams after retrofit with external steel reinforcement method (left 2Ø6, right 3Ø6)

Fig -6: Beams after retrofit with external steel confinement Ø6-60

2.3 Test Setup

Tests are carried out on a frame made of steel profiles designed with simple placement (roller joints) to test the flexural strength of the beam with a span length of 100 cm and a rectangular cross section with dimensions of 15 cm x 15 cm with a planned maximum load of 7 tons (Fig. 7) and 3d view setting up (Fig. 8).

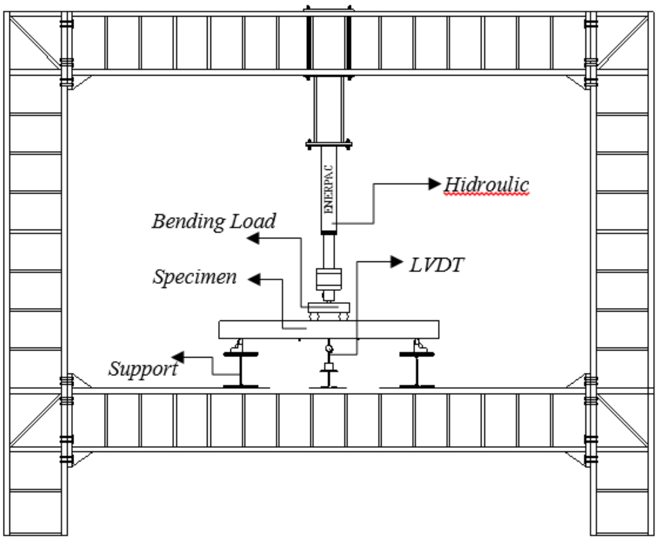

Fig -7: Flexural beam testing scheme on loading frame

Fig -8: 3D View Setting up on loading frame

3. RESULTS AND DISCUSSIONS

3.1 Stiffness

The load graph and deflection in the middle of the span from the experimental results above show flexural stiffness of the cross section. Stiffness is formulated with P/Δ. According to Ujianto, 2006 (in Handika, 2016) stating beam stiffness can be seen from the slope of the load relationship curve and beam deflection. The steeper the slope of the curve, the more rigid the beam is, or vice versa.

3.2 Stiffness Pre-Crack

The results obtained flexural stiffness for pre-crack conditions, in terms of load P = 1000 kg, can be seen in table 2 below.

Table -2: Beam Stiffness in Pre-crack conditions

NO	CODE	Load (P) (kg)	Δ (mm)	Stiffness (kg/mm) K = (P/Δ)	Average
1	A1B1C2D1 (1)	1000	0,85	1176,47	1188,63
2	A1B1C2D1 (2)	1000	0,89	1123,60	
3	A1B1C2D1 (3)	1000	0,79	1265,82	
4	B1 (1)	1000	1,21	829,88	818,79
5	B1 (2)	1000	1,26	791,77	
6	B1 (3)	1000	1,20	834,72	
7	A3B1C2D1 (1)	1000	0,6	1666,67	1463,64
8	A3B1C2D1 (2)	1000	0,71	1408,45	
9	A3B1C2D1 (3)	1000	0,76	1315,79	
10	B2 (1)	1000	0,995	1005,03	1049,11
11	B2 (2)	1000	1,07	934,58	
12	B2 (3)	1000	0,828	1207,73	
13	A1B1C2D1 FA(1)	1000	1,11	900,90	847,15
14	A1B1C2D1 FA(2)	1000	1,14	877,19	
15	A1B1C2D1 FA(3)	1000	1,31	763,36	
16	B1 (4)	1000	1,464	683,06	842,22
17	B1 (5)	1000	1,24	808,41	
18	B1 (6)	1000	0,966	1035,20	
19	A3B1C2D1 FA(1)	1000	2,62	381,68	764,30
20	A3B1C2D1 FA(2)	1000	0,96	1041,67	
21	A3B1C2D1 FA(3)	1000	1,15	869,57	
22	B2 (4)	1000	1,081	925,07	921,80
23	B2 (5)	1000	1,16	862,81	
24	B2 (6)	1000	1,02	977,52	

The graph of the average stiffness value of each variation in table 2 can be shown in Figure 9 below.

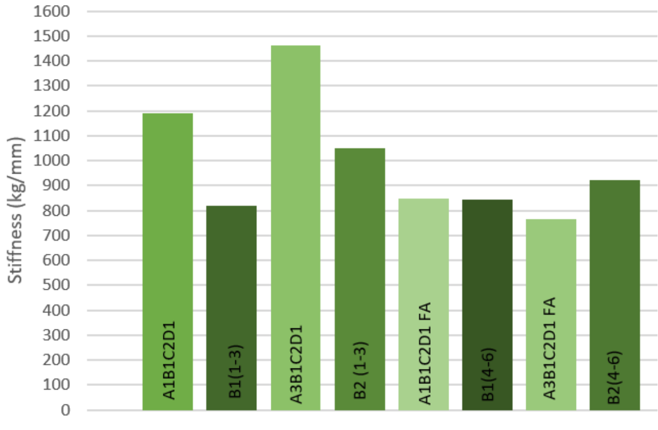

Fig -9: Comparison of Beam Average Stiffness in Pre-crack Conditions for Each Variation (Before and After Retrofit)

From Figure 6 above, it can be seen that there is a decrease in stiffness when compared between beams before and after retrofitting using external steel reinforcement which is between beams (A1B1C2D1) and beams (B1 1-3) of 31.11%, beams (A3B1C2D1) and beams (B2 1-3) of 28.32%, beam (A1B1C2D1 FA) and beam (B1 4-6) of 0.58%, and vice versa began to increase the stiffness of the beam (A3B1C2D1 FA) and beam (B2 4-6) amounting to 17.09%. Before cracking, the role is concrete, so after retrofitting we cannot ascertain the condition of the micro crack filling grouting beam that occurs after testing. So the stiffness of the beam after retrofitting will definitely decrease.

3.3 Stiffness After Crack

The results obtained flexural stiffness for after crack conditions, in terms of load P = 3000 kg, can be seen in table 3 below.

Table -3: Beam Stiffness in After crack conditions

NO	CODE	Load (P) (kg)	Δ (mm)	Stiffness (kg/mm) K = (P/Δ)	Average
1	A1B1C2D1 (1)	3000	3,27	917,43	846,57
2	A1B1C2D1 (2)	3000	3,86	777,20	
3	A1B1C2D1 (3)	3000	3,55	845,07	

4	B1 (1)	3000	3,33	900,63	861,80
5	B1 (2)	3000	3,79	792,18	
6	B1 (3)	3000	3,36	892,59	
7	A3B1C2D1 (1)	3000	2,68	1119,40	1057,24
8	A3B1C2D1 (2)	3000	3,16	949,37	
9	A3B1C2D1 (3)	3000	2,72	1102,94	
10	B2 (1)	3000	2,553	1175,09	1086,85
11	B2 (2)	3000	3,89	771,41	
12	B2 (3)	3000	2,283	1314,06	
13	A1B1C2D1 FA(1)	3000	3,52	852,27	728,26
14	A1B1C2D1 FA(2)	3000	4,33	692,84	
15	A1B1C2D1 FA(3)	3000	4,69	639,66	
16	B1 (4)	3000	3,497	857,88	1033,24
17	B1 (5)	3000	3,18	943,69	
18	B1 (6)	3000	2,311	1298,14	
19	A3B1C2D1 FA(1)	3000	5,58	537,63	690,59
20	A3B1C2D1 FA(2)	3000	4,04	742,57	
21	A3B1C2D1 FA(3)	3000	3,79	791,56	
22	B2 (4)	3000	2,697	1112,35	1103,01
23	B2 (5)	3000	2,91	1031,64	
24	B2 (6)	3000	2,58	1165,05	

The graph of the average stiffness value of each variation in table 3 can be shown in Figure 7 below.

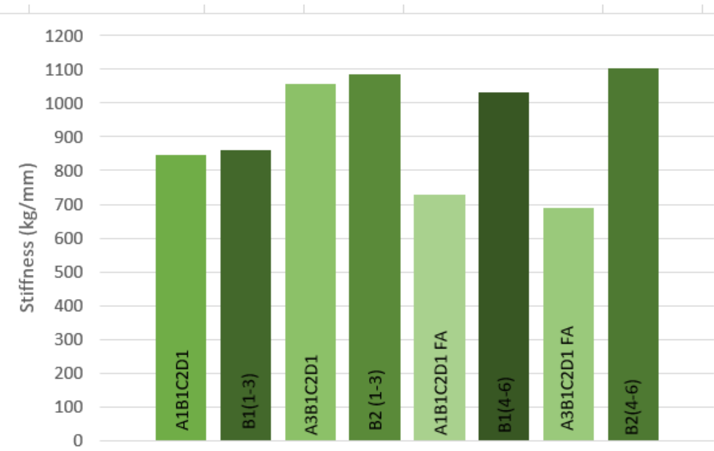

Fig -10: Comparison of Beam Average Stiffness in After crack Conditions for Each Variation (Before and After Retrofit)

From Figure 10 above, it can be seen that there is an increase in stiffness when compared between beams before and after retrofitting using external steel reinforcement which is between beams (A1B1C2D1) and beams (B1 1-3) of 1.8%, beam (A3B1C2D1) and beams (B2 1-3) of 2.8%, beam (A1B1C2D1 FA) and beam (B1 4-6) of 41.88%, and significant increase in stiffness of beam (A3B1C2D1 FA) and beam (B2 4-6) of 59.72%.

From the results above, it can be analyzed that retrofit using external steel reinforcement also affect the increase in stiffness of post-beam beam compared to the beam before retrofit are carried out. because after a crack, the one that holds the load is reinforcement. So that the addition of external reinforcement can increase the stiffness of the beam after cracking,

4. CONCLUSIONS

- The stiffness of the beam after retrofit with the external steel reinforcement method has increased after cracks in the beam
- For external confinement installations also need to be considered, to avoid the shear failure of the beam.

REFERENCES

[1] Zhang, Y. 2012. Repair and Strengthening of Reinforced Concrete Beams. Thesis: The Ohio State University M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[2] Alanwar A. and Elbatal S. 2015. A Smart Reinforced Steel Wire Mesh U-Shape Jacketing Technique in Strengthening and Retrofitting RC Beams. Kairo IJERT. ISSN: 2278-0181, Vol.4 Issue 12, December 2015.

[3] Al Saadi, H .S .M., Hoby P. Mohandas., and Aravind Namasivayam. 2017. An Experimental Study on Strengthing of Reinforced Concrete Flexural Members using Steel Wire Mesh. Muscat, Oman: Curved and layer Struct. 2017; 4;31-37

[4] Susanto, S. dan Widjaya, A. Without Years. Balok Beton Bertulangan Eksternal. Surabaya State University.

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