COMPARATION OF BENDING STRENGTH CONCRETE FLOOR PLATE CFRP REINFORCING WITH WIRE MESH REINFORCING AN ALTERNATIVE THE BEST CHOICE FOR CONCRETE REINFORCING FLOOR PLATES

By Made Dharma Astawa

COMPARATION OF BENDING STRENGTH CONCRETE FLOOR PLATE CFRP REINFORCING WITH WIRE MESH REINFORCING AN ALTERNATIVE THE BEST CHOICE FOR CONCRETE REINFORCING FLOOR PLATES

Made Dharma Astawa[1], Nyoman Dita P Putra[2], Eddy Poernomo[3]
[1), 2)] Lecturer Department of Civil Engineering, Faculty of Engineering, the University of Pembangunan Nasional "Veteran" East Java-Indonesia
[3)]Lecturer at Faculty of Sicial and Polytical Science, the University of Pembangunan Nasional "Veteran" East Java-Indonesia.
Email: [1)]masdawa@yahoo.com, mdastawa@upnjatim.ac.id

ABSTACT

Floor plate is one of the major structural elements of the building frame structure, as loadbearing gravity directly consisting of dead load, self weight and live load. As a result of this gravity loads will occur bending moment and will cause a sizeable deflection. To eliminate deflections occurring and to improve the flexural strength as resistance to the gravity loads, generally done by providing reinforcement as a reinforcement in the slab.

The development of Carbon Fiber Reinforced Polymer (CFRP) and Wire-mesh reinforcing has opened up new opportunities to provide rigidity and improve the flexural strength concrete frame structure of the building in general, in particular on the concrete floor plate elements. To select the material flexural the concrete floor slabs, researchers are trying mengkomparasi use of CFRP and Wiremesh as reinforcement bending, the specimen concrete slab dimensions panjang1200 mm, width 500 mm and thickness of 120 mm, with the number of each of the three specimens of concrete plate bertulangan CFRP, and 3 specimens bertulangan Wire-mesh. Once the concrete specimen minimum age of 28 days, and then tested in experimental powerful flexibility of a laboratory with monotonic bending loads, the loading process increased gradually until the specimen fractured, and setrusnya sampi collapse. The data is then analyzed test results of the flexural strength of the two types of reinforcement (CFRP and Wire-mesh), and then compared the results which is better.

Analysis results of the best flexural strength and mechanically efficient than alternative two kinds of material that is applied to the concrete slab specimens will be selected as the material for the reinforcement of concrete floor plate in this study.

Keywords: CFRP, Wiremesh, comparative flexural capacity, the best alternative.

INTRODUCTION

Improvement and retrofiting on concrete structures often do both at the time of construction of a structure or in a structure that is already in operation. The purpose of repair is to restore the structure to its original state both strength capacity and functionality, or increase the load capacity structure for switching function so that it can carry a larger load.

Several studies of concrete retrofitting, among others, retrofitting bending in concrete beams using CRFP material plate (Mohsen Shahawy et al, 2001). Installation of FRP Reinforcement near the surface for Bending Retrofitting Concrete Structures (Hacha R. F and Rizkalla S. H, 2004), column Concrete reinforced with CFRP (Marolop Tua Sianipar, 2009), Planning Plate Concrete Flooring Grid Reinforcement wiremesh using materials Add fly ash (Zaenuri 2010), the use of CFRP Laminate to increase the shear strength Beams reinforced Concrete (Alferjani MBS, et al, 2013), Reinforced Concrete plate structures (Aprelia R, 2014), Technology of concrete reinforcing steel (Ikhfan M, 2015).

To get the improvement and retrofiting of concrete structures are optimal, then it should be done three important stages, namely the investigation, evaluation and implementation. The third stage is very important to do, and no one is more important stage than the other stages (Hartono, 2008). Because without a good investigative, then we can not evaluate it properly, so without a proper evaluation, the improvement and reinforcement is done can not achieve the goals that have been set, the next without good execution, then all stages investigation and evaluation was done properly and well be meaningless.

STUDY LITERATURE

The following refers to several studies that have been done by previous researchers.

Tensile Strength Research of CFRP.

Astawa M. D., et al (2015), doing research CFRP tensile strength. Manufacturing procedures follow the provisions of the American Standard Testing Materials (ASTM) D 3039 / D 3039M-00, with an odd number minimum of 3 samples. In this study, 7 pieces of samples with sizes as listed in the following table.

Table 1. Dimensions and number of CFRP specimen.

No.	Name/Type Specimens	Function	Thick (mm)	Wide (mm)	Long (mm)
1	Carbon Fiber Reinforcement Polymer (CFRP)	In lieu tensile reinforcement / flexure	1.20	15.40	250.00
2			1.20	15.00	250.00
3			1.20	15.25	250.00
4			1.20	14.70	250.00
5			1.20	15.00	250.00
6			1.20	14.50	250.00
7			1.20	14.90	250.00

Standard actual dimensions of 1.20 X 15.00 X 250.00 mm. but the size is listed in the table can not be precise as standard. The reason is precisely because of the difficulty to form flat plate composed of fibers. the fiber edge plate plates apart so often can not be precise as wide as the width of 15.00 mm. however the size of the width is still within tolerance (Figure 1).

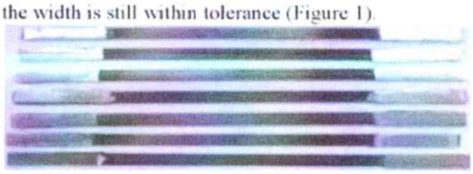

Figure 1. CFRP specimen already formed (7 pieces)
(Astawa. M.D. at al. 2015)

Perform the test specimen in one by one using the testing machine Pull Universal Testing Machine (UTM) with a capacity of 500 kN. From 7 Specimens tested worked well as 5 specimen. while the two specimen failure due to a slip at the end of the specimen clamps.

Although there were 2 Specimens that have failed. but still meet the requirements of the amount due has been more than 3 Specimen and odd number. Document the testing process is shown in Figure 2.

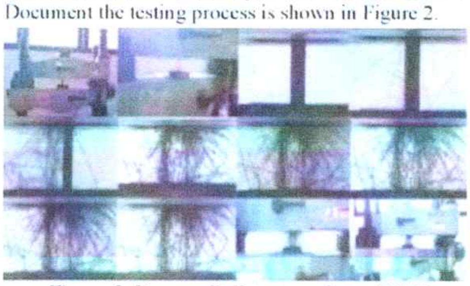

Figure 2. Process Pull test specimen CFRP
(Astawa. M.D. at al. 2015)

After the specimen was removed from the testing machine UTM. reconfiguration of the conditions had been severed. forming fibers from CFRP can be seen clearly. and documentation can be seen in Figure 3. below.

Figure 3. Archives CFRP specimen that had broken
(Astawa. M.D. at al. 2015)

From the image illegible work processes Pull given in Specimens from the beginning to break up. after breaking up visible material specimen back to form fibers. Strong relationships Pull and CFRP strain in the laboratory test results are shown in Figure 4

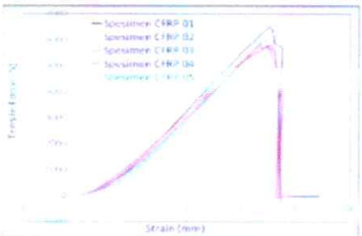

Figure 4. Strong Pull-Strain Relationship Curve Specimen of CFRP, a combined 1 s / d 5
(Astawa. M.D. at al. 2015)

Pull powerful look of of CFRP Specimens from laboratory test results Pull melting an average of fy = 3073.60 N / mm2. the increase of the standard manufacturer quite significant a value of fy = 2520 N / mm2. Thus it can be concluded that the CFRP is used in the field is very strong because it has a capacity above from the analysis that has been done.

What is lacking is disqualify strain (strain) that only reached an average of 4.614‰ is still below 9.00‰ according to the provisions of ASTM 615-2000.

Near-Surface-Mounted Fiber-Reinforced Polymer Reinforcements for Flexural Strengthening of Concrete Structures.

The use of Near Surface Mounted FRP reinforcement is currently emerging as a promising strengthening technique and a valid alternative to externally bonded FRP reinforcement for increasing the flexural strength of reinforced concrete members (Raafat El-Hacha, Sami H. 2004). Rizkalla. The structural performance of reinforced concrete beams strengthened in flexure with NSM FRP reinforcement was examined and compared with beams strengthened with externally bonded FRP reinforcement. The behavior prior to and after cracking, ultimate carrying capacity, and modes of failure of all tested beams are discussed in this paper. The variables investigated were the type of fibers, including carbon fiber-reinforced polymer (CFRP) and glass fiber-reinforced polymer (GFRP) thermoplastic, and the configuration of the FRP reinforcement, including reinforcing bars and strips. The effectiveness of NSM FRP reinforcing bars and strips was examined and compared with externally bonded FRP strips using the same material and axial stiffness. The findings of this research provide data for the design guidelines currently under consideration by ACI Committee 440 for the NSM FRP strengthening technique. Test specimens and setup A total of eight, simply supported, 2.7 m (9 ft) long, concrete T -beams were constructed and tested under a monotonically increasing concentrated load applied at midspan of the beam. The test setup of aT-beam specimen is shown in Figure. 5

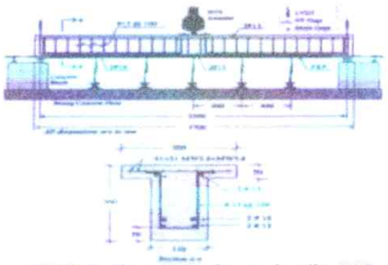

Figure 5. Test setup, beam details, and instrumentation of beam specimens
(Hacha & Sami, 2004)

Test matrix One beam was tested without strengthening (BO) and served as the control specimen for comparison purposes. Four beams (B 1, B2, B3, and B4) were strengthened with different NSM FRP systems using CFRP reinforcing bars, two types of CFRP strips, and thennoplastic GFRP strips. Three beams (B2a, B2b, and B4a) were strengthened with different externally bonded CFRP and GFRP strips. A summary of these beams is given in Table 2.

Table 2: Test matrix for T-beam specimens

Beam no.	FRP strengthening system
BO	No strengthening
B1	One NSM CFRP reinforcing bar
B2	Two Type 1 NSM CFRP strips
B3	Two Type 2 NSM CFRP strips
B4	Five NSM GFRP thennoplastic strips
B2a	Two Type 1 eXlernally bonded CFRP strips
B2b	Two Type 1 externally bonded CFRP strips
B4a	Five externally bonded GFRP thermoplastic strips

Installation of the NSM FRP reinforcing bars and strips begins by making a series of grooves with specified dimensions cut into the concrete cover in the longitudinal direction at the tension side of the beam specimens. A special concrete saw with a diamond blade was used to cut the grooves with the dimensions shown in Figure. 6.

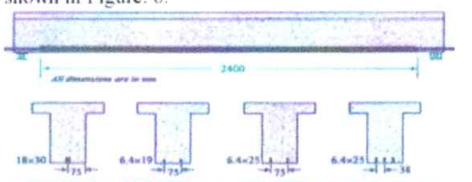

Figure 6. Groove dimensions for various NSM FRP strengthening systems.
(Hacha & Sami, 2004)

Installation of externally bonded FRP reinforcements: To ensure a good, strong bond, the bottom surface of the concrete beams was prepared by grinding until the coarse aggregates were exposed, then cleaned by washing and airbrushing to remove dust or debris and fine particles. Care was taken to ensure that the resulting concrete surface after grinding was unifonn. Following cleaning, a unifonn 2 mm (0.0[illegible] in.) thin layer of the two-part epoxy-based adhesive was applied by palette knife to the bottom surface of the concrete beam. The FRP strips were placed in position on the concrete surface and pressed onto the epoxy by hand. To ensure a good bond with concrete, a uniform pressure was applied along the entire length of the strips. AU-shaped wrap CFRP sheet with 100 mm (4.0 in.) width was placed around the web of the concrete beams at both ends of the externally bonded FRP flexural reinforcements, with the direction of the fibers perpendicular to the longitudinal axis of the member, to improve the anchorage of the FRP strengthening system (Fig. 6). The externally bonded CFRP strips (Type 1) were placed at the bottom surface of the concrete beams (B2a and B2b) with spacing in between equal to twice the width of the strip (Fig. 3). The externally bonded GFRP strips were placed side by side at the bottom surface of the concrete beam (B4a) leaving 25 mm (LO in.) from each side of the beam (Figure. 7).

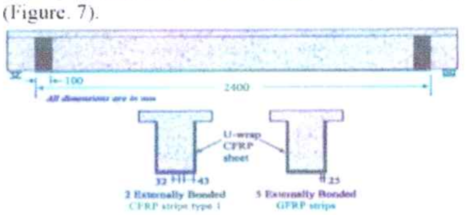

Figure 7. Externally bonded FRP strengthening systems.
(Hacha & Sami, 2004)

A summary of significant test results describing the flexural behavior of all tested beams is presented in Table 3. The concrete compressive strength when the beams were tested was detennined according to ASTM C 39-01, using three standard concrete cylinders and ranged between 48 MPa (6962 psi) for Beams BO, BI, B3, and B4, and 57 MPa (8267 psi) for Beams B2, B2a, B2b, and B4a. Beam BO was tested without strengthening and used as a control specimen for comparison purposes to evaluate the improvement in flexural strength provided by the various NSM and externally bonded FRP reinforcements. The un strengthened control beam failed by crushing of the concrete after yielding of the steel tension reinforcement. Load-midspan deflection of beams strengthened with NSM CFRP reinforcing bar and strips, can be seen in Fig. 8.

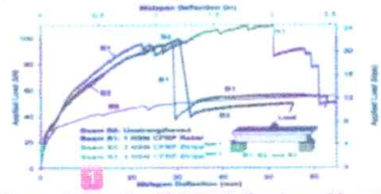

Figure 8. Load-midspan deflection of beams strengthened with NSM CFRP reinforcing bar and strips (Hacha & Sami, 2004)

Installation method of Wiremesh.

Wiremesh an iron material that is made from plain or threaded wire rod formed sheet with a box of 15 cm x 15 cm long x 2.1 m 5,4m having a thickness of 4-10 mm are used for the casting floor reinforcement (Triyanto, 2016). Wiremesh a material that is also less familiar to people because usually casting Indonesia using begel assembled themselves. For those who understand the building using a wiremesh be an option without a doubt, because wiremesh designed to help speed and simplify development, in terms of strength and efficiency, wiremesh superior to other materials. Suppose the casting use 10mm plain stirrup, because the plain reinforcement quality classification bjtd 24 while wiremesh with quality bjtp 40, so it is better to use wiremesh kekutan. Financially use concrete steel is more expensive than on wiremesh, one meter begel spending concrete steel wiremesh worth 99. 000 being only 50. 000. Judging from the application installation begel require a long time and requires a lot of people, while wiremesh its application faster, requiring more less labor. Wiremesh installation method shown in Figure 9, 10, 11 and 12.

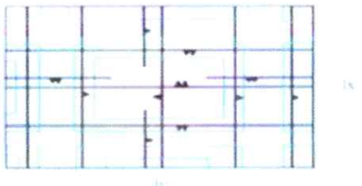

Figure 9. Wiremesh installation pattern on concrete floor plate (Trianto, 2016)

Figure 10. Wiremesh Reinforcement on footstool for beams (Trianto, 2016)

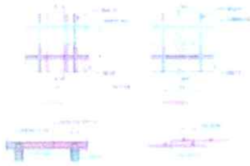

Figure 11. Installation joining methods wiremesh (Trianto, 2016)

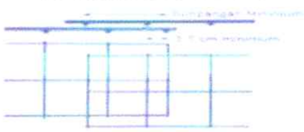

Figure 12. Installation Connection Details wiremesh (Trianto, 2016)

METODOLOGY

Analysis of Statics Concrete Floor Plate.

Numerical analyzes were performed with Software Analaysis Structure Program (SAP 2000). After creating a modeling plate, then to imput load and property, then its output results can be displayed as follows.

Figure 13. Shell Element Stress and Internal Forces

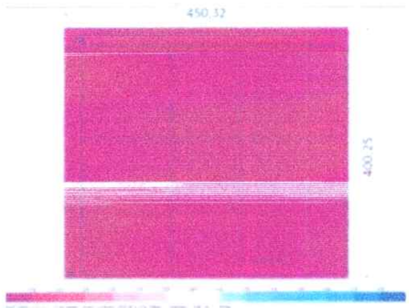

Figure 14. Discrete Floor Plate

(a) M-11 Direction of long spans (Ly)

(b) M-22 Direction of short span (Lx)

Figure 15. Flexure deformation of span Ly and Lx direction

Research Laboratory

Testing needed in the laboratory are:

1. Tensile Test Wire-mesh, using a piece of wire-mesh material along the 600 mm, then tested for tensile strength (fy) using the UTM test machine. Yield tensile strength test results if successful properly according to the American Standard Testing Materials (ASTM, 2000), will yield curve as follows:

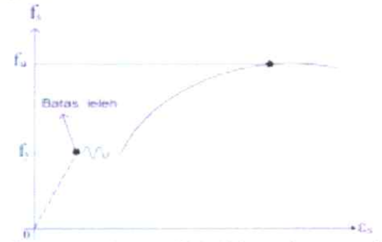

Figure 16. Curve of Model specimen tensile Rebar (ASTM, 2000)

2. Bending test concrete plate with CFRP reinforced, cross-sectional dimensions of plate: thickness 12 cm, width 50 cm, length 100 cm. Reinforcement plate mounted CFRP each second rod towards landscape Lx and Ly. Use 3-point load of ≥ 22 kN in accordance with the results of the analysis. Schematic drawing as follows

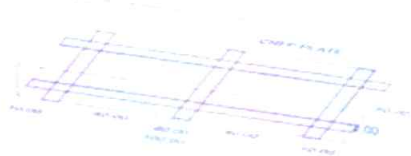

Figure 17. Concrete Plates Specimens with CFRP reinforcement

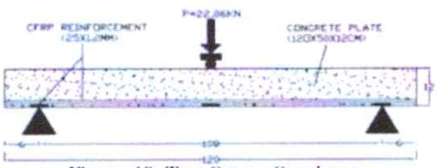

Figure 18. Test Set-up Specimen CFRP Reinforcing

Reinforced concrete slab bending test Wiremesh M8, cross-sectional dimensions of the same plate with reinforced CFRP plate. Wiremesh reinforced concrete plate configuration is shown below:

Benda Uji	Beban Crack		Beban Ultimate	
	kgf	kN	kgf	kN
CFRP	1750	17.17	2040	20.01
	2050	20.11	2330	22.86
	2070	20.31	2070	20.31
Rata-rata	1957	19.19	2147	21.06

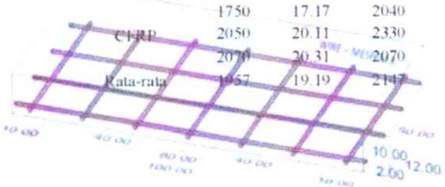

Figure 19. Concrete plate Specimens with Wiremesh Reinforcing

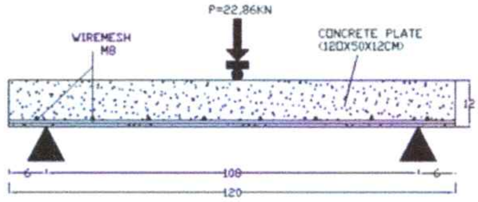

Figure 20. Test Set-up Specimen reinforced Wiremesh

TEST RESULTS AND DISCUSSION.

Flexure strength test results.

Flexural strength test performed by following the provisions of JIS A 5335-1987, samples of CFRP reinforced concrete slab and Wiremesh each 3 pieces, by loading a centralized (Uniflexure Load), using a machine press UTM test, carried out gradually with the increase in each stage 2kN up to plates cracked and then collapsed. To measure the deflection, using a dial gauge is installed in the middle of the span, and log machine through reading tool UPM Transducer. Evaluation of the results of the bending test, taken the average value of all the test results, the evaluation includes bending strength and deflection. Data flexural strength test results are listed in Table 3, as follows :

Table 3. The test results in the laboratory.

Specimen	Ultimate Loads (kN)	Crack Loads (kN)	Average loads Ultimate (kN)	Average loads Crack (kN)
CFRP	20,40	17,50	21,47	19,57
	23,30	20,50		
	20,70	20,70		
Wire mesh	30,10	16,70	30,00	17,50
	29,50	18,00		
	30,40	17,80		

Relations load and deflection of the CFRP concrete slab can be seen in the following table 4.

Table: 4. Load-deflection relationship on Plate with CFRP Reinforced.

Specimen	Crack Loads	Ultimate Loads	Deflection (mm)		Ductility $\Delta ult/\Delta cr$ (δ_{φ}, rad)
	kN	kN	Δcr	Δult	
CFRP	17.17	20.01	1.56	6.78	4.35
	20.11	22.86	4.06	10	2.46
	20.31	20.31	7.23	7.23	1.00
Average	19.19	21.06	4.28	8.00	2.60

Dial gauge results of the reading bending test CFRP reinforced concrete slab, successively initial fractured, specimen 1 at load 17.17 kN with a deflection of 1.56 mm, the specimen 2 at load 20,11 kN with a deflection of 4.06 mm and in specimen 3 at load 20,31 kN with a deflection of 7.23 mm. Reaches maximum load and deflection in succession, the specimen 1 by 20,01 kN with a deflection of 6.78 mm, the specimen 2 at 22.86 kN with a deflection of 10 mm and specimens 3 at 20,31 kN with a deflection of 7.23 mm (see table 4).

The following are the load-deflection curve of the specimen CFRP reinforced concrete slab, in figure 21.

Figure 21. Load-deflection curve of the specimen CFRP reinforced concrete slab

Furthermore, the relationship load and deflection concrete plate with Wiremesh reinforced, shown in Table 5 below.

Table: 5. Load-deflection relationship on plate with Wire mesh Reinforced .

Specimen	Crack Loads	Ultimate Loads	Deflection (mm)		Ductility Δult/Δcr (δ_φ, rad)
	kN	kN	Δcr	Δult	
Wiremesh	16.38	29.53	3.61	11.11	3.08
	17.66	28.94	2.78	7.78	2.80
	17.46	29.82	2.50	7.78	3.11
Average	17.17	29.43	2.96	8.89	3.00

The relationship Curve of load-deflection bending test results wiremesh reinforced concrete slab can be seen in Figure 22. Iinitial cracks of 3 in succession specimens, for specimen 1 at load 16.38 kN with a deflection of 3.61 mm, the specimen 2 at the load 17, 66 kN with a deflection of 2.78 mm and specimens 3 at load 17.46 kN with a deflection of 2.50 mm. Reaches maximum load respectively, specimen 1 at load 29.53 kN with a deflection of 11.11 mm, the specimen 2 at load 28.94 kN with a deflection of 7.78 mm and specimens 3 at load 29.82 kN with a deflection of 7.78 mm.

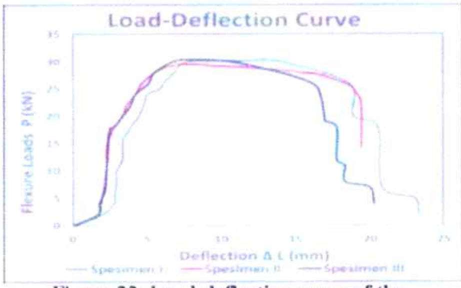

Figure 22. Load-deflection curve of the specimen Wiremesh reinforced concrete slab

Discussion

Behavior and flexural capacity of reinforced concrete slab with CFRP less effective, because the ultimate load is significantly lower than planned expenses in the amount of 22.86 kN. CFRP experiencing first concrete slab crack of 19.19 kN, ultimate load of 21.06 kN, the ultimate moment of 5.69 KNm, deflection 2.60 mm and a flexural strength of 3.51 MPa.

The use of CFRP plates as external reinforcement on concrete without steel reinforcement plate is less effective, because the ultimate load that occurs fell by 28.44% against the concrete slab wiremesh. The decline also occurred on a deflection by 13.11%, amounting to 28.44% ultimate moments and bending strength of 28.44%. That's because the debonding failure or release of the bond between the concrete with CFRP to CFRP not work optimally as a composite structure. But the installation of CFRP on a plate can inhibit the first crack as evidenced by the increasing burden of 11.76% fisrt crack at Wiremesh plate.

Behavior and flexural capacity of reinforced concrete slab WIREMESH good enough, it can be seen with increasing load on the ultimate load that is equal to 22.86 kN planned. Wiremesh experiencing first concrete slab crack of 17.17 kN, ultimate load of 29.43 kN, the ultimate moment of 7.95 KNM, a deflection of 3.00 mm and a flexural strength of 4.91 MPa.

The following pictures are document of the testing process in the laboratory.

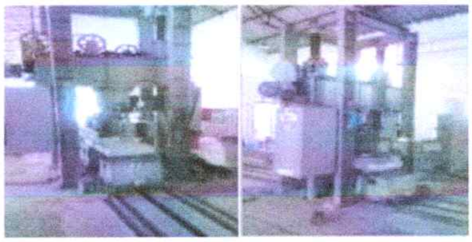

Figure 23. Test set-up specimens reinforced CFRP and Wiremesh

Figure 24. Fracture Specimens reinforced FRP

Figure 25. Fracture Specimens reinforced Wiremesh

CONCLUSION

After analysis and discussion, it can be deduced that that the results of laboratory research indicate reinforced concrete plate WIREMESH better results compared with CFRP plate reinforced concrete. Thus the alternative choice as the best reinforcement concrete slab between two options, CFRP and wiremesh, is a reinforced concrete plate Wiremesh.

REFERENCES

1. ACI 201.1R, 1992, ***"Guide for Making a Condition Survey of Concrete in Service"***
2. ACI 364.1R, 1993,***"Guide for Evaluation of Concrete Structures Prior to Rehabilitation"***
3. ACI 440, 2000, ***"Guide For Design and Construction of Externally Bonded FRP Systems For Strengthening Concrete Structures"***, January 2000.
4. American Concrete Institut (ACI 318M-11) , 2011 ***"Building Code Requirements for Structural Concrete and Commentary"*** First Printing September 2011.
5. Astawa M. D., et al. 2015, ***"Repair and Strengthning with CFRP on Concrete Slab Structure of Structural Crack due to Shortage Reinforcement Footstool" Presiding Seminar International Bisstech, Kuta-Bali, 15-17 Oktober 2015.***
6. Astawa M. D., et al. 2015, ***"Tensile Strength Test of Carbon Fiber Reinforced Polymer (CFRP) as an alternative Reinforcement Substitution Bending on Concrete Structures "*** Presiding The Research Month LPPM-UPN "Veteran" East Java, Surabaya, December 8, 2015
7. Astawa M. D., 2008 ***"Concrete Struktures I"***, . Civil Engineering Department-Faculty of Engineering, UPN "Veteran" East Java, ISBN : 978-979-1005-21-0.
8. FIP, 1986, ***"Inspection and Maintenance of Reinforced and Prestressed Concrete Structures"***, London, 1986.
9. FIP, 1991***"Repair and Strengthening of Concrete Structures"***, London, 1991.
10. Hartono (2008), ***"Repair and Strengthening Concrete Structures"***, Civil Engineering Seminar of papers UPN "Veteran" East Java, 2008.
11. Fizailly, Dian, 2004, ***"Bending Capacity Styrofoam Plates Concrete Floor light with woven Reinforcing Steel Wire (wiremesh)"***, UGM Yogyakarta.
12. Hendra Putra, 2012, ***"Table Calculation of Reinforced Concrete Floor Reinforcement Plate with SNI 03-2847-2002, PBI 1971 and SAP 2000 modeling version 14"***, ITS Surabaya.
13. Mohsen Shahawy et al, (2001), ***"Flexural Strengthening with Carbon Fiber-Reinforced Polymer Composites of Preloaded Full-Scale Girders"*** ACI Structural Journal/ September-Oktober 2001
14. Meier U., Erki M.A., ***"Advantages of Composite Materials in the Post Strengthening Technique For Developing Countries, Sixth International Colloquium on Concrete in Developing Countries"***, Pakistan, January 1997.
15. Reference of Sika's, ***"Strengthening and Repair Projects"*** whole project from the year 2000-2013.
16. SNI-2847-2013, ***"Procedure for Calculation of Concrete Structures for Buildings"***, National Standardization Agency, Jakarta 2013.
17. Sumber Makmur, 2015 **"Standard dimensions Reinforcement Woven Wire Mesh"**, Jl. Mangga Besar I No. 78 CDE, Jakarta Barat 11180.
18. The Concrete Society, 2000, ***"Design Guidance For Strengthening Concrete Structures Using Fibre Composite Materials"***, Technical Report No. 55, London, tahun 2000.
19. Technical Data of Sika's Product, from the years 2000 – 2014.

COMPARATION OF BENDING STRENGTH CONCRETE FLOOR PLATE CFRP REINFORCING WITH WIRE MESH REINFORCING AN ALTERNATIVE THE BEST CHOICE FOR CONCRETE REINFORCING FLOOR PLATES

ORIGINALITY REPORT

20%

SIMILARITY INDEX

PRIMARY SOURCES

1	www.ccee.ncsu.edu Internet	288 words — 8%
2	quakewrap.com Internet	82 words — 2%
3	Advances in FRP Composites in Civil Engineering, 2011. Crossref	81 words — 2%
4	issuu.com Internet	43 words — 1%
5	M D Astawa, W Kartini, F X E Lie. "Partial Prestress Concrete Beams Reinforced Concrete Column Joint Earthquake Resistant On Frame Structure Building", Journal of Physics: Conference Series, 2018 Crossref	36 words — 1%
6	Firas Al-Mahmoud, Arnaud Castel, Raoul François, Christian Tourneur. "RC beams strengthened with NSM CFRP rods and modeling of peeling-off failure", Composite Structures, 2010 Crossref	34 words — 1%
7	eprints.upnjatim.ac.id Internet	28 words — 1%
8	El-Hacha, Raafat, R. Gordon Wight, and Mark F. Green.	

"Prestressed Carbon Fiber Reinforced Polymer Sheets for Strengthening Concrete Beams at Room and Low Temperatures", Journal of Composites for Construction, 2004.
Crossref — 16 words — < 1%

9 www.concrete.org
Internet — 13 words — < 1%

10 theses.ucalgary.ca
Internet — 12 words — < 1%

11 Nageh Mohammed Ali, Xin Wang, Zhishen Wu, Ahmed Yehia Hassanein. "Basalt fiber reinforced polymer grids as an external reinforcement for reinforced concrete structures", Journal of Reinforced Plastics and Composites, 2015
Crossref — 12 words — < 1%

12 An Zeng, Qi-Lun Zheng, D. Pan, Hong Peng. "A practical strategy for acquiring rules based on rough sets and principal component analysis", 2004 IEEE International Conference on Systems, Man and Cybernetics (IEEE Cat. No.04CH37583), 2004
Crossref — 11 words — < 1%

13 Guohua Xing, Tao Wu, Boquan Liu, Hua Huang, Songlin Gu. "Experimental Investigation of Reinforced Concrete T-Beams Strengthened with Steel Wire Mesh Embedded in Polymer Mortar Overlay", Advances in Structural Engineering, 2016
Crossref — 9 words — < 1%

14 media.proquest.com
Internet — 8 words — < 1%

15 www.ce.ncsu.edu
Internet — 8 words — < 1%

16 Al-Mahmoud, Firas, Jean-Michel Mechling, and Mohamed Shaban. "Bond strength of different strengthening systems – Concrete elements under freeze–thaw — 7 words — < 1%

cycles and salt water immersion exposure", Construction and Building Materials, 2014.
Crossref

17	Rizzo, Andrea De Lorenzis, Laura. "Behavior and capacity of RC beams strengthened in shear with NSM FRP reinforcement.", Construction and Building Materials, April 2009 Issue Publications	7 words — < 1%

EXCLUDE [illegible] OFF   [illegible] OFF

EXCLUDE [illegible] ON