Long-term Structural Performance of Simplified Slab System with Steel Deck-plate and SFRC

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Abstract

Slab is one of the most important members in building because it covers the largest amount of total structural members. The structural type and construction method of a slab can have a large influence on the construction period and the amount of structural materials. This study investigates a simplified slab system with simple construction procedures. The simplified slab system consists of steel deck plate and steel fiber reinforced concrete (SFRC) without conventional reinforcing bar placing in construction field. The purpose of this study is to evaluate the long-term structural performance of a simplified slab system that replaces the form work and tensile reinforcement using structural deck-plate and replaces the temperature reinforcement using steel fiber reinforced concrete. Two continuous-span slab specimens were tested and analyzed in the view-point of long-term serviceability such as deflection and crack, and evaluated the structural capacity and behavior.

Keywords: slab system, deck-plate, SFRC, long-term performance

1. Introduction

Slab is one of the most important members in building structures because it covers the largest area of the building. The structural type and construction method of the slab can have a large influence on the construction period and the amount of structural materials.[1-2]

This study investigated a simplified slab system with simple construction procedures. The simplified slab system consists of a composite steel deck plate and steel fiber reinforced concrete (SFRC) without conventional steel reinforcing bar. Placing of the reinforcing bars is not required in the construction procedure of the slab. In this system, the composite steel deck plate replaces the tensile reinforcement, temporary concrete forms and shores, which results in simpler construction. The steel fibers can replace the temperature reinforcement of the slab, and reduce cracks.[3] Previous research results indicated that the overall flexural performance of the simplified slab system was suitable in slab members, even though reinforcing bars were not used. It has higher flexural capacity and stiffness than normal RC slab in the simply supported slab specimens, and improves the crack resistance performance. [4]

The purpose of this study is to evaluate the long-term structural performance of a simplified continuous slab system because short-term characteristics of simply supported it have been confirmed in previous studies. Serviceability such as deflection and crack development was tested and evaluated in the viewpoint of long-term loading conditions.

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2. Experimental Program

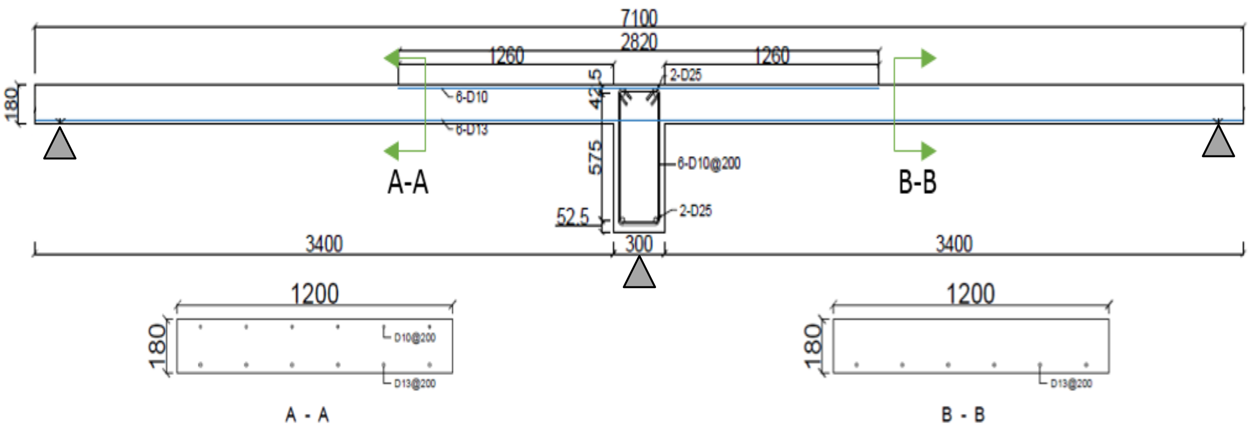
2.1. *Test plan and method*

Two continuous slab specimens were planned and tested for evaluating their long-term structural characteristics. The details of test specimens are summarized in Table 1 and Figure 1. All slab specimens were designed as a two continuous span slab to be supported by a beam in the middle span. The first specimen was a conventional one-way RC slab with top and bottom reinforcing bars. Yield strength of reinforcing bars was 400 MPa. The second one was a simplified slab system with steel deck-plate and SFRC without reinforcing bars.

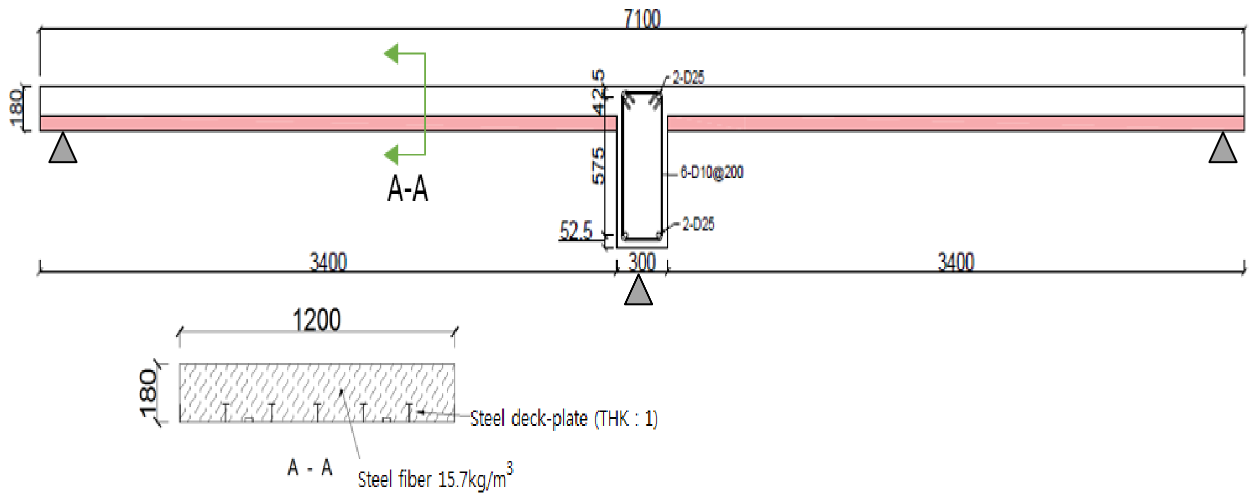
Test was performed in three stages. The first stage was to fabricate the specimen and to observe the crack propagation while curing until the concrete compressive strength was developed. In the second stage, crack developments and deflections were observed under the long-term loading condition by concrete blocks over a period of 100 days as shown in Figure 2. At the final stage, the structural recovery was observed after removing the long-term load.

Table 1 Detail of test specimens

Specimen	Length (mm)	Width (mm)	Thickness (mm)	f_{ck} (MPa)	Steel fiber (kg/m^3)	Re-bar (Bottom/Top)	Deck-plate
RC	7100	1200	180	24	None	6-D13/6-D10	None
SS					15.7	None	1mm Thk.



(a) RC



(b) SS

Fig. 1 Test specimen

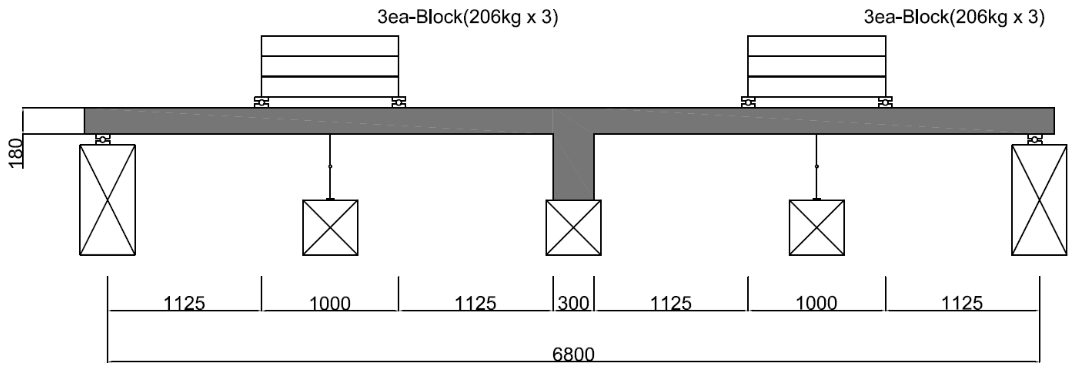


Fig. 2 Long term loading concept diagram

2.2. Materials

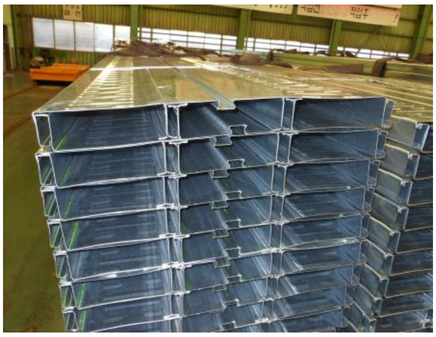
The most important materials in simplified slab system are deck-plate and steel fiber. The role of deck-plate is to replace the temporary form, shore and bottom reinforcement. Structural composite steel deck plate in this study was made by SGC400 in KS D 3506 which has 295N/mm^2 yield strength, and 400N/mm^2 tensile strength. Section properties of deck-plate are shown in Table 2. The steel fiber was an end hooked type with an aspect ratio 80. Table 3 shows the mechanical properties of steel fiber, and Fig. 3 shows the shape of the constituent materials.

Table 2 Material properties of deck-plate

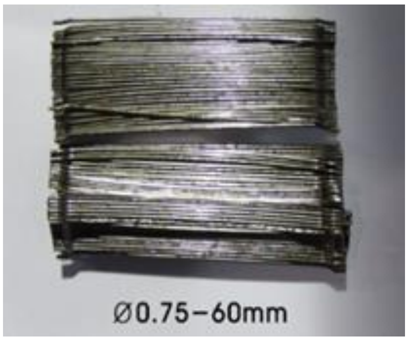
Standard	Mechanical property			Thickness (mm)	Weight (kg/m^2)	Section property (1m)		
	Yield strength (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)			Area (mm^2)	Neutral axis (mm)	Moment of inertia (mm^4)
KS D 3506	295	400	18	1.0	15.45	1,947	17.72	948,000

Table 3 Mechanical properties of end-hook type steel fiber

Diameter (mm)	Length (mm)	Aspect ratio (L/D)	Density (g/cm^3)	Elastic modulus ($\times 10^3$ N/mm^2)	Tensile strength (N/mm^2)
0.75	60	80	7.85	200	The average over 500



(a) Deck-plate



(b) steel fiber

Fig. 3 Materials

3. Results and Discussion

The experimental results were mainly evaluated in terms of cracks and deflection in the slab specimens. In the first stage, cracks due to drying shrinkage and self-weight were measured by the crack measuring instrument at the upper surface of the specimen after curing was carried out. In the second stage, concrete block corresponding to half of the live load and additional dead load was loaded at the center of the slab after 28 days of concrete curing, and the progress of deflection and cracking was observed. Fig. 4 is a photograph showing a long-term loading test, and Fig. 5 is a photograph of crack measurement.

Fig. 4 Long-term loading test

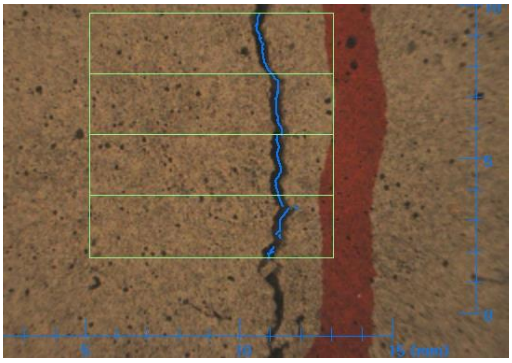
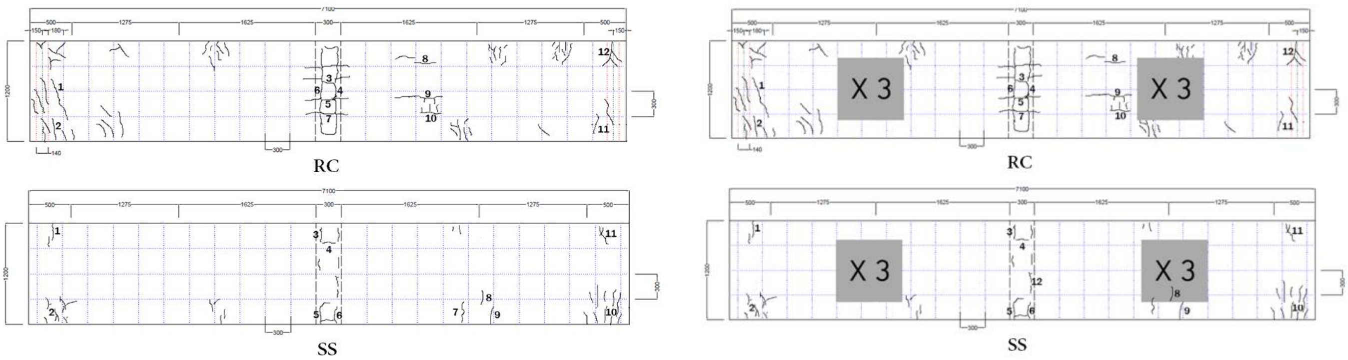


Fig. 5 Crack measurement

Fig. 6 shows the schematic diagram of cracking behavior just before and after long-term loading test. As shown in the figure, it can be seen that the number of cracks in SS specimen is remarkably reduced compared with that in conventional RC specimen. And the crack width in the negative moment area which is the upper part of the center supporting beam was the largest in both specimens.



(a) Age 27 (b) Age 30

Fig. 6 Crack pattern and development

Fig. 7 shows the number of cracks caused by shrinkage and dead load in each specimen before the long-term loading experiment. The number of cracks in normal RC slab was 37, and the number of it in SS slab was 6, showing about 16% cracks compared to RC slab cracks. The number of cracks in the two specimens increased sharply after the 11th day of age, which is consistent with the fact that the strain of steel fiber reinforced concrete changes rapidly around 10 days in Choi et al. [5] Since then, the development of crack numbers has grown slowly until the 28th day.

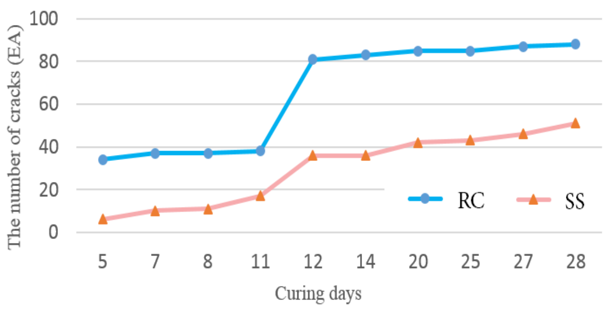


Fig. 7 Number of cracks

Fig. 8 shows the crack width change in negative moment region according to the loading conditions. All specimens were loaded with concrete blocks at 28 days of age, and the load was removed at 138 days. As a result of observing the crack with the largest crack width in the negative moment area, the crack width of the SS specimen was only about 65% of the RC specimen crack width before additional load was applied. After the concrete blocks were loaded, the crack width of the negative moment area of SS specimen increased rapidly, and the crack width was larger than that of RC specimen after 55 days of age. However, number of cracks and crack width other than negative moment area of SS specimen were evaluated to have fewer cracks and crack width than normal RC specimen. In other words, the load resistance of the SS specimen in positive moment area was evaluated to be superior to that of the RC specimen due to the deck-plate effect. From these results, it can be concluded that the steel fiber reinforced concrete deck-plate slab itself without reinforcement is not expected to have efficient resistance against the load in the negative moment area, but the resistance against drying shrinkage is excellent.

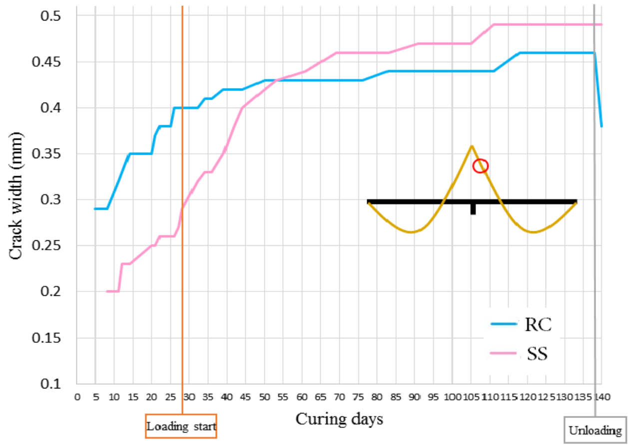


Fig. 8 Crack width development in negative moment area

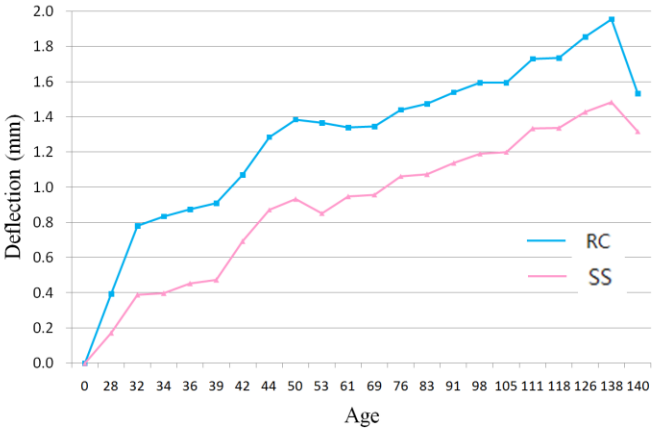


Fig. 9 Long-term deflection

Fig. 9 shows the measured long-term deflection of the two slab specimens. In the viewpoint of overall deflection behavior, the deflection of both slab specimens continuously increased until the concrete blocks were was removed. The overall shape of deflection pattern was similar. Due to the stiffness effect of deck-plate, deflection of the SS specimen was less overall than those of the RC specimen. The amount of elastic deflection of SS specimen was only about 50% of that of the RC specimen. The amount of deflection increase due to the long-term loading showed a similar tendency, but the increase of long-term deflection in SS specimen was slightly smaller than that of RC.

4. Conclusions

The conclusions of the two continuous slab long-term loading tests are as follows.

(1) The cracks generated in the SS specimen before long-term loading were less than half of the RC specimen and the crack width was also smaller than RC slab. This result indicates that the crack resistance of the steel fiber reinforced concrete was superior to that of the normal reinforced concrete slab.

(2) The steel fiber reinforced concrete deck-plate slab itself without reinforcement is not expected to have efficient resistance against the load in the negative moment area, but the resistance against drying shrinkage is excellent than normal reinforced concrete slab.

(3) The overall shape of long-term deflection pattern was similar in two specimens. But, the amount of deflection in the SS specimen was less overall than that of the RC specimen because of the stiffness effect of deck-plate. The amount of elastic deflection of SS specimen was only about 50% of that of the RC specimen. And, the amount of deflection increase due to the long-term loading showed a similar tendency, but the increase of long-term deflection in SS specimen was slightly smaller than that of RC.

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