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Study on Flexural Performance of One-Way RC slab strengthened by FRCM

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ABSTRACT

Fabric reinforced cementitious matrix (FRCM) is an external strengthening method for deteriorated existing reinforced concrete (RC) structures, in which fabrics are embedded in a cementitious matrix. To investigate the flexural performances of strengthened RC slabs, an experimental study was conducted for one-way RC slabs strengthened by carbon FRCM with key variables such as the number of fabrics and spacing of fabric layers embedded in mortar. In addition, a cross-sectional analysis was applied to estimate the flexural behaviors of specimens with three different material models of FRCM which were established based on the properties of fabric and direct-tensile test results of FRCM. The test results showed that the flexural performance of specimens strengthened by FRCM increased by 21~44% compared to the control specimen. It was found that the sectional analysis considering the stiffness of FRCM and ultimate strength of carbon fabric well captures the flexural behavior of slab specimens strengthened by FRCM. Moreover, nominal and design flexural strength calculated by the current design code provided conservative results compared to the flexural capacity obtained from the experimental study.

1. INTRODUCTION

Reinforced concrete (RC) structures gradually deteriorate in function and structural performance due to various internal and external factors over time. Then, the structures should be repaired and strengthened, and sometimes reconstruction is considered if required (Cho et al. 2015). FRP (fiber reinforced polymer) sheet has been used to strengthen RC structures, but since FRP should be accompanied by epoxy to bond the FRP to a substrate, it is hard to apply in high temperature and humidity circumstances.

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Moreover, it's vulnerable to fire because the FRP surface is exposed to the outside air. Recently, to overcome the shortcomings of the FRP method, research on fabric reinforced cementitious matrix (FRCM) is actively underway. FRCM is addressed with fabrics embedded in the cementitious matrix, thus fabrics can be prevented from high temperatures such as fire, and it can be applied to the wet surface unlike the typical FRC method (Babaeidarabad et al. 2014; Ju et al. 2014). In this study, one-way RC slabs strengthened by FRCM were tested to investigate their flexural performance. A total of 4 slab specimens including the control RC specimen were investigated and they were estimated by sectional analysis considering the material model of FRCM.

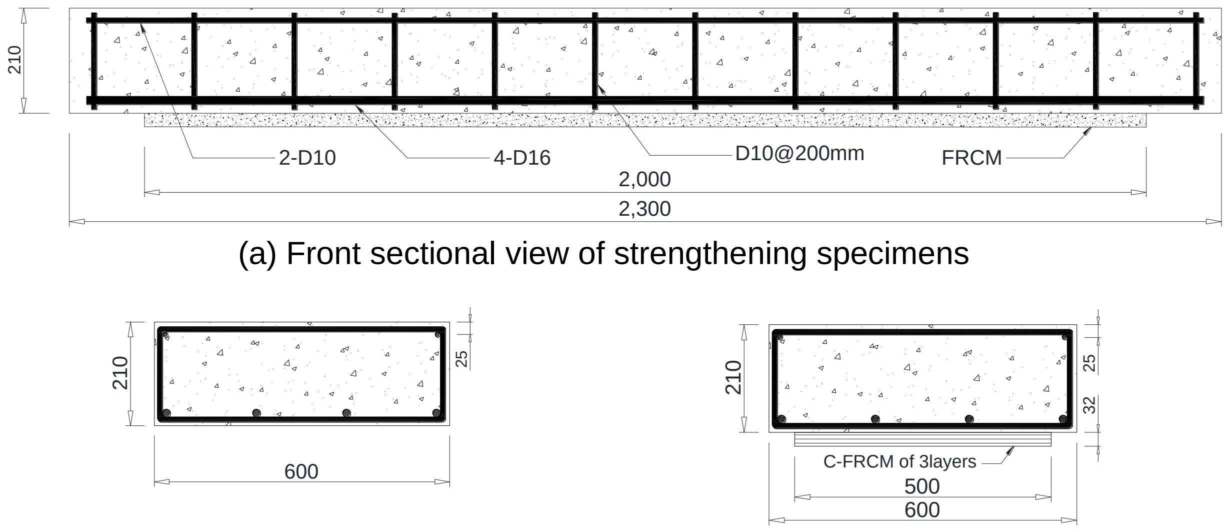
2. EXPERIMENTAL STUDY

2.1 Experimental method and materials

Carbon fabric was used for the strengthening system of FRCM, and its material properties are presented in Table 1. Fig. 1 shows the details of the RC slab specimen in which the key variables are the layer number and spacing of carbon fabrics. The flexural test was conducted under two-point loading in a simply supported condition.

Table 1 Material properties of carbon fiber

Fiber Type	Width (mm)	Area (mm^2)	Tensile strength (MPa)	Ultimate tensile strain	Elastic modulus (GPa)
Carbon	500	0.419	1,753	0.0126	139



(a) Front sectional view of strengthening specimens

(b) Section of SRC (c) Section of SC3

(d) Section of SC4 (e) Section of SR6

Fig. 1 Detail of specimens

2.2 Experimental results

Table 2 presents experimental results including load and deflection at cracking, yielding, and maximum loads. The strengthened slab specimens SC3, SC4, and SC6 showed an increase in cracking load control specimen as much as 55%, 100%, and 181% of maximum load of the control specimen, SRC, respectively. Also, the strengthened specimens showed maximum load as much as 21%, 23%, and 44% of that of the SRC specimen, respectively.

Table 2 Test results

Specimen	Load			Deflection at loading point			Note
	P_{cr}	P_y	P_{max}	δ_{cr}	δ_y	δ_{max}	SE
	kN	kN	kN	mm	mm	mm	%
SRC	13.74	101.18	117.66	1.84	17.31	65.61	-
SC3	21.32	121.80	142.22	0.83	14.61	20.72	1.21
SC4	27.44	119.09	144.93	1.44	11.25	18.87	1.23
SC6	38.57	137.94	169.66	1.34	12.06	20.69	1.44

Note. P_{cr}: cracking load, P_{cr}: cracking load, P_y: yielding load, P_{max}: maximum load, δ_{cr}: cracking deflection at mid-span, δ_y: yielding deflection at mid-span, δ_{max}: deflection at maximum load at mid-span, SE: strengthening effect defined as the ratio of P_{max} of *SC* specimens to P_{max} of SRC

3. SECTIONAL ANALYSIS

Sectional analysis was carried out to estimate the test results of one-way RC slab specimens strengthened by FRCM, and the analysis results were compared with the test results in the form of moment-curvature curves. The analysis considers force equilibrium, strain compatibility, and material models of concrete, steel rebars, and FRCM. Especially, three material models for FRCM were established considering:

① Combination of direct tensile test results of carbon FRCM (Choi et al. 2021) according to layer number and type. (Analysis 1).

② Tensile test results of carbon fabric presented in Table 1 (Analysis 2).

③ Initial stiffness from ① and tensile strength from ② (Analysis 3).

The first model assumes that cementitious matrix is already cracked at the ultimate state in the flexural behavior then its contribution can be neglected. Thus, the secant modulus from origin to maximum load in the direct tensile stress-strain curve of FRCM was taken for the material model, and the stress-strain curves for FRCMs with different layer numbers and types were combined according to the configuration that is applied to the slab strengthening. The second one is simply neglecting the cementitious matrix but considering the material properties of carbon fabric only. In the last model, the initial stiffness of FRCM was obtained from the direct tensile test of FRCM, and the tensile strength of carbon fabric was taken as the maximum tensile strength of FRCM.

Fig. 2 shows the analysis results based on the material models presented above. The experimental results are compared with the analysis results and nominal flexural strength by ACI 318 (2019) was also presented. Black solid line and red lines refer to test result and analysis results, respectively.

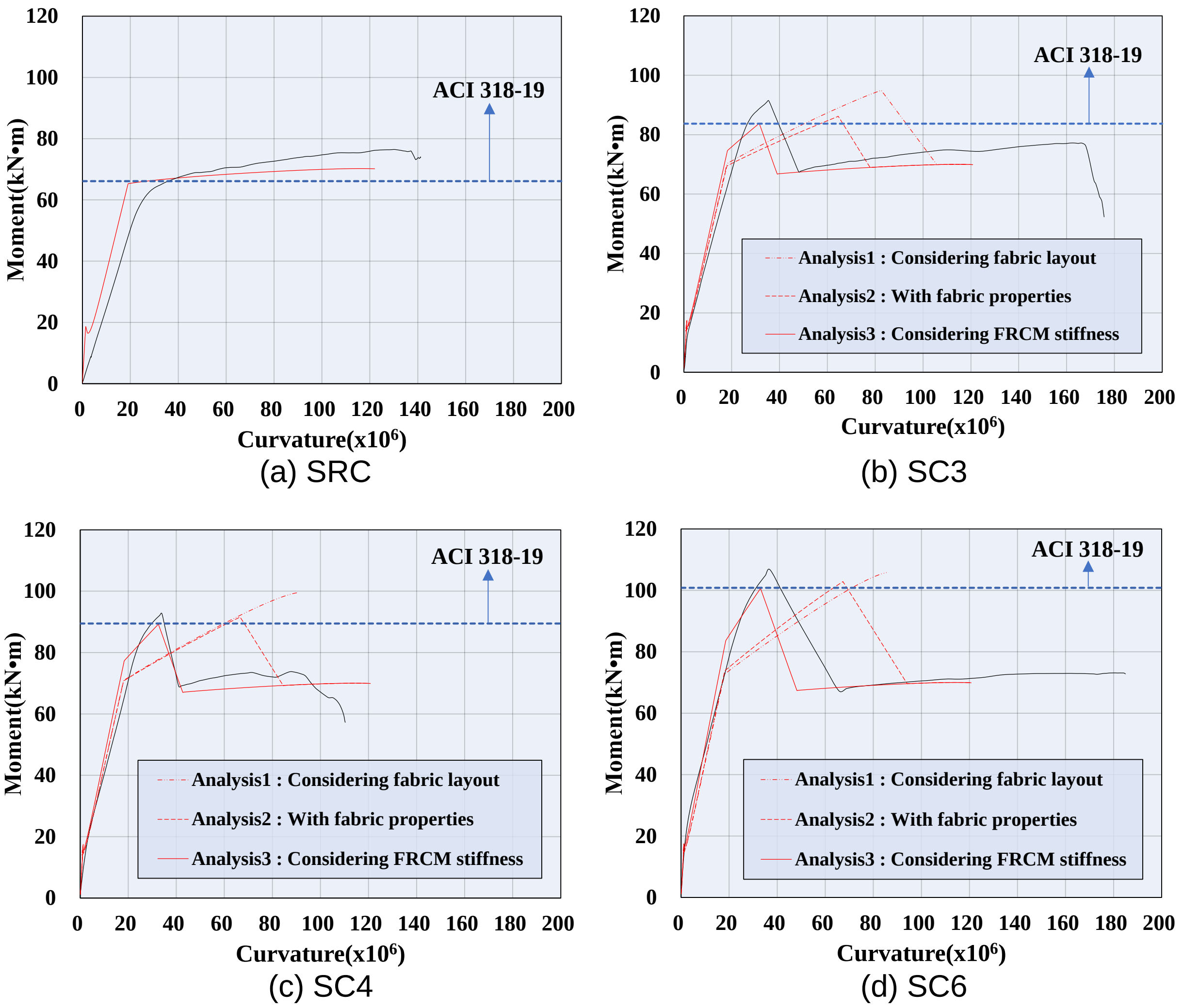


Fig. 2 Comparison of analysis and experiment results

4. CONCLUSIONS

Analysis 3 most accurately estimated the moment-curvature curve of specimens strengthened by FRCM. Especially, it well-captured the post-peak behavior after fracture of FRCM. Also, the maximum strength of the specimens was greater than the nominal flexural strength calculated by ACI 318 (2019). The investigation from test and analysis in this study suggests that the bond between FRCM and RC slab was sufficient so that the FRCM system can fracture leading to an increase in strength by the strengthening method without slippage or reduction in stiffness. Thus, although the cementitious matrix of FRCM can be rarely counted for the contribution of maximum strength, it significantly affects the initial stiffness of the flexural performance of the strengthened slab. For future research, it is recommended to conduct experimental and analytical studies on the key influencing factors such as type, layer spacing, and the number of the fabric.

REFERENCES

ACI Committee 318. (2019), Building Code Requirements for Reinforced Concrete and Commentary. American Concrete Institute, Detroit.

Babaeidarabad, S., Loreto, G., and Nanni, A. (2014), “Flexural Strengthening of RC Beams with an Externally Bonded Fabric-Reinforced Cementitious Matrix”, *Journal of Composites for Construction*, **18**(5), 04014009.

Cho, H. C., Lee, D. H., Ju, H., Kim, K. S., Kim, K. H., and Monteiro, P. J. M. (2015), “Remaining Service Life Estimation of Reinforced Concrete Buildings Based on Fuzzy Approach”, *Computers and Concrete*, **15**(6), 879-902.

Choi, D., Vachirapanyakun, S., Ochirbud, M., Naidangjav, U., Ha, S., and Kim, Y. (2021), “Tensile Performance, Lap-Splice Length and Behavior of Concretes Confined by Prefabricated C-FRCM System”*, Internaitonal Journal of Concrete Structres and Materials,* **15**(45), 761-778.

Ju, H., Lee, D. H., Cho, H. C., Kim, K. S., Yoon, S., and Seo, S. Y. (2014), “Application of Hydrophilic Silanol-Based Chemical Grout for Strengthening Damaged Reinforced Concrete Flexural Members”, *Material*, **7**(6), 4823-4844.