Jurnal Mekintek,13 (1) (2022) pp. 12-18

Published by: IHSA Institute

Jurnal Mekintek: Jurnal Mekanikal, Energi, Industri, Dan Teknologi

Journal homepage: www.ejournal.isha.or.id/index.php/Mekintek

Analysis And Experimental Use Of CFRP Wrap Type On Flexible Reinforcement Of Concrete Beam

Andrew Agaton Pakpahan

Department Of Civil Engineering, University Of North Sumatra, Jl. Dr. Mansur No. 9 Padang Bulan, Kec. Medan Baru, Kota Medan 20222

ARTICLE INFO

Article history:

Received Feb 10, 2022
Revised Mar 07, 2022
Accepted Apr 30, 2022

Keywords:

Reinforced Concrete Beams
CFRP
Flexural Strength
Deflection
External Reinforcement
Retrofitting

ABSTRACT

Now, reinforced concrete structures are more commonly used in buildings because they are cheaper than steel structures. However, many concrete structures are damaged due to planning errors and changes in building functions, so there are several ways to overcome this problem, by providing Fiber Reinforced Polymer (FRP) reinforcement. In this study, researchers discussed the comparison of the flexural strength of reinforced concrete beams using Fiber Reinforced Polymer (FRP). In this case, the researcher uses a Wrap-Type Carbon Fiber Reinforced Polymer (CFRP) as external reinforcement. The beam dimensions are 15 x 25 cm with a length of 320 cm. Based on the results of the analysis, the strength of the beam with CFRP is 1.877 times its initial strength. Based on the test results, the strength of the CFRP beam is 1.5 times its initial strength. Based on the results of this test.

Corresponding Author:

Andrew Agaton Pakpahan,
Department Civil Engineering,
University Of North Sumatra,
Jl. Dr. Mansur No. 9 Padang Bulan, Kec. Medan Baru, Kota Medan 20222.
Email : andrewpakpahan@gmail.com

1. INTRODUCTION

Concrete structures in the long term are expected to decrease in strength due to several factors. Many reinforced concrete structures are starting to break down, marked by the appearance of fine cracks, excessive deflection, and even visible reinforcement from the outside. This can be caused by several factors, including: changes in the function of the building structure, unanticipated loads in the initial planning, errors in the mix design, human error during casting in the field or improper curing process. So it is necessary to carry out retrofitting so that the existing structure can accept the load in accordance with the initial design and the new load for a structure that changes function. This repair can be done in several ways such as adding a layer of concrete, strengthening steel plates,

FRP itself has many types, including CFRP (Carbon Fiber Reinforced Polymer) and GFRP (Glass Fiber Reinforced Polymer) whose functions are almost the same as the use of thin steel plates as reinforcement of reinforced concrete beams, namely strengthening the tensile part of reinforced concrete beams (Ireneus G. Petrico, 2013).

CFRP and GFRP are generally often used in reinforcement with consideration of tensile strength, stiffness, durability and creep properties. CFRP and GFRP are available in the form of PLATE (Strip), FABRIC (WRAP) , and ROD (Reinforcement).

Fiber Reinforced Polymer has a tensile strength greater than steel and a fairly high rigidity, this is supported by several studies both analytically and experimentally that have been done before. Fiber Reinforced Polymer (FRP) itself also has a lighter weight than reinforcement and is also more practical so that installation is easier and Fiber Reinforced Polymer (FRP) itself is also resistant to corrosion. Despite its relatively high cost, FRP , provides the most economical solution to retrofitting because it can dramatically reduce labor costs.

Manna Haloho and Johannes Tarigan (2015), in their research discuss the reinforcement of reinforced concrete beams using anchored steel plates. The beams used are 15x25 cm and 320 cm long. Based on the analytical results, there was an increase in the strength of the beam, namely 3.79 times the initial strength, while from the test it was obtained that the increase in the strength of the beam was 2.44 times the initial strength. Based on the results of this test, it can be concluded that the use of steel plates in the tensile area can increase strength and reduce deflection and the use of anchors to attach steel plates to concrete can overcome the problem of detaching plates from concrete blocks.

2. RESEARCH METHOD

The methodology and stages of implementation that the author made in the work of this final project use several approaches, including:

a. The research was conducted using experimental methods
b. The writing of this final project refers to the analytical study method based on data and literature related to the topic and carried out experiments and inputs from the supervisor.
c. Analysis of the calculation of the reinforcement of concrete structures using the USA Building Code- Retrofitting CFRP ACI 440.
d. Analytical data will be compared with experimental data.
e. The experimental mechanism that will be carried out are:

3. RESULTS AND DISCUSSIONS

3.1 CONCRETE BEAM TEST RESULT

In this section, the test results for each variation of the concrete beam will be summarized in a tabular form containing the load with the deflection in the middle of the span and span.

a. Unreinforced Concrete Blocks

In unreinforced reinforced concrete beams, the dial is placed at three points, namely: 1/4 L left, 1/2L, and 1/4L right where the beam is loaded until cracks occur and the dial reading is constant.

Table 1. Test Results of Unreinforced Beam Decompression

BURDEN (2P)	**1/4 LL**		**CL**		**1/4 LR**	
	DIAL READING	DEFLECTION	DIAL READING	DEFLECTION	DIAL READING	DEFLECTION
Kg	x 0.01	Mm	x 0.01	Mm	x 0.01	Mm
500	11.5	0.115	18	0.180	13	0.130
1000	36.5	0.365	54	0.540	39	0.390
1500	88.5	0.885	126	1,260	89	0.890
2000	129	1,290	256	2,560	134	1,340
2500	188	1,880	318	3,180	192	1,920
3000	253	2,530	378	3,780	273	2,730
3500	375	3,750	479	4,790	385	3,850
4000	463	4,630	588	5,880	486	4,860
4500	538	5,380	689	6,890	542	5,420
5000	589	5,890	774	7,740	592	5,920

5500	642	6,420	853	8,530	662	6,620
6000	739	7,390	975	9,750	749	7,490
6500	835	8,350	1055	10,550	861	8,610
7000	979	9,790	1215	12,150	992	9,920
7500	1108	11,080	1650	16,500	1127	11.270
8000	1159	11,590	1764	17,640	1174	11,740
8500	1243	12,430	1995	19,950	1326	13,260
9000	1267	12,670	2245	22,450	1369	13,690

b. Concrete Beams With Steel Plate Reinforcement

In reinforced concrete beams with steel plate reinforcement, the dial is placed at three points, namely: 1/4 L left, 1/2L, and 1/4L right where the beam is loaded until cracks occur and the dial reading is constant.

Table 2. Test Results for Lowering Beams With Steel Plate Reinforcement (Manna Haloho, 2015)

Load (kg)	**1/4L-L**		**CL**		**1/4L-R**	
	DIAL READING x 0.01	DEFLECTION Mm	DIAL READING x 0.01	DEFLECTION Mm	DIAL READING x 0.01	DEFLECTION Mm
500	5	0.050	71	0.705	55	0.550
1000	46	0.460	129	1,290	102	1.020
1500	89	0.890	196	1.960	151	1.505
2000	118	1.180	244	2,440	185	1.850
2500	161	1.610	307	3.070	235	2,345
3000	204	2,040	372	3,720	286	2,860
3500	240	2,400	428	4.280	328	3.280
4000	258	2,580	456	4,562	349	3,490
4500	292	2,920	508	5.080	388	3.875
5000	341	3.410	581	5.810	440	4,400
5500	371	3,710	625	6.250	475	4.745
6000	398	3.980	664	6.640	502	5.020
6500	442	4.420	724	7.240	547	5.470
7000	481	4.810	776	7,760	588	5.875
7500	513	5.130	820	8,200	621	6.210
8000	539	5,390	857	8,570	649	6.490
8500	576	5760	913	9,130	691	6.910
9000	613	6,130	965	9.650	728	7.280
9500	666	6.660	1042	10,420	785	7.850
10000	687	6.870	1073	10,730	808	8080
10500	734	7,340	1134	11,340	859	8,585
11000	786	7,860	1215	12,150	915	9.145
11500	809	8090	1247	12,470	939	9.385
12000	845	8,450	1296	12,960	977	9,770
12500	899	8,990	1374	13,740	1028	10,280
13000	966	9.660	1470	14,700	1073	10,730
13500	1015	10,150	1539	15,390	1103	11.030
14000	1057	10,570	1595	15,950	1125	11,250
14500	1109	11.090	1663	16,630	1143	11,425
15000	1153	11,530	1725	17,250	1150	11,500

15500	1170	11.700	1810	18,100	1163	11,630
16000	1171	11,710	1945	19,450	1167	11,670
16500	1173	11,730	2070	20,700	1171	11,710
17000	1174	11,740	2155	21,550	1262	12,620
17500	1178	11,780	2320	23,200	1286	12,860
18000	1178	11,780	2355	23,550	1435	14,350
18500	1178	11,780	2480	24,800	1376	13,760
19000	1178	11,780	2580	25,800	1435	14,350
1500	1178	11,780	2680	26,800	1551	15.510

c. Concrete Beams With CFRP Plate Reinforcement

In reinforced concrete beams with CFRP reinforcement, the dials are placed at three points, namely: 1/4 L left, 1/2L, and 1/4L right where the beam is loaded until cracks occur and the dial reading is constant.

Table 3. Test Results for Deriving Beams With CFRP PLATE Reinforcement (Ivandy Yoman, 2016)

BURDEN	1/4 LL		CL		1/4 LR	
(2P)	DIAL READING	DEFLECTION	DIAL READING	DEFLECTION	DIAL READING	DEFLECTION
Kg	x 0.01	Mm	x 0.01	Mm	x 0.01	Mm
500	25	0.250	50	0.500	32	0.320
1000	43	0.430	62	0.620	51	0.510
1500	61	0.610	94	0.940	72	0.720
2000	87	0.870	118	1.180	95	0.950
2500	107	1.070	143	1,430	112	1,120
3000	124	1,240	167	1,670	134	1,340
3500	153	1,530	194	1,940	177	1,770
4000	187	1,870	227	2,270	208	2,080
4500	211	2,110	253	2,530	229	2,290
5000	236	2,360	286	2,860	257	2,570
5500	254	2,540	310	3,100	284	2,840
6000	285	2,850	352	3,520	312	3,120
6500	324	3,240	386	3,860	358	3,580
7000	361	3,610	427	4,270	393	3,930
7500	396	3,960	463	4,630	427	4,270
8000	419	4,190	503	5,030	456	4,560
8500	447	4,470	555	5,550	487	4,870
9000	472	4,720	597	5,970	503	5,030
9500	496	4,960	650	6,500	538	5,380
10000	517	5,170	710	7,100	554	5,540
10500	548	5,480	763	7,630	579	5,790
11000	583	5,830	827	8,270	623	6,230
11500	629	6,290	863	8,630	674	6,740
12000	673	6,730	892	8,920	739	7,390
12500	707	7,070	953	9,530	783	7,830
13000	735	7,350	989	9,890	826	8,260
13500	758	7,580	1064	10,640	863	8,630
14000	789	7,890	1093	10,930	908	9,080
14500	803	8,030	1135	11.350	964	9,640
15000	847	8,470	1174	11,740	994	9,940
15500	873	8,730	1196	11.960	1053	10,530
16000	901	9.010	1235	12,350	1097	10,970
16500	934	9,340	1272	12,720	1153	11,530
17000	962	9,620	1318	13,180	1186	11,860
17500	995	9,950	1356	13,560	1227	12,270
18000	1038	10,380	1478	14,780	1264	12,640
18500	1071	10,710	1523	15,230	1289	12,890

19000	1137	11,370	1647	16,470	1347	13,470
1500	1183	11,830	1786	17,860	1386	13,860
20000	1257	12,570	1995	19,950	1438	14,380
20500	1324	13,240	2186	21,860	1487	14,870
21000	1418	14,180	2388	23,880	1557	15.570
21500	1574	15,740	2608	26.080	1645	16,450
22000	1648	16,480	2898	28,980	1708	17.080

C. Concrete Beams With Reinforced GFRP Wrap

In reinforced concrete beams with GFRP reinforcement, the dials are placed at three points, namely: 1/4 L left, 1/2L, and 1/4L right where the beam is loaded until cracks occur and the dial reading is constant.

Table 4. Test Results for Lowering Beams With GFRP Wrap Reinforcement (Fadel Muhammad, 2017)

BURDEN (2P)	**1/4 LL**		**CL**		**1/4 LR**	
	DIAL READING	DEFLECTION	DIAL READING	DEFLECTION	DIAL READING	DEFLECTION
Kg	x 0.01	Mm	x 0.01	Mm	x 0.01	Mm
500	33	0.330	65	0.650	55	0.550
1000	85	0.850	93	0.930	90	0.900
1500	126	1,260	133	1,330	128	1,280
2000	145	1,450	174	1,740	164	1,640
2500	186	1,860	225	2,250	210	2,100
3000	215	2,150	276	2,760	249	2,490
3500	287	2,870	325	3,250	314	3,140
4000	314	3,140	386	3,860	359	3,590
4500	374	3,740	438	4,380	403	4,030
5000	412	4,120	470	4,700	442	4,420
5500	483	4,830	525	5,250	507	5.070
6000	512	5,120	573	5,730	536	5,360
6500	572	5,720	643	6,430	612	6,120
7000	604	6,040	676	6,760	644	6,440
7500	659	6,590	723	7,230	693	6,930
8000	689	6,890	785	7,850	749	7,490
8500	733	7,330	825	8,250	813	8.130
9000	784	7,840	884	8,840	852	8,520
9500	826	8,260	925	9,250	910	9,100
10000	857	8,570	980	9,800	946	9,460
10500	883	8,830	1020	10,200	986	9,860
11000	917	9,170	1080	10,800	1067	10,670
11500	947	9,470	1130	11,300	1105	11,050
12000	989	9,890	1190	11,900	1154	11,540
12500	1030	10,300	1224	12,240	1196	11.960
13000	1074	10,740	1268	12,680	1232	12,320
13500	1108	11,080	1321	13,210	1298	12,980
14000	1147	11,470	1367	13,670	1318	13,180
14500	1178	11,780	1432	14,320	1385	13,850
15000	1204	12,040	1475	14,750	1446	14,460
15500	1249	12,490	1521	15,210	1486	14,860
16000	1332	13,320	1621	16,210	1553	15,530
16500	1457	14,570	1685	16,850	1621	16,210
17000	1574	15,740	1773	17,730	1685	16,850
17500	1649	16,490	1863	18,630	1724	17,240
18000	1694	16,940	1903	19.030	1756	17,560

18500	1736	17,360	1980	19,800	1783	17,830
19000	1783	17,830	2140	21,400	1828	18,280
1500	1827	18,270	2275	22,750	1849	18,490
20000	1856	18,560	2483	24,830	1865	18,650
20500	1872	18,720	2745	27,450	1885	18,850
21000	1893	18,930	2969	29,690	1910	19,100

3.2 CRACK PATTERNS OCCURRING IN CONCRETE BEAM

The crack pattern found in the test of these two beams is flexural crack. Flexural cracks are cracks that usually occur because the load exceeds the beam capacity. In this test, the first crack occurred when the load was 6 tons on the unreinforced beam and 12 Tons for beams with CFRP Wrap reinforcement, then followed by subsequent cracks reaching the ultimate load of 9 Tons for unreinforced beams and 22.5 Tons for beams with CFRP reinforcement and finally the beam collapses.

Figure 1. Bending Cracks in Concrete Beams with CFRP Wrap Reinforcement

4. CONCLUSION

Based on theoretical analysis and test results, it is proven that the addition of external reinforcement, both FRP (CFRP and GFRP) and steel plates can increase the ability of the beam to withstand bending much better than its normal condition (without reinforcement).

Among the four types of reinforcement that have been tested, it can be concluded that reinforcement with CFRP Wrap is the best solution to increase the ability of concrete beams to withstand bending, followed by GFRP Wrap and CFRP Plates and Steel Plates.

REFERENCES

Ali, Alnadher, JamalAbdalla, Rami Hawileh, Khaled Galal, 2014, *“CFRP Mechanical Anchorage for Externally Strengthened RC Beamsunder Flexure”*, UAE.

Muhammad, Fadel, Johannes Tarigan, 2017, “ Analisa dan Eksperimen Penggunaan *Glass Fiber Reinforced Polymer* Pada Perkuatan Lentur Balok Beton’ ,International Conference 4th Friendly City, Medan.

Yoman, Ivandy, Johannes Tarigan, 2016, “ Perbandingan Kekuatan Balok dengan Pelat Baja dan Fiber Reinforced Polymer (FRP)”, Skripsi, Medan.

Haloho,Manna G.D., Johannes Tarigan, 2015, “ Perbandingan Kekuatan Balok Beton tanpa Perkuatan dengan Balok Beton Menggunakan Pelat Baja yang Diangkur”, Skripsi, Medan.

ACI 440 Committee, 2008,*“Guide for the Design and Construction of Externally Bonded FRP Systems for Strengthening Concrete Structures”* American Concrete Institute, Farmington Hills, Michigan

Alami Fikri, 2010, *“Perkuatan Lentur Balok Beton Bertulang dengan Glass Fiber Reinforced Polymer”*, Seminar dan Pameran Haki.

Petrico G, Ireneus, 2013*,” Perbandingan Kekuatan Lentur Balok Beton Bertulang Dengan Menggunakan Perkuatan CFRP Dan GFRP”,* Malang

Seracino, R, 2004,*”Design of FRP and Steel Plated RC Structures”*,Elsevier Seracino, R, 2004, *“FRP Composites in Civil Engineering”,* A.A Balkema Publishers.

Gangarao, Hota V. S, Narendra Taly, P. V. Vijay, 2006,”*Reinforced Concrete Design With FRP Composites*”, London : CRC Press.

Bank, Lawrence C, 2006, *“Composites Construction Structural Design with FRP Materials”*, John Wiley & Sons, Inc.

Hollaway,L C, MB Leeming, 2000, *“Strenghtening of Reinforced Concrete Structure; Using Externally-bounded FRP composites in Structural and Civil Engineering”*, Cambridge Island.

Dipohusodo, Istimawan, 1994, *“Struktur Beton Bertulang”*, Jakarta : Gramedia Pustaka Umum.

McCormac, C. , Jack, 2004, *“Desain Beton Bertulang”* Edisi Kelima Jilid 1, Jakarta : Erlangga.

Nawy, G. , Edward, 2008, *“Beton Bertulang Suatu Pendekatan Dasar”*, Bandung : PT. Refika Aditama

Pangestuti Endah Kanti, Handayani Fajar Sri, 2009, *“Penggunaan Carbon Fibre Reinforced Plate Sebagai Tulangan Eksternal Pada Struktur Balok Beton”,* Semarang.

Giulio A., Luciano R, Simonelli G, 2005, *“ Modelling of Failure Mechanisms in RC Beams Retrofitted with FRP in Flexure.* Barcelona.