EXPERIMENTAL ANALYSIS OF SANDWICH PANELS USING TEXTILE REINFORCED CONCRETE FACES AND LIGHT WEIGHT CONCRETE CORE

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Summary: *Textile reinforced concrete (TRC) combines a fine grained concrete with textile fabrics to create a thin structural layer providing high tensile and flexural performances. Thank to these advantages, TRC systems are suitable for the outer layers in sandwich structures. In this paper, the flexural performance of sandwich panels is presented by means of experimental results. The sandwich panels use three layers of different materials: an TRC layer for the bottom skin, lightweight concrete for the core material and fine grained concrete for the top face.*

Keywords: *Textile reinforced concrete, light weight concrete, sandwich panel...*

I. INTRODUCTION

Recently, carbon and glass textiles have emerged as a promising alternative material for reinforcement of concrete structures. These textiles are extremely strong in tension, non-corrosive, and can thus be used to eliminate the corrosion problem invariably encountered with conventional reinforcing steel [4]. Textile reinforced concrete is a combination of high performance fine grained concrete and high tensile strength textile reinforcement, which can be used in form of millimeter thin layers.

Due to the suitability of the properties for thin layers, TRC has been successfully applied for strengthening existing buildings as well as fabricating new structural elements. A wide range of prefabricated products using TRC exists, including exterior cladding panels, parapet walls, and sandwich panel v.v. Research on TRC-based sandwich panels has also been conducted by Hegger [1], Schneider [2] and Nguyen Viet Anh [3] v.v. These panels comprise TRC layers with difference core materials, such as plastic foams or lightweight concrete. Fundamental work on sandwich panels with thin-walled TRC facings has been done by Hegger [1]. Hegger tested different configurations of TRC sandwich panels, which comprised a core layer made of polyurethane foam and two Ankali Resistance-glass TRC skin layers. Schneider [2] carried out the three- and four-point bending tests with sandwich specimens consisted of 8 mm thick TRC facings with an 80-mm thick insulating core. Schneider used different textile materials (AR-glass and carbon) and incorporated different core materials (PU of varying densities or aerated concrete). Nguyen Viet Anh [3] developed a new type of sandwich beams using TRC skins and Expanded Polystyrene Concrete (EPC) in the core. The failure process detected by the experiments showed that the bond between the layers of the experimental specimens existed until the failure. Hence, using the selected EPC for the core, the bond resistance between the layers of TRC-EPC sandwich beams is ensured without any shear connector device.

In this research, the proposed hybrid panel is a sandwich structure consisting of three layers with different materials: TRC for the tension skin, lightweight concrete (LC) as a core material and fine grained concrete (FGC) for the compression skin. The objective of the test program was to investigate the flexural performance of sandwich panels loaded up to failure. This includes load – deflection behavior, crack patterns, ultimate capacities, and modes of failure.

II. EXPERIMENTAL TESTS

2.1. Test specimens

In this experiment, nine TRC-LC sandwich beams were tested. Three types of rectangular sandwich panel had the different dimensions and textile configurations, as shown in Figure 1 and Table 1. All experimental specimens had three layers, including: fine grained concrete in the top layer, carbon textile reinforced concrete in the bottom skin and the lightweight concrete for the core. The bottom skins consist of 2 carbon textile layers in specimen SW3, and 3 layers in specimen SW4 and SW5.

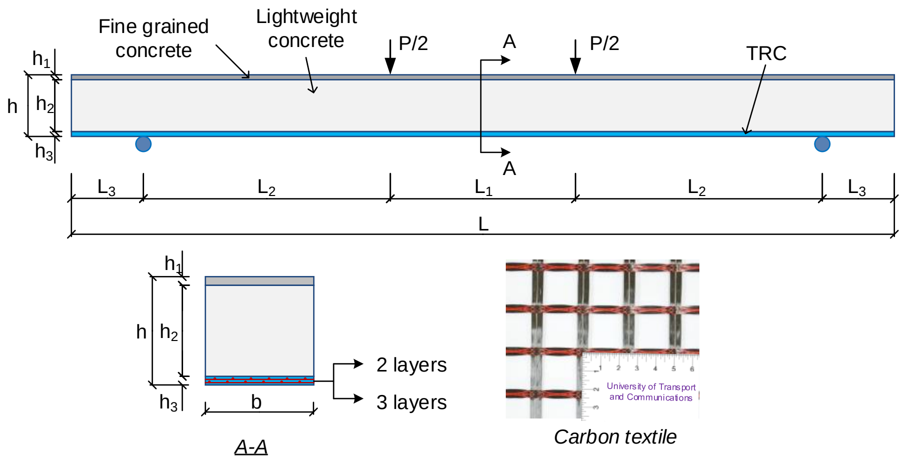


***Figure 1**. Test specimens*

***Table 1.** Dimensions of sandwich panels (unit: mm)*

`	Width	Depth				Length				No. of textile layers
		Total depth	Fine grained concrete	LWC	TRC	Total length	Distance between loading points	Distance between loading point and support	End part	
	b	*h*	*h1*	*h2*	*h3*	*L*	*L1*	*L2*	*L3*	*n*
SW 3	150	150	12	126	12	2000	600	500	200	2
SW 4	150	150	12	122	16	2000	600	500	200	3
SW 5	150	100	10	74	16	1600	400	500	200	3

2.2. Material

The concrete used to manufacture all beams was mixed, cast and cured in the laboratory. The compositions of fine grained concrete and lightweight concrete were shown in table 2 and table 3. The measured compressive strength of the FGC was 64.5 MPa. The compressive strength and the density of LC was 18.6 MPa and 1420 kg/m^3, respectively.

Table 2. *Composition of fine grained concrete (unit: kg)*

Cement	Fly ash	Silica fume	Water	Quartz sand	Superplasticize
480	154	41	211	1380	12.1

Table 3. *Composition of lightweight concrete (unit: kg)*

Cement	Keramzit	Water	Sand	Superplasticize
440	289	243	336	4.4

The carbon textile product Sigratex Grid 350 with a fineness of 1600 tex was used in this study. The distance between the rovings is 25 mm in longitudinal direction as well as transversal direction (figure 1). The textile had the tensile strength of 3550 MPa, while elastic modulus was 225 GPa.

2.3. Test setup

All test specimens were air cured in indoor conditions for 28 days. The beams were tested with four-point bending, using displacement controlled method, with loading rate of 1 mm/min. Schematic view and a view of the test setup are shown in figure 2. Two LVDTs were installed on the bottom surface of the beams to measure their deflections during the test. Moreover, strain gages were used to record concrete strains at top and bottom surfaces, intersection between these layers. The arrangement for the beams testing with LVDT and strain gage locations is also presented in figure 2. All the tests were conducted in the Structural Engineering Laboratory at University of Transport and Communications, Vietnam.

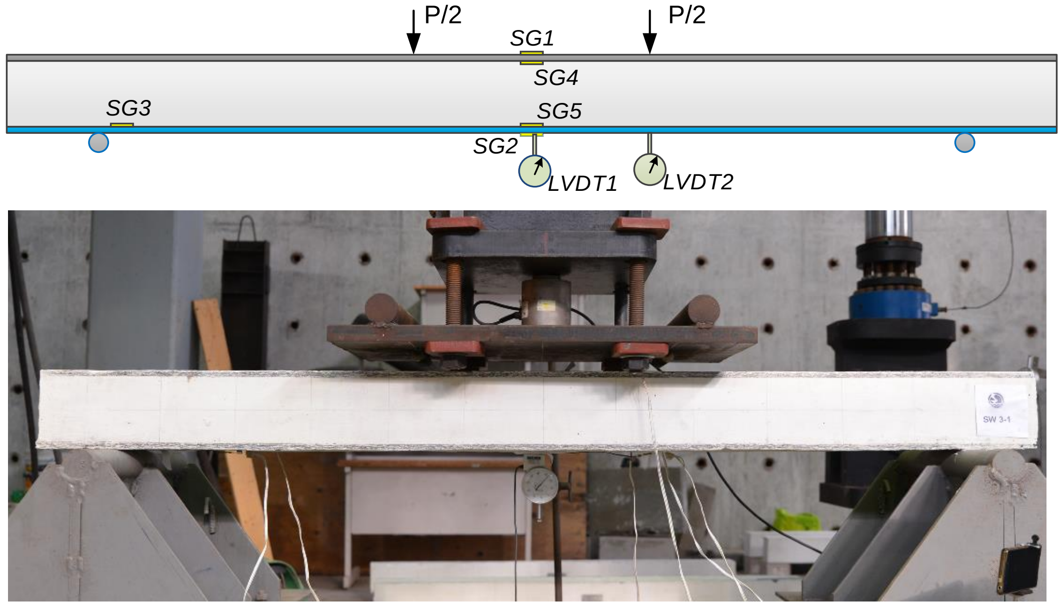


Figure 2. *Test setup*

2.4. Test results

The load versus deflection curves are presented as shown in figure 3 and figure 4 for all test beams. In addition, final modes of failure and crack patterns are illustrated in figure 6. Table 4 shows a summary of the ultimate load of all test specimens.

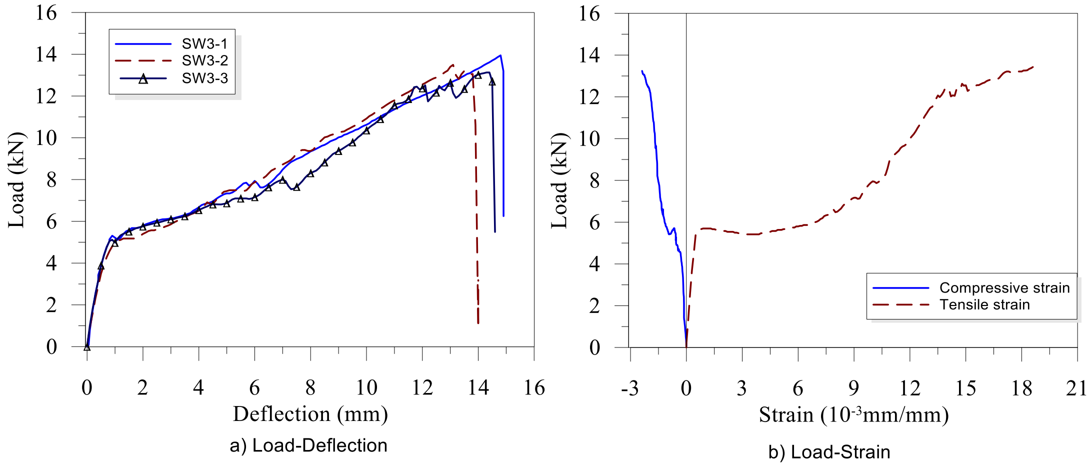
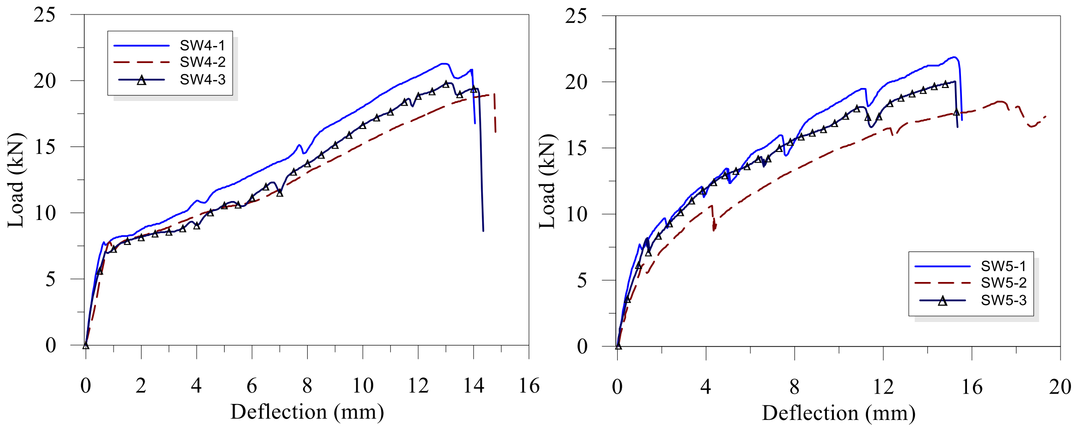


Figure 3. *Experimental results of sandwich panel SW3*

Figure 3-a shows the load deflection behavior of the three TRC-LC sandwich panels. The behavior was linear up to the initiation of the first flexural crack in the TRC bottom layer, followed by a non-linear behavior up to failure. After the first crack, the stiffness of specimens decreased dramatically. Due to the bond between textile roving and concrete, forces were initiated in the concrete, until the tensile strength of the FRC is reached once more. With an increasing of the tension force, additional cracks occurred, resulting the continuous multiple cracks (figure 6). By a load increase, the filaments are strained up to their tensile strength. In this stage, the crack pattern was stabilized, no further cracks occur, but the biggest crack expanded larger (figure 6). Since the carbon textile has no plastic capacity, the sandwich panels failed when the reinforcement reach their tensile strength. All two textile layers were continuously broken in a brittle manner. Before breaking, there were no sign of compressive failure in top edge of sandwich beams.

The relationships between load and strains on compressive and tensile edges are displayed in figure 3-b. It can be seen that, the compressive strain in top edge was approximately 2.5‰, smaller than the ultimate strain of concrete in compression (3‰, according to ACI 318-14). On the other hand, the tensile strain of FGC on bottom edge (a few millimeters below textile layers) reached to 18‰. This value was suitable to experimental results, representing the tensile failure of textile reinforcements.



a)SW4 b) SW5

Figure 4. *Load – deflection results of specimen SW4 and SW5*

Figure 4 displays load and deflection relationship of specimen SW4 and SW5. There specimens exhibited similar performances which were observed for the beams SW3. The comparison of load and deflection between specimens SW3-1, SW4-1 and SW5-1 is shown in Figure 5. Due to the increase of the textile reinforcement ratio, the stiffness and strength of sandwich beams increased. At earliest stage (i.e. before flexural cracking), the load–deflection curves are close to each other. A slightly greater cracking load is observed at the beam SW4-1 (3 layers of textile). After cracking, the specimen SW4-1 exhibited larger stiffness compared to specimen SW3-1. The average ultimate load of SW4 specimens was increased approximately 50% compared with SW3. As can be seen in Figure 5, the depth of the sandwich panels also affects to the stiffness. Specimens SW4-1 and SW5-1 failed at the similar deflection (about 15.4 mm), however the ratios between deflection and span are 1/120 and 1/86, respectively. Table 4 also show that, the ultimate loads for each type of sandwich beams are not quite consistent. This could be due to the unstableness of the bond between textile and fine grained concrete.

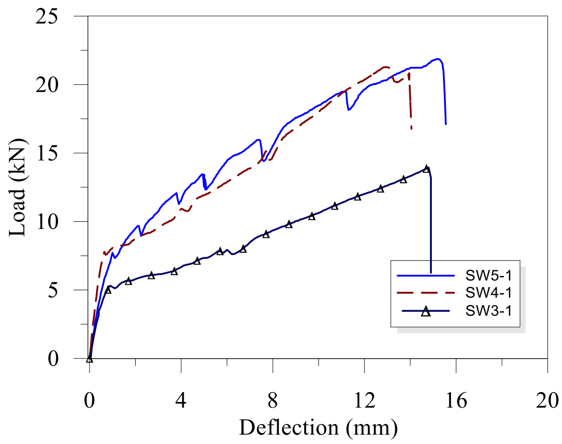


Figure 5. *Comparison of load and deflection between specimens SW3-1, SW4-1 and SW5-1*

__Table 4.__ Ultimate load of sandwich specimens (unit: kN)

Panel	Specimen 1	Specimen 2	Specimen 3	Average
SW3	13.9	13.5	13.1	13.5
SW4	21.3	18.9	19.8	20.0
SW5	21.8	18.5	20.1	20.1

The final modes of failure and crack patterns are illustrated in Figure 6. All sandwich beams failed due to the sudden tensile rupture of carbon textile, accompanied by a loud noise. It should be noted that there was no horizontal bond crack in the bonding surfaces between TRC and LC core, i.e. the layers of sandwich cross section did not slip to each other. Therefore, the adhesion performance was sufficient enough to safely transfer tensile loads from the TRC layer to the LC core. Thus, the durable bond between the core and face layers was achieved without any shear connector device.

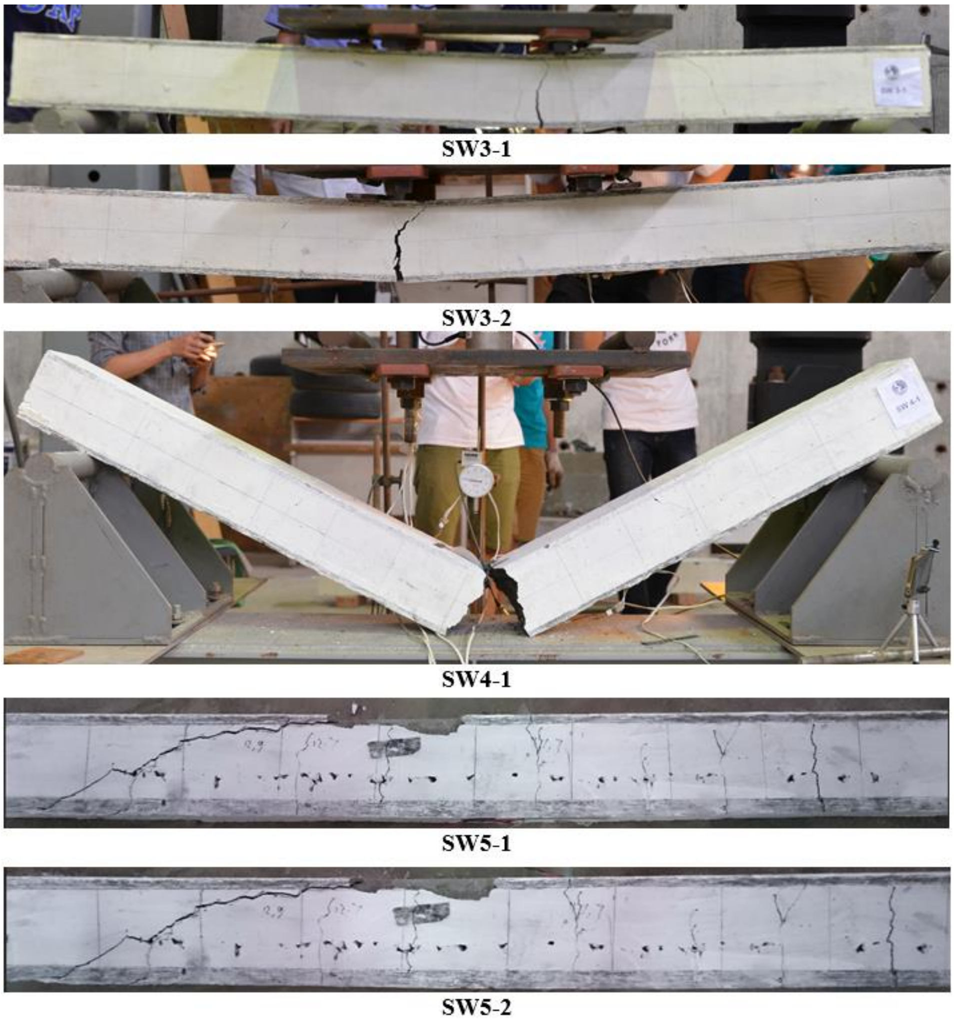


Figure 6. *Crack pattern of tested sandwich beams*

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III. CONCLUSION

This research developed a new type of TRC-LC sandwich beams. The main purpose of the study was to determine the flexural performance of sandwich beams, with different textile reinforcement ratio and depth of beam. The results show that, the adhesion performance was sufficient enough to safely transfer tensile loads from the TRC layer to the LC core. The durable bond between the core and face layers was achieved without any shear connector device. The ultimate loads of the sandwich beams were reached when one of the vertical flexural cracks turned suddenly and developed widely through the LC core. The failure of all the specimens occurred due to tensile break of textile reinforcements, along with the development of critical cracks. Thus, the textile reinforcement ratio increases, the stiffness and strength of sandwich beams also increase. Besides, the stiffness of sandwich panel is affected by the depth of the beams. The stiffness will increase significantly when the thickness of LC core increases.

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