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A Study on the Creep behavior of FRP beam-strengthened RC beams

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***Abstract*— This paper presents the results of creep behavior experimental testing of FRP beam-strengthened concrete (RC) beams subjected to two different sustained loads. The specimen had dimensions of 400 mm(W) × 600 mm(D) × 6,000 mm(L) were used with or without externally strengthened FRP beam. Test results showed that additional long-term deflection from ACI equation for RC beams did not comply with the long-term deflection of RC beam strengthened with FRP beam.**

Keywords-creep; FRP beam; RC beams; long-term deflection; time-dependent factor

I. INTRODUCTION

The previous long-term behavior tests on FRP strengthened RC beams usually have been conducted with relatively small or scale-down member size due to the difficulty and safety of tests. So it is required to conduct an experiment of strengthened RC members with real size scale. Thus the aim of this study is to contribute a partial solution for the application of FRP materials in strengthening of RC building structures that have poor earthquake resistant.

II. EXPERIMENT

In this study, long-term experiment with real size beam with length(6,000 mm) has been conducted to evaluate the creep behavior of FRP beams-strengthened reinforced concrete beams.

A. Matetials

The following materials were used in this study: type I/II Portland cement, 19 mm maximum size of crushed coarse aggregate with a specific gravity of 2.64, natural sand with a specific gravity of 2.56 and a fineness modulus of 2.42. Mechanical property of the GFRP composite beam was presented in TABLE Ⅰ.

TABLE I. MECHANICAL PROPERTY OF THE GFRP COMPOSITE BEAM

System	*Cross section (mm^2)*	*Tensile strength (MPa)*	*Compressive elastic modulus (GPa)*	*Ultimate elongaion (%)*
Hybrid GFRP composite beam	1,312	418	28	2.1

B. Specimens

A total of five RC beams with dimensions of 400 mm(W) x 600 mm(D) x 6,000 mm(L) were used using for this experiment and 28-days' average concrete compressive strength was 22.8MPa. Each RC beam had been reinforced with five and two bars having 19mm size as tension and compression reinforcement, respectively as following FIGURE Ⅱ. All steel bars used in the RC beam had yielded at strength of 400MPa.

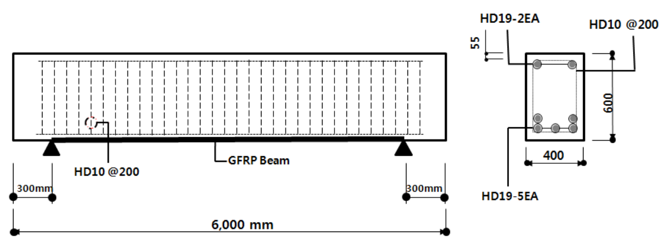

FIGURE Ⅰ DETAILS OF REINFORCED CONCRETE BEAM SPECIMEN

FIGURE Ⅱ COMPRESSIVE STRENGTH TEST

C. Loading and Test setup

Before long-term creep test, a static test was conducted on concrete beam without strengthening of FRP beam to determine its ultimate load. The result of static test presented that ultimate load of 250kN and maximum mid-span deflection of 24mm.

After a static test, for the 33% loading level, two RC beams with or without FRP beam strengthening was performed. For the 50% loading level, one RC beams without FRP beam strengthening and two RC beams with FRP beam strengthening were performed.

D. Test Preocedures

After loading, the deflections at mid-span and horizontal concrete tension strains at bottom of beams were measured at the following time intervals;

Step 1: once each 10min for the first 1 hour.
Step 2: once each 1 hour for the next 24 hours after step 1.
Step 3: twice each day for the next 1 month after step 2.
Step 4: once each day for the next month.
Step 5: once each 7 days

To measure the long-term deflection, a dial gauge was installed at the middle of beam for each specimen during the applying sustained loading levels as shown in FIGURE Ⅲ and FIGURE Ⅳ.

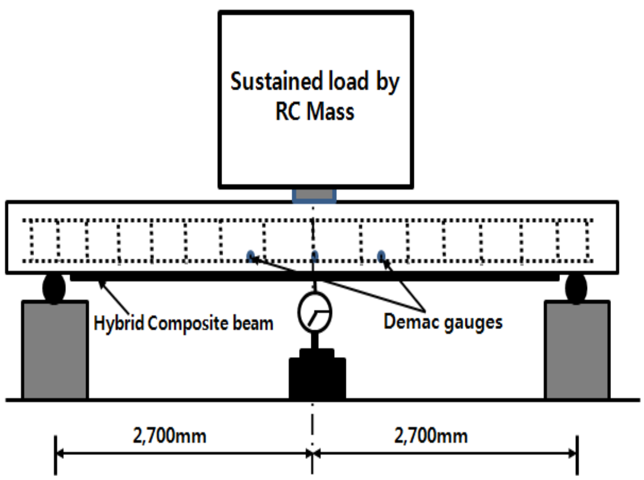

FIGURE Ⅲ SCHEMATIC TEST SETUP AND CREEP MEASUREMENT

FIGURE Ⅳ LONG-TERM TEST SET UP

III. RESULTS AND DISUCCIONS

A. Long-term deflection

The results of Long-term deflections for un-strengthened and strengthened beams under the two different sustained loads at the end of 1 year are presented in TABLE Ⅱ. From TABLE Ⅱ, the deflections of strengthened beams are approximately 15% and 38% lower than those of un-strengthened beams for 33% and 50% sustained loads, respectively. Also the result presented that the long-term deflection of strengthened beams after 1 year was approximately 245% and 176% higher than that of instantaneous deflection for 33% and 50% sustained loads, while the long-term deflection of un-strengthened beams was approximately 278% and 152% higher than that of instantaneous deflection for 33% and 50% sustained loads, respectively.

TABLE II. LONG-TERM DEFLECTION OF RC BEAMS STRENGTH WITH FRP BEAM

Time (days)	NHCB 33 (mm)	HCB 33 (mm)	NHCB 50 (mm)	HCB 50 (mm)
0	5.14	4.35	16.15	10.05
30	9.25	7.06	19.26	13.48
90	10.69	9.19	21.08	15.07
180	12.73	9.93	22.29	15.91
360	14.32	10.77	24.54	17.72

B. Long-term concrete tension strains

FIGURE Ⅴ shows that the results of average long-term horizontal concrete tension strains measured at the bottom surface of specimens during applying the two different load levels. From the results, the instantaneous strains of strengthened beams are approximately 3.6% and 2.6% lower than those of un-strengthened beams for 33% and 50% sustained loads, respectively. Also the result presented that the long-term strains of strengthened beams after 1 year was approximately 37.5% and 34.7% lower than those of un-strengthened beams for 33% and 50% sustained loads, respectively. For the strengthened beam, strain indicates that approximately 28.5% and 27.0% of the total strain at 1 year occurred in the first 24 hours, and 35.8% and 34.6% occurred in the first 1 month under 33% and 50% load levels, respectively. For the un-strengthened beam, strain indicates that approximately 19.7% and 18.5% of the total strain at 1 year occurred in the first 24 hours, and 24.0% and 24.23% occurred in the first 1 month for 33% and 50% load levels, respectively.

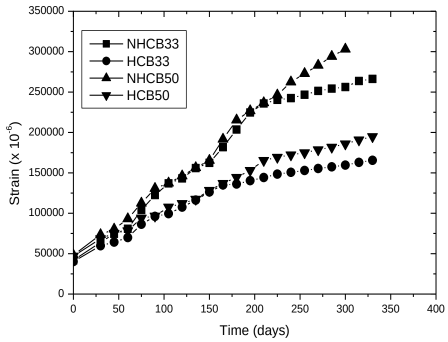

FIGURE V HORIZONTAL STRAIN VARIATION UNDER SUSTAINED LOADING

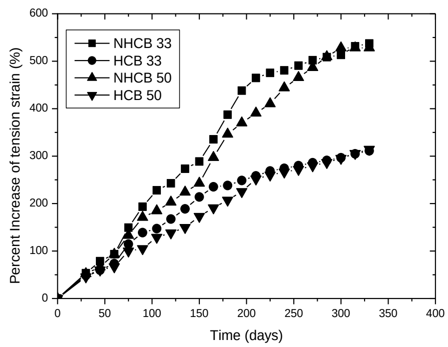

FIGURE VI PERCENT VATIATION OF HORIZONTAL STRAINS

TABLE III. OBTAINED TIME-DEPENDENT FACTOR ξ

Load duration (day)	Specimen				ACI	Chami	Arockiasamy
	NHCB33	HCB33	NHCB50	HCB50			
30	0.90	0.70	0.22	0.386	0.50	0.40	-
90	1.22	1.25	0.34	0.565	1.00	0.60	0.70
180	1.67	1.45	0.43	0.660	1.20	0.80	0.85
270	1.87	1.57	0.53	0.750	-	-	-
360	2.01	1.668	0.59	0.848	1.40	1.00	1.15

C. Evaluation of long-term deflection

Several researchers have investigated the long-term deflections for concrete beams with fiber reinforced polymer composite materials. The ACI 318 code 9.5.2.5 can be used to calculate the additional long-term deflection resulting from creep and shrinkage of steel reinforced concrete beams using multiplying the instantaneous deflection by a factor. The additional long term deflection (Δ_{add}) for beams reinforced with FRP bars can also similarly be determined by multiplying the immediate deflection (Δ_i) as follows;

$$\Delta_{add} = \frac{\xi}{1+50\,\rho'}\,\Delta_i \tag{1}$$

Where, ξ = time-dependent factor for sustained load, ρ' = compression reinforcement ratio of steel bars. The TABLE III shows the early values of time-dependent factor for about 1 year with other researchers. The obtained time-dependent factor (ξ) in this investigation shows that beams subjected to higher load level resulted in lower value in the both un-strengthened and strengthened beams. It is also shows that the obtained the time-dependent factor of un-strengthened beam is higher than that of the strengthened beam at the 33% sustained load level while the time-dependent factor of strengthened beam showed slightly higher than that of the un-strengthened beam at the 50% sustained load level. It is need to more tests and studying for verifying such a difference up to loading levels.

From these results, it can be concluded that the time-dependent factor of FRP strengthened RC beams is strongly dependent with types of FRP, strengthened method and sustained loading levels. Also ACI equation for steel reinforced concrete beams does not comply with the time-dependent behavior of FRP strengthened reinforced concrete beams.

Ⅳ. CONCLUSION

(1) For the strengthened beams under 33% sustained load, the deflection at 1, 3, 6 and 12 months were approximately 24%, 14%, 22% and 25% lower than those of un-strengthened beam, respectively. For the strengthened beams under 50% sustained load, the deflection at 1, 3, 6 and 12 months were approximately 30%, 29%, 29% and 28% lower than those of un-strengthened beam, respectively. Thus, it can be concluded that reinforced concrete beam strengthened by FRP beam not only reduces the instantaneous deflection but it was also more effective in controlling the long-term deflection under the sustained load.

(2) It was observed that the long-term strains of strengthened beams after 1 year was approximately 37.46% and 34.66% lower than those of un-strengthened beams for 33% and 50% sustained loads, respectively. For the strengthened beam, strain indicates that approximately 28.45% and 26.96% of the total strain at 1 year occurred in the first 24 hours, and 35.80% and 34.56% occurred in the first 1 month under 33% and 50% load levels, respectively. For the un-strengthened beam, strain indicates that approximately 19.70% and 18.50% of the total strain at 1 year occurred in the first 24 hours, and 24.0% and 24.23% occurred in the first 1 month for 33% and 50% load levels, respectively.

V. ACKNOWLEDGEMENT

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