International Journal of Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: 10.31695/IJASRE.2022.8.4.4

Volume 8, Issue 4
April - 2022

Study of Structural Analysis of Damaged Concrete Beams Strenghted with Carbon Fiber Reinforced Polymer

Marsudi, Dianita Ratna Kusumastuti, Nursetiaji Pamungkas, Dedi Budi Setiawan, Primasiwi Harprastanti, and Marton

Engineering Program Maintenance and Repair Building

Civil Engineering Departement

State Polytechnic of Semarang

Indonesia

ABSTRACT

It is necessary to repair the cracks in the concrete structure to prevent further damage that can lead to the collapse of the structure. Repairs can restore and increase the strength of structural elements so that they are able to withstand the load in accordance with the design load, finally further decisions can be made for the next function. The results of the flexural strength test of K-150 collapsed concrete beams 100% able to withstand a load of 58 kN, K-250 collapsed 100% able to withstand a load of 64.33 kN, K-150 coated with CRFP tensile part collapsed 100% able to withstand a load of 82 kN, K -250 is coated with CRFP, the tensile part collapses 100% able to withstand a load of 91.67 kN, the quality of K-250 collapses 60% is able to withstand a load of 39.17 kN. K-250 strength concrete beam collapsed 60% maximum CRFP repair able to withstand a load of 87.67 kN. For testing of concrete beams with f'c quality of 20.71 MPa, 100% collapse with a maximum average of 29.00 MPa. The flexural strength of the concrete beam with f'c quality is 20.71 MPa, 60% collapse with an average load of 19.00 MPa. For the flexural strength of the f'c 20.71 MPa concrete beam, improvements were made to be able to withstand an average load of 52.86 MPa. Analysis of the test results by increasing the area and CRFP can increase the bearing capacity of concrete blocks. If in a construction work there is a doubt from the user about the portal being built, then CRFP can increase its flexural strength.

Keywords: *CRFP, Flexural Strength, Concrete Quality.*

1. INTRODUCTION

Reinforced concrete has problems that can reduce its advantages. Among the problems that are often encountered is the problem of cracks. If the cracks in the structure are not immediately addressed, it is very likely that the structure will collapse. Structural collapse under these conditions is very dangerous because it can occur suddenly with little or no warning. According to Mangkoesoebroto (1998), cracks are cracks in concrete in relatively long and narrow lines. It is necessary to repair the cracks in the concrete structure to prevent further damage that can lead to the collapse of the structure. In addition, it is expected to be able to restore or increase the strength of structural elements so that they are able to withstand the load in accordance with the design load. With the current technology, structural crack repair can be done by various methods. One method of repairing structural cracks is by injection of epoxy resin. This injection method is a way to improve concrete by filling gaps or voids with concrete filler material that does not have the characteristics of shrinking when injected using a pressurized machine..

Epoxy resin injection method for repair of reinforced concrete beams is assumed to affect the flexural shear strength of reinforced concrete beams. Based on research conducted by Erick, Dalmantias (2015) Experimental Study of Retrofitting Reinforced Concrete Beams Using the Injection Method, it is concluded that repairing I - 2 damage (cracks) of reinforced concrete beams with the injection method with failures reaching 30% and 60% of the maximum load, can restore the flexural strength of the beam is the same as before fracture.

Research related to the epoxy resin injection method needs to be reviewed to determine its effect on increasing the flexural strength of reinforced concrete beams. Therefore, in this study an experimental study was carried out to repair reinforced concrete beams engineered to overload with a load of 60%, and the application of Carbon Fiber Reinforced Polymer Type Cf 230 in a circular manner to Application Beams to Repair Collapsed Beam Structures at 60% of the maximum load collapse.

2. LITERATUR REVIEW

2.1. Concrete

In general, concrete contains cement paste (cement and water) 25% - 40%, aggregate (fine and coarse aggregate) 60% - 75% and air 1% - 3%. Concrete can be referred to as artificial stone consisting of a mixture of aggregate, portland cement and water (Kusdiyono, 2011).

The nature of the concrete material is very strong to withstand compression, but not strong (weak) to withstand tension. Therefore, concrete can crack if the load it carries causes a tensile stress that exceeds its tensile strength (Asroni, 2010). The relationship between the compressive and tensile stresses and strains of concrete can be seen in **Figure 1 and Figure 2.**

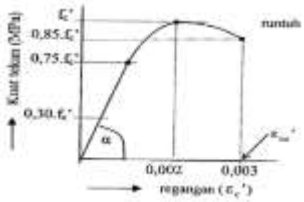


Figure 1 Relationship of Stress with Compressive Strain of Concrete (Asroni, 2010)

Figure 1 shows that when the concrete is about to collapse (concrete compressive strength has reached the peak fc'), the concrete stress drops (to 0.85.fc') while the compressive strain continues to rise until it reaches the crack limit (εcu' = 0.003).

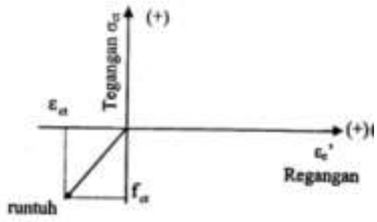


Figure 2 Relationship between Stress and Tensile Strain of Concrete (Asroni, 2010)

2.2. Reinforcing steel

Reinforcement steel is steel in the form of rods used for concrete reinforcement. Compared to concrete, reinforcement is a high-strength material. The reinforcing steel can withstand both tensile and compressive strength, its yield strength is approximately 10 times the compressive strength of a common concrete structure, or one hundred times its tensile strength. On the other hand, steel is an expensive material when compared to concrete (Oscar Fitrah Nur, 2009). The relationship between stress and tensile strain of reinforcing steel can be seen in Figure 3

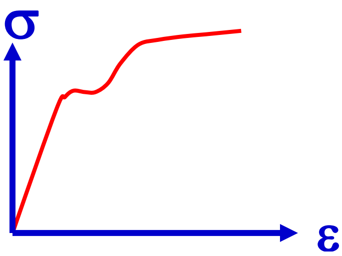


Figure 3 Relationship between Stress and Tensile Strain of Reinforcing Steel (Asroni, 2010)

2.3. Concrete Block

Concrete beams as structural elements that are now encountered, in field applications are elements that have a large enough role in carrying loads, especially for carrying flexural loads (Marsudi and Martono, 2016).

DOI: 10.31695/IJASRE.2022.8.4.4

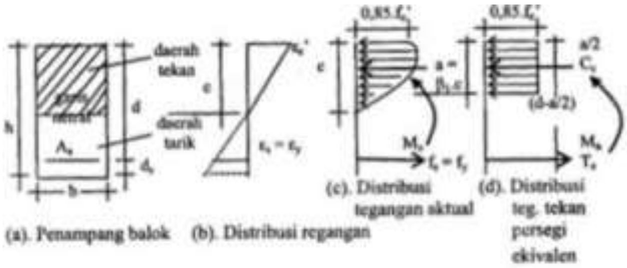


Figure 4 Distribution of Strain and Stress in Single Reinforcement Beams

Due to the nature of the concrete which is not strong in tension, it can be seen in Figure 4 (b) that the part of the beam that resists tension (below the neutral line) will be supported by reinforcement, while the part that resists compression (above the neutral line) is retained by the concrete..

2.4. Compressive Strength of Concrete.

The compressive strength of concrete is the ability of concrete to carry the maximum compressive load per unit area which causes the concrete test object to crumble when loaded with a certain compressive force, which is produced by a press machine. In the theory of concrete technology, it is explained that the compressive strength of concrete is strongly influenced by several factors, such as water-cement factors, density, age of concrete, type of cement, amount of cement and aggregate properties. The higher the water-cement factor, the slower the increase in concrete strength, and the higher the treatment temperature, the faster the increase in concrete strength. The type of cement used affects the rate of increase in the compressive strength of concrete (Arusmalem, 2011). Compressive failure is the failure that occurs due to the crushed concrete first (reaching M) before the steel stress reaches fy'. Or in other words, the concrete crumbles before the steel melts. This compressive failure is also called an "over reinforced" failure (Riza, 2008).

2.5. Bending on Concrete Blocks

In the flexural planning of reinforced concrete beams, the beam cross-section can be designed with less, more, and balanced reinforcement. Theoretically, it is very easy to see the difference between the three types of plans, namely only by limiting the value of the tensile reinforcement ratio to the balanced reinforcement ratio value. But it is very difficult to imagine the form of collapse that occurs from these three types of planning. (Marsudi and Martono, 2016).

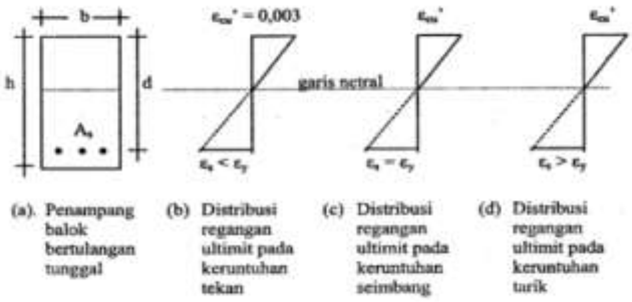


Figure 5 Ultimate Strain Distribution on Flexural Failure (Asroni, 2010)

2.6. Epoxy Resin Injection Method Improvement

Epoxy injection can be used for repair of structural cracks resulting from one-time events such as accidental overloads, vehicle impacts, earthquakes, restrained II – 8 shrinkage or large thermal differences. This method is suitable for horizontal, vertical, and overhead applications in cracks as narrow as 0.002 in, (0.05 mm). Epoxy injection can be used to restore structural integrity and provide resistance to moisture penetration (Tom Murphy, 2015).

Grouting is a repair method and application process for high-pressure injection, namely by inserting a type of grout cement paste material that does not experience shrinkage into gaps / places that are difficult to reach or to repair porous concrete due to poor implementation of concrete casting (Niaga Artha Chemcons, nd).

2.7. Fiber Reinforced Polymer (FRP)

FRP (Fiber Reinforcement Polymer) is a composite material used in civil construction. This material combines resin polymer, filler, and fiber. The resins used are polyester, vinylester or epoxy and the fillers used are kaolin clay, calcium carnonate and

DOI: 10.31695/IJASRE.2022.8.4.4

alumina. While the fiber consists of several types such as glass, carbon, and aramide. Carbon Reinforced Polymer (CFRP) is an advanced application or development of FRP (Fiber Reinforcement Polymer).

This CFRP contains at least 90% carbon by weight. This reinforcement technique is more efficient, does not cause rust like external steel. Durability CFRP is more economical to use in corrosive environments where the steel will rust more easily. (Meier; 1997). FRP itself is produced from Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP), where in several ways it is proven that the use of CFRP is more satisfactory than the use of GFRP. (K. Narmashiri & M.Z. Friday, 2009).

Table 1. Spesification of Masterbrace CF 230

No.	Materials	Specifications
1	Fibre Reinforcement	Carbon - High Modulus
2	Fibre Modulus	230 Gpa
3	FibreAeral Weight (carbon 4fibre only)	300 g/m²
5	Thickness	0.166 mm
6	Ultimate Tensile Strenght	4900 Mpa
7	Ultimate Tensile Elongation 8(Strain)	2,10%
9	Roll Length	100 m
10	Sheet Width	500 mm

2.8. Beam Dimension Planning

Based on the Procedure for Calculation of Concrete Structures for Buildings, SNI 03-2847-2002 (table 8, page 63) with a beam span of 1 m, the dimensions of the beam are planned as follows:

1) Thickness of beam (h) :

$$h \geq \frac{L}{16}$$

$$h \geq \frac{1000\ mm}{16}$$

$$h \geq 62{,}5\ mm$$

Take h = 150 mm.

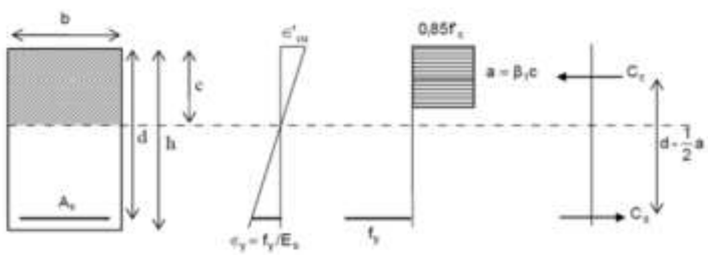
2) Beam width (b)

3) $\frac{1}{2}\text{ h} \leq \text{b} \leq \frac{2}{3}\text{ h}$

$\frac{1}{2}\,.150\text{ mm} \leq \text{b} \leq \frac{2}{3}\,.150\text{ mm}$

2.9. Reinforcement Planning

The strain diagram is based on $\in'_{cu}$ = 0,3% and tensile stress of steel $\in_y = \frac{f_y}{E_s}$.



(a) (b) (c) (d)

Figure 6. Cross section of the strain and stress diagram in a balanced state

2.10. Bending Strength Requirements

According to the Procedure for Calculation of Concrete Structures for Buildings, SNI 03-2847-2002, the flexural strength requirements are:

M_n≥ M_u .... (1)

DOI: 10.31695/IJASRE.2022.8.4.4

where for pure bending is 0.8.
The above requirements can also be written down
$M_u \leq M_n$.. (2)
With the planning requirements $M_u \leq M_n$, the analysis and design problems of single reinforced concrete flexural beams can be solved.

2.11. Types of Flexural Failure based on Reinforcement Ratio

According to the Procedure for Calculation of Concrete Structures for Buildings, SNI 03-2847-2002, in planning for flexural reinforced concrete beams, there are three types of failure that can occur, namely tensile failure, balanced failure and compression failure. Pull Collapse, Balanced Collapse, CollapsePress

1.12. Test Object Model

The test object is modeled as a simple beam with two supports with a concentrated load in the middle of the span as shown in Figure 3. The test object is designed against a beam experiencing tensile failure.

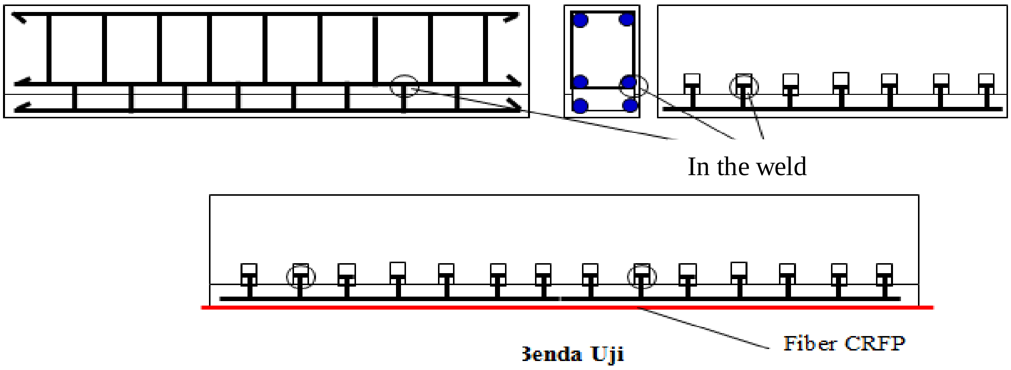


Figure 7. Test Object

3. Research Method

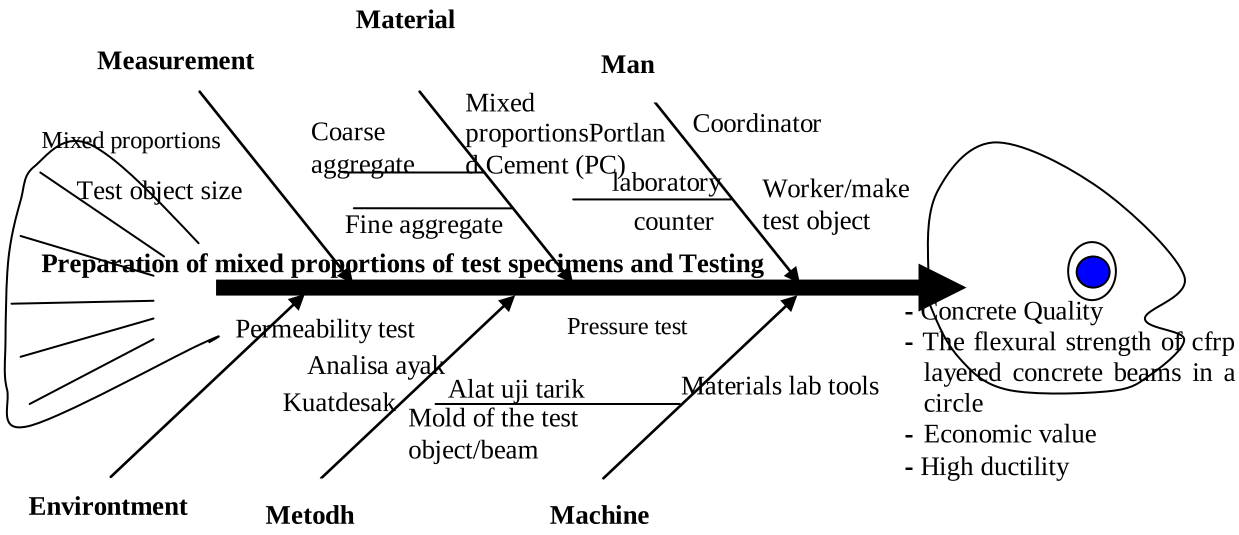


Figure 8 Fisbon Diagram

4. RESULTS AND DISCUSSION

The quality of the design concrete used with K-254,33 kg/cm^2

$$\frac{f'c}{K} = \frac{0,83}{1,00}$$

DOI: 10.31695/IJASRE.2022.8.4.4

$$f'c = \frac{0,83}{1,00} xK$$

$$f'c = \frac{0,83}{1,00} x254,33$$

F'c = 20,71 M.Pa

With assumption 1 kg/cm^2 = 0,00981 Mpa

4.1. Concrete Mix Planning

The concrete mix is planned in such a way based on the standards that have been set to get the composition of the components (elements) of wet concrete with the provisions of the characteristic compressive strength and slump of the plan. In this study used concrete quality f'c 20.71 Mpa

4.2. Begesting

Begesting is made according to the modeling of the test object, namely beam dimensions of 150 mm x 200 mm with a beam span of 65 cm. This dimension is taken according to the availability of begesting in the laboratory.
The slump test is used to determine the ease of pouring concrete (workability). Before the concrete is cast into the test object, a slump test is carried out, the results of which show that in the casting process it is not difficult to pour.

.

Figure 9. Slump Test.

In this study, the slump value was obtained by calculating the average distance between the compaction level and the test object at three different points. The slump data in this test are as follows:
- Point 1: 7.7 cm
- Point 2: 13 cm
- Point 3: 10 cm

So that the slump value in fresh concrete for this study can be calculated as follows:

$$slump = \frac{7,7 + 13 + 10}{3}$$

Slump + 10,233 cm

4.3. Making of Beam Test Items

After the test specimen mixture is prepared, the concrete mixture is poured into the prepared beam molds. The first 1/3 part of the mixture is poured, then pricked so that there is no separation of aggregates (segregation). Then pour another 1/3 of the second part and pierce. Then poured the last 1/3 of the part and pricked. Then the surface of the block is leveled

4.4. Strong Press

Based on JMF d by Supriyadi, Kusdiyono and Hery Ludiro in the Wahana Civil Engineering Journal Vol. 11, N0. 3 Pg. 123 for the proportion of the concrete mixture used, the quality of f'c is 20.71 MPa.

4.5. Tensile Strength Test Results

Based on the specimens that were carried out tensile tests, the following results were obtained: Tensile tests were carried out at the Metallurgical Laboratory, Department of Mechanical Engineering, Semarang State Polytechnic.

DOI: 10.31695/IJASRE.2022.8.4.4

Table 2. Tensile Test Results of Test Objects

No.	The Object Type	σ max (kN)
1.	concrete iron ∅ 10 (1)	33,5
2.	concrete iron ∅ 10 (2)	32,0
3	concrete iron ∅ 10 (3)	32,5
	Average	32,67

4.6. Testing of Bending Strength of Concrete Beams

In accordance with the test object beam model, the test carried out is a tensile failure test. The equipment used is the Ele Brand Concrete Compression Test Equipment in the Semarang State Polytechnic Materials laboratory. The beams are arranged according to the modified model, with the top piston rod of the moving press acting as a concentrated load P. The profile iron is used to adjust the test conditions on the modified beam press. In this test, a tensile test was carried out by modifying the compression test equipment. The compressive strength of the test results can be seen in the following table:

a. K-150 quality intact beam flexure test collapses 100%

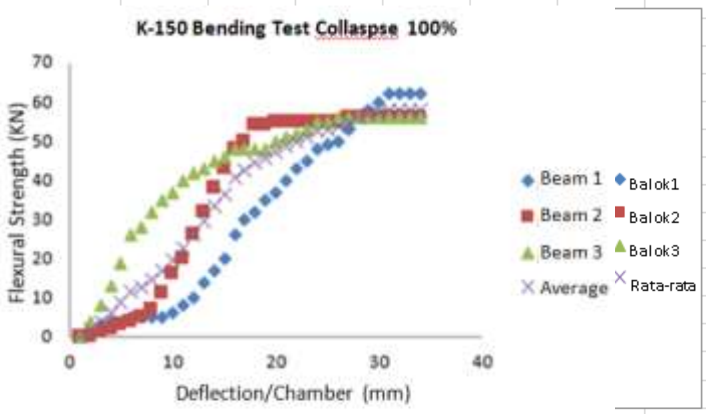


Figure 10. K-150 Bending Test Collapse 100%

b. K-250 quality intact beam bending test collapses 100%

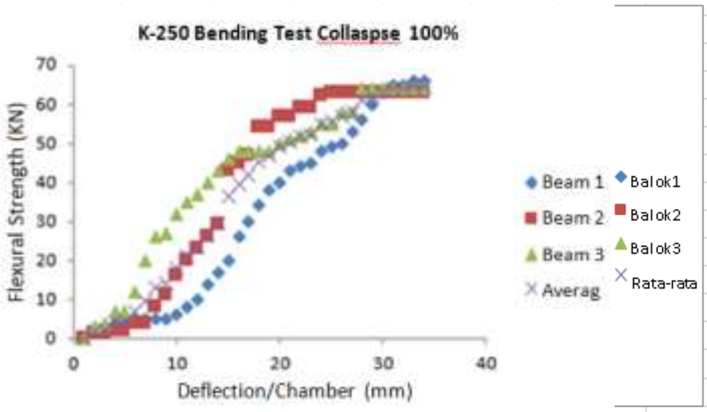


Figure 11. K-250 Bending Test Collapse 100%

DOI: 10.31695/IJASRE.2022.8.4.4

c. K-150 quality intact beam flexure test with the addition of 100% collapsed membrane

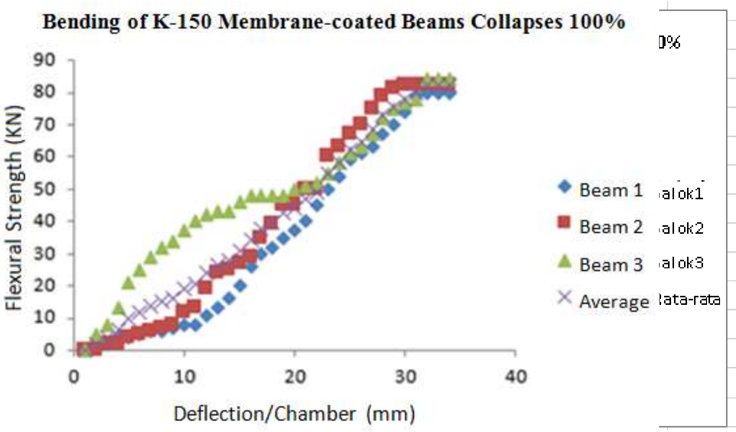


Figure 12. Bending of K-150 Membrane-coated Beams Collapses 100%

d. quality intact beam flexure test with the addition of 100% collapsed membrane

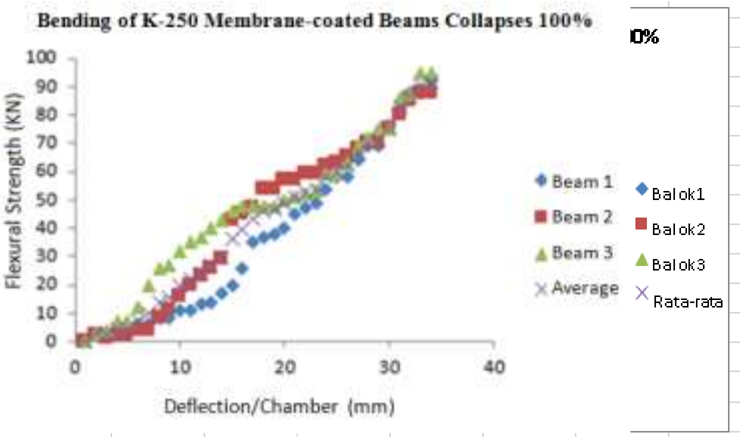


Figure 13. Bending of K-250 Membrane-coated Beams Collapses 100%

e. K-150 strength intact beam flexure test collapses 60%

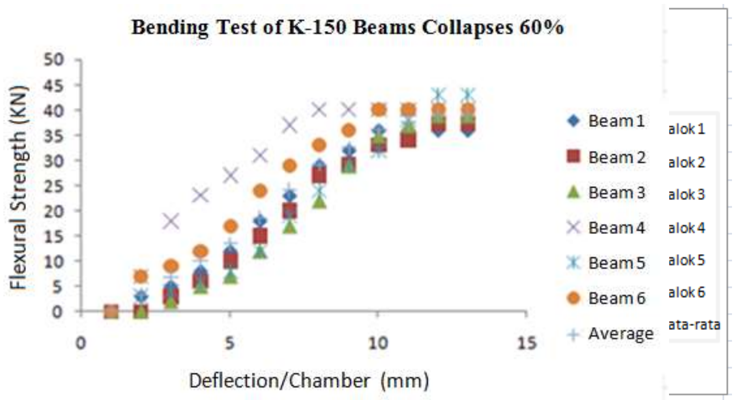


Figure 14. Bending Test of K-150 Beams Collapse 60%

DOI: 10.31695/IJASRE.2022.8.4.4

f. K-250 strength beam flexural test collapse 60% repair membrane collapse 100%

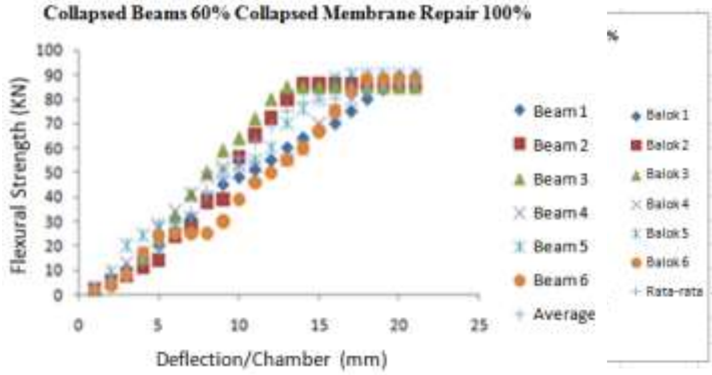


Figure 15. Collapsed Beams 60% Collapsed Membrane Repair 100%

g. K-250 strength beam bending test combined 60% collapse membrane repair 100%

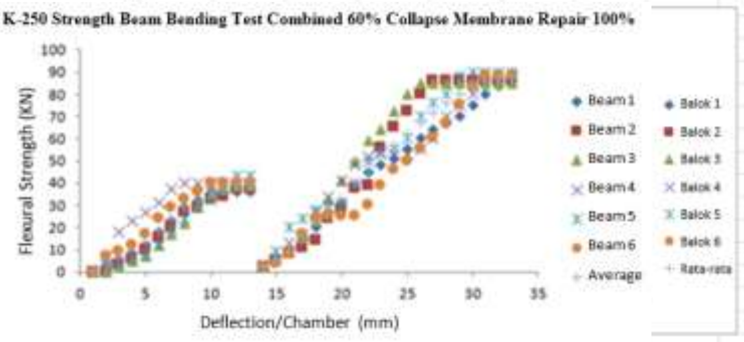


Figure 16. K-250 Strength Beam bending test combined 60% collapse membrane repair 100%

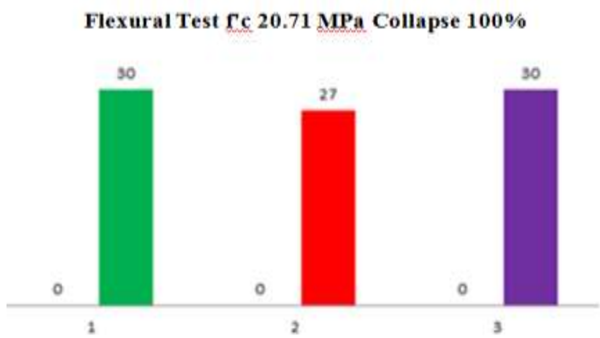


Figure 17. Flexural Test f'c 20.71 MPa Collapse 100%

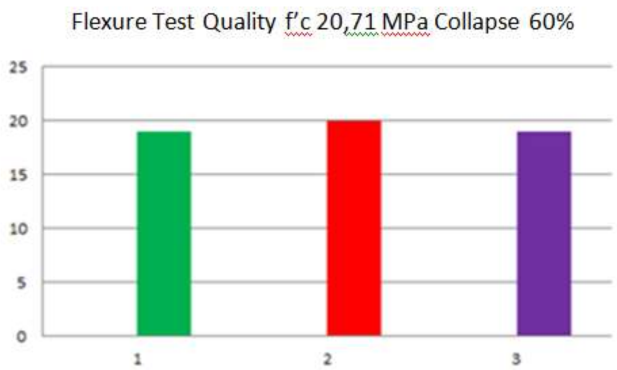


Figure 18. Flexural Test f'c 20.71 Collapse 60%

DOI: 10.31695/IJASRE.2022.8.4.4

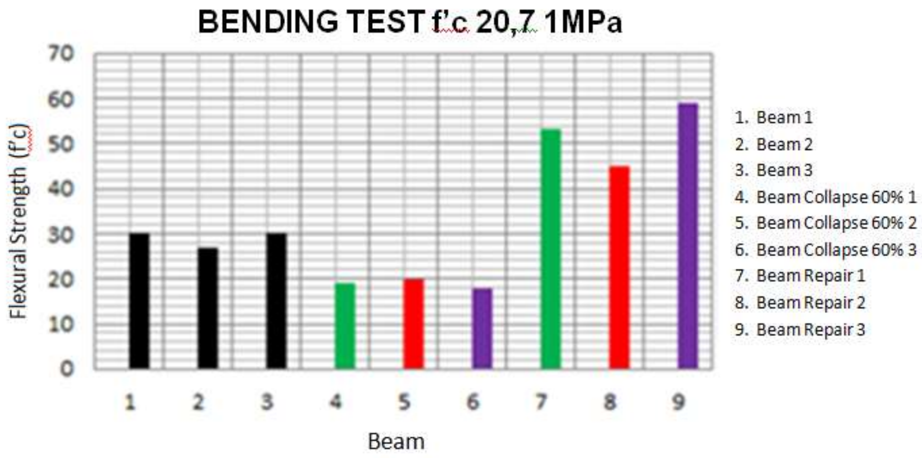


Figure 19. Bending of Whole Beam Collapses 100%, Full Beam Collapses 60% and Repair Beam Collapses 100%

The results of testing the flexural strength of concrete beams with K-150 quality collapse 100% maximum able to withstand a load of 58 kN. The flexural strength of concrete beams with K-250 quality collapsed 100% maximum capable of withstanding a load of 64.33 kN. For the flexural strength of the K-150 quality concrete beam which is coated with a membrane on the tensile part in the test until it collapses 100%, it is maximally able to withstand a load of 82 kN. Testing of the flexural strength of concrete beams K-250 quality concrete beams which are coated with a membrane on the tensile part in the test until it collapses 100% maximally can withstand a load of 91.67 kN. Testing the flexural strength of concrete beams with K-250 quality which at 60% collapse is maximally able to withstand a load of 39.17 kN. Meanwhile, the test of K-250 quality concrete beams collapsed 60% which were repaired with a maximum membrane capable of withstanding a load of 87.67 kN. While the results of the test of the flexural strength of the concrete beam with the quality of f'c 20.71 MPa, 100% maximum collapse is able to withstand an average load of 29.00 MPa. The flexural strength of the concrete beam with f'c quality is 20.71 MPa, 60% maximum collapse is able to withstand an average load of 19.00 MPa. For the flexural strength of the f'c 20.71 MPa concrete beam which has been repaired maximally, it can withstand an average load of 52.86 MPa.

Analysis of the test results with the addition of the membrane layer can increase the bearing capacity of the concrete beam. This is what is needed if in a construction work there is a doubt from the user about the roll being built, this membrane layer can increase its flexural strength.

The results of testing the flexural strength of concrete beams with K-150 quality collapse 100% maximum able to withstand a load of 58 kN. The flexural strength of concrete beams with K-250 quality collapsed 100% maximum capable of withstanding a load of 64.33 kN. For the flexural strength of the K-150 quality concrete beam which is coated with a membrane on the tensile part in the test until it collapses 100%, it is maximally able to withstand a load of 82 kN. Testing of the flexural strength of concrete beams K-250 quality concrete beams which are coated with a membrane on the tensile part in the test until it collapses 100% maximally can withstand a load of 91.67 kN. Testing the flexural strength of concrete beams with K-250 quality which at 60% collapse is maximally able to withstand a load of 39.17 kN. Meanwhile, the test of K-250 quality concrete beams collapsed 60% which were repaired with a maximum membrane capable of withstanding a load of 87.67 kN. While the results of the test of the flexural strength of the concrete beam with the quality of f'c 20.71 MPa, 100% maximum collapse is able to withstand an average load of 29.00 MPa. The flexural strength of the concrete beam with f'c quality is 20.71 MPa, 60% maximum collapse is able to withstand an average load of 19.00 MPa. For the flexural strength of the f'c 20.71 MPa concrete beam which has been repaired maximally, it can withstand an average load of 52.86 MPa.

Analysis of the test results with the addition of the membrane layer CONCLUSIONS AND SUGGESTIONS

5. CONCLUSION

From the results of the research conducted above, the following conclusions can be drawn.

a. K-150 quality concrete beams which are given a membrane layer can increase the flexural strength up to + 41%.

b. K-250 quality concrete beams which are given a membrane layer can increase the flexural strength up to + 42%.

c. Concrete beams with a quality of f'c 20.71 MPa given a membrane layer can increase the flexural strength up to + 50%.

DOI: 10.31695/IJASRE.2022.8.4.4

d. Visually it appears that the condition of the cracks in the test object is the same as the cracks in the vertical direction, indicating that there is a tensile strength.

Suggestion

Based on the research that has been done, it can be put forward some suggestions as follows:

1. Comparative Analysis of Application Beam Behavior by Repairing Carbon Fiber Reinforced Polymer Membrace Type CF 230 on various concrete qualities is still experimental.
2. In order to be able to be more detailed in the application of the results of this study, an in-depth study of the economy is needed by comparing it with the production (economic value) of this proportioned fiber concrete.

ACKNOWLEDGMENT

Research requires perseverance, seriousness to achieve maximum results, besides the required funds are not small, but sometimes it becomes an obstacle in the success and continuation of the research, to be further applied to practitioners, academics and the public. In this study, on behalf of the research team, I would like to thank various parties who have supported the implementation of this research, including:

1. Polines who have helped fund this research.
2. P3M who has helped the implementation of this research.
3. Head of Materials Department of Civil Polines who has provided the opportunity to conduct research
4. Mr. Sugiyono and Mr. Sincere who has helped carry out the research
5. Students who have helped this research
6. Colleagues who have given many suggestions and input.

Finally, hopefully the results of this research can be useful for researchers, practitioners and the public.

BIBLIOGRAPHY

1. Anonymous, 1983. Material Testing, PEDC, Bandung
2. Bappeda TK I. Central Java. 1997. Development of Lime/Lime (CaO) Soil Processing System into Gypsun with Salting Reaction.
3. BPKM. 2000. Building Materials Module I. Semarang State Polytechnic.
4. D.F. Orchard (1979). "Concrete Technology – Properties and Materials." Applied Science Publishers Ltd, London.
5. Marsudi, 2004. Utilization of Blanket Soil as the Main Material for Construction of Irrigation Buildings and Residential Foundations, Wahana Teknik Sipil Semarang
6. Marsudi, 2009, Development of Blangket Land from Jatitree Village as Material for Making Brick to Increase Local Revenue (PAD) of Grobogan Regency. Semarang. Development Research
7. Marsudi, 2010, Blangket Soil Brick With Portland Cement Added Proportion 1: 5, 1 : 10, 1 : 15 and 1 : 20. Semarang. Applied Research
8. Marsudi, 2020, Analysis of the Characteristics of Concrete Beam Structural Improvements in Applications with Carbon Fiber Reinforced Polymer on Various Failures and Engineering Models of Implementation and Workability. Competitive Applied Research.
9. M.S. Shetty (1986). "Concrete Technology – Theory and Practice."S.Chand& Company Ltd, Ram Nagar New Delhi
10. Nawy, Edward G. 1990. Reinforced Concrete A Basic Approach. Translation of Ir. Bambang Suryanto, MSc. Bandung : PT. Eresco.
11. Parhadi, et al. 2005. Aggregate Examination Results. Young Lecturer Research
12. Indonesian Reinforced Concrete Regulation (PBBI) 1971, Directorate of Investigation of Building Problems, Ministry of Public Works
13. SKSNI T-15-1991-03. "Procedures for Calculation of Concrete Structures for Buildings" Ministry of Public Works
14. Subakti, Aman, 1994. Concrete Technology in Practice. Surabaya : ITS
15. Sudibyo, Ir. 1993. Dam Engineering. Pradnya Paramitha. Jakarta
16. Supriyadi, Kusdiyono and Heri Ludiro, 2006. Complete Concrete Mixture Determination Model. Civil Engineering Forum. Vol. 11, No. 3. Pg. 115-125.
17. Tjokrodimuljo, K. 1996. Concrete Technology. trumpet. Yogyakarta

DOI: 10.31695/IJASRE.2022.8.4.4