International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:11, No:7, 2017

Flexural Strength of Alkali Resistant Glass Textile Reinforced Concrete Beam with Prestressing

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***Abstract*—**Due to the aging of bridges, increasing of maintenance costs and decreasing of structural safety is occurred. The steel corrosion of reinforced concrete bridge is the most common problem and this phenomenon is accelerating due to abnormal weather and increasing CO_2 concentration due to climate change. To solve these problems, composite members using textile have been studied. A textile reinforced concrete can reduce carbon emissions by reduced concrete and without steel bars, so a lot of structural behavior studies are needed. Therefore, in this study, textile reinforced concrete beam was made and flexural test was performed. Also, the change of flexural strength according to the prestressing was conducted. As a result, flexural strength of TRC with prestressing was increased compared and flexural behavior was shown as reinforced concrete.

***Keywords*—**AR-glass, flexural strength, prestressing, textile reinforced concrete.

I. Introduction

THERE is a problem in the safety of the bridges because of the aging, and the maintenance cost increase is accelerating [1]. In addition, carbonization of concrete and corrosion of reinforcing steel due to exposure in the air is occurred with reduction of durability and accelerating with increase of CO_2 concentration due to climate abnormalities. To solve this problem, various researchers are studying textile reinforced concrete.

Textile Reinforced Concrete (TRC), which is a composite material of textile and concrete, can reduce the thickness of concrete cover compared to reinforced concrete, thus reducing the weight of composite. In addition, various shapes of the thin member can be realized. It is also an economical structure because non-corrosive materials can be used to prevent the deterioration of strength or durability due to external environmental effects.

In the RILEM (International Union of Laboratories and Experts in Construction Materials, Systems and Structures), research on TRC has been carried out such as material properties, pull-out test, tensile test of composite member and bending test of thin member. As a result, it is applied to non-structural areas such as insulation and exterior materials of present buildings [2]. TRC has advantages such as reduction of self-weight and cross section, and convenience of designing, so it is appropriate as a structural member of infrastructure and buildings such as bridges. However, there is still a lack of performance verification and application on infrastructures.

Jung strengthened reinforced concrete by FRCM (Fabric Reinforced Cementitious Matrix), which is fabricated by FRP (Fiber Reinforced Polymer), and carried out bending test according to the reinforcement amount and type. However, there is a limit to the focus on utilization of FRP [3]. Yin et al. used a method of laying textiles on the bottom of reinforced concrete and covering the concrete. Two types of limit failure states are presented for reinforced concrete beams of rectangular cross section according to the textile reinforcement ratio and the relationship between textile reinforcement ratio and steel ratio is established [4]. Portal et al. studied the structural behavior of TRC slab under bending. A 4 - point loading test was carried out with a thin TRC member made of carbon textile and modeled using a nonlinear finite element method. Deflection and cracks, and effects of differences in the attachment areas between the textile and the concrete matrix were analyzed [5]. Volkova et al. investigated the maximum bending strength and reinforcement efficiency of glass fiber and carbon fiber [6].

Various researches have been conducted on the bending strength and verified deflection and cracks using various fiber materials and reinforcing methods. However, these studies focused on reinforced concrete strengthened with textile, so behavior research of TRC without any steel bars is needed. Therefore, in this study, performance test of TRC which is reinforced with only textile has been carried out.

II. Experiment Program

A. Textile

The textile used in this experiment is AR-Glass textile manufactured by Taishan Fiberglass Inc. of China and it contains 16.5% zircon to resist alkali component in concrete. As shown in Fig. 1, textile is fabricated by roving in a lattice pattern, spaced 8 mm apart. Table I shows the properties of the materials.

TABLE I
PROPERTIES OF AR-GLASS TEXTILE

Properties	Quantity
Tex (g/km)	640 tex
Diameter	14 μm
Tensile strength	1300 MPa
Elastic of modulus	72 GPa

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Fig. 1 AR-glass textile of 640tex

B. Concrete

Table II shows the mixing proportion of fine concrete for the design compressive strength of 40 MPa. The concrete specimen for the 28 day compressive strength test was made as a 100 × 200 mm circular specimen according to KS F 2403 and the test result showed an improvement of more than 10%.

TABLE II
MIX PROPORTION OF FINE CONCRETE

Component	Quantity (kg/m^3)
Water	315
Cement	490
Fly ash	175
Silica fume	35
Sand	1213.75
Superplasticity	0.7 (% of binder)

C. Tested Specimen

To compare the flexural behavior of TRC member, the presence of prestressing and the amount of textile reinforcement were set as variables. Table III shows the variables. H-PS (High-Presrtressing) was reinforced 15 layers of textile with prestressing. L-PS (Low-Prestressing) was reinforced 8 layers with prestressing and L-NPS (Low-Not Prestressing) was reinforced same amount of L-PS without prestressing.

TABLE III
TESTED SPECIMEN BY VARIABLES

Name of Specimen	Prestressing	Amount of Reinforcement (mm^2)
H-PS	10% of tensile strength	138
L-PS	10% of tensile strength	74
L-NPS	None	74

If prestressing is not applied to the textile, there is a high possibility that the position of textile will change irregularly. Therefore, L-PS and L-NPS were set to analyze the effect of prestressing by allowing textile to play a role in designing position.

The TRC specimen was designed with a total length of 2,500 mm, a width of 300 mm and a height of 220 mm. D10 shear reinforcements were arranged at 100 mm intervals in support point. Fig. 2 shows the detail specification of TRC specimen and Fig. 3 shows the procedure for manufacturing the specimen.

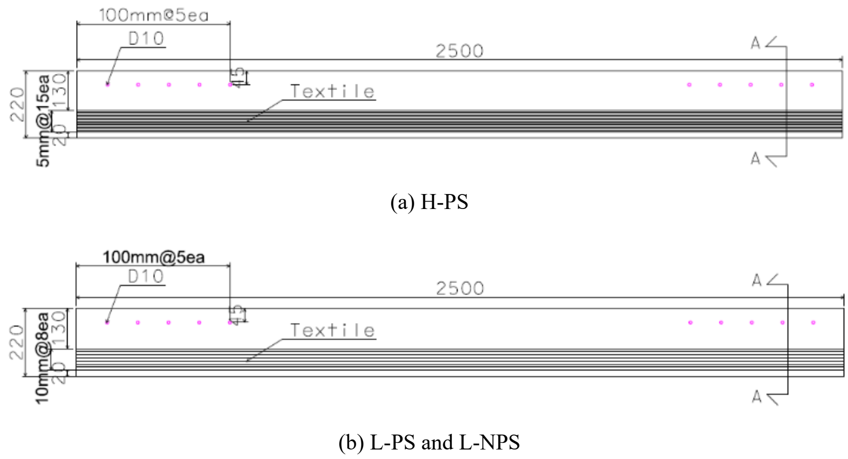

Fig. 2 Detail specification of tested TRC specimen

D. Test Set-up

As shown in Fig. 4, four points were placed and a 2000 kN universal test machine (UTM) was used so that the maximum moment was generated at the center of the test specimen and maintained constant. The span was 2.1 m and loading point was 0.25 m both sides at the center of the span of the specimen. The displacement was applied at a rate of 0.1 mm/sec until the specimen was destroyed. Three LVDTs were installed at the lower part of the specimen.

III. EXPERIMENT RESULT

A. Crack

Fig. 5 shows the cracks just before fracture of the specimen. In the case of the H-PS specimen, the initial crack occurred at the loading application point. After that, cracks gradually propagated to the center by increasing of load like RC-Beam. However, brittle fracture, which caused instant failure of the textile and concrete, occurred. This was different behavior compared to reinforced concrete beam which had ductile behavior with compressive fracture of concrete. In the case of the L-PS, the initial crack occurred at the center, and cracks occurred at the loading point as the load increased. At the final fracture, the initial crack grew to the top of specimen and showed the fracture pattern like H-PS. Crack of L-NPS at the center and brittle fracture were occurred at the same time.

Fig. 3 Manufacturing procedure of TRC specimen

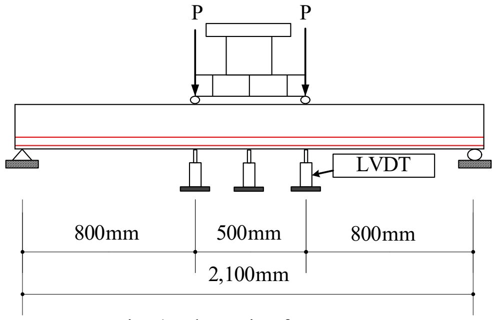

Fig. 4 Schematic of test set up

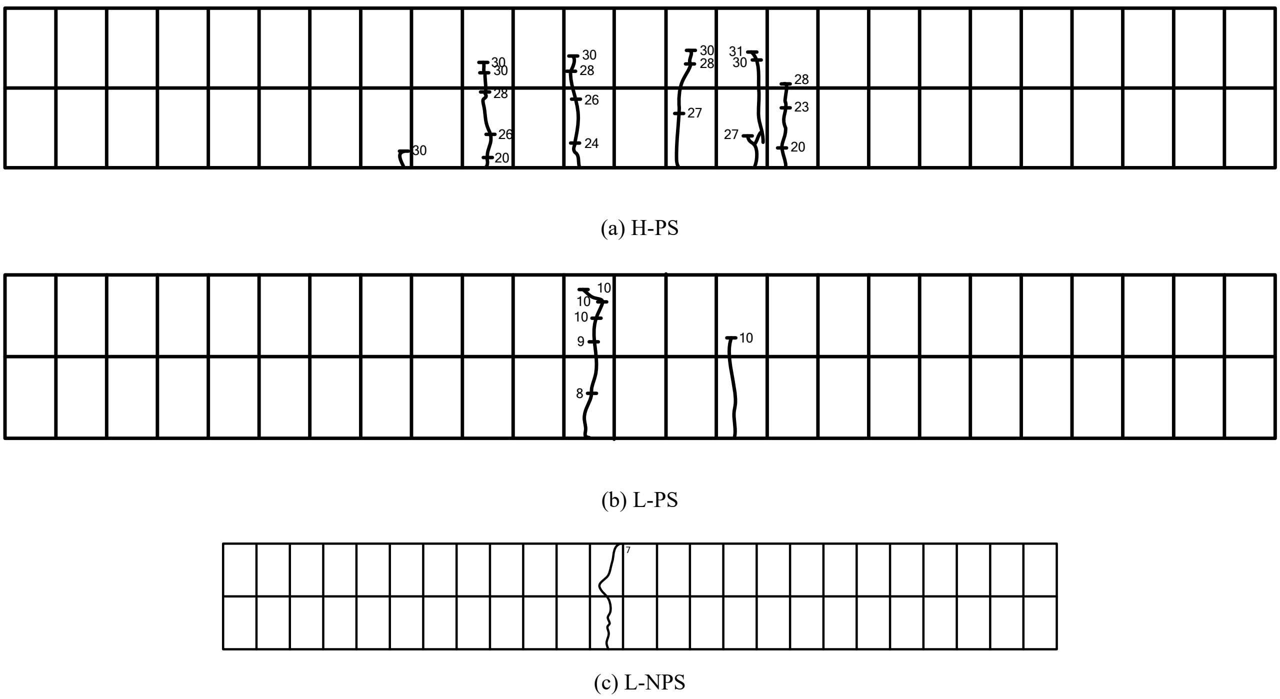

Fig. 5 Schematic of crack before fracture

B. Load and Displacement

Fig. 6 and Table IV show the test results. The maximum flexural strength of H-PS, L-PS and L-NPS were measured to be 12.48 kN·m, 4.19 kN·m and 2.81 kN·m respectively. The L-PS specimens introduced to prestressing compared to the L-NPS specimens without prestressing showed an improved flexural strength of 49%, and the H-PS specimens with a 1.86 times larger amount of textile than the L-PS specimens had an improved flexural strength of 298% compared to L-PS.

Textile of H-PS and L-PS specimens that introduced prestressing was spaced uniformly and placed accurately in tensile section of the composite. In addition, reinforced textile of the H-PS specimen was more uniformly distributed in the tensile part than L-PS and had bigger flexural strength. However, the textile of L-NPS specimens were bundled and located in neutral axis. As a result, it seems that textile of L-NPS did not play a role as a tensile reinforcement.

TABLE IV
TEST RESULT OF MAXIMUM LOAD AND MOMENT

Name of Specimen	Maximum Load (kN)	Maximum Moment (kN·m)
H-PS	31.19	12.48
L-PS	10.48	4.19
L-NPS	7.03	2.81

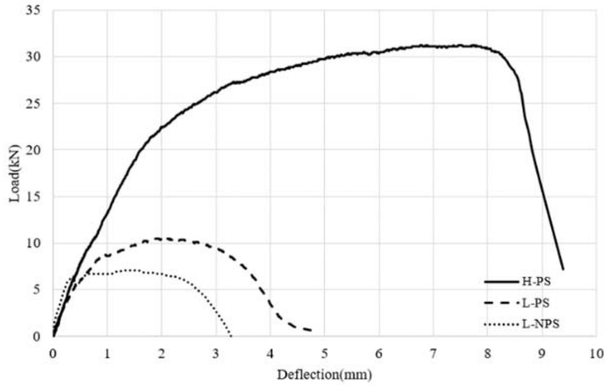

Fig. 6 Load and displacement curve of TRC specimen

Flexural behavior especially based on the H-PS specimen shows that the stress increases linearly with the stiffness of the concrete before crack occurred, and the stress is applied by the textile and the load gradually increases after crack occurred. After 30 kN, the fracture occurred while reaching the tensile strength of the textile. On the other hand, as shown in Fig. 7, in the thin TRC member of the existing study, there are additional sections where the small cracks occur and the load does not increase but only deflection increasing. However, in this study, the phase IIa was not shown.

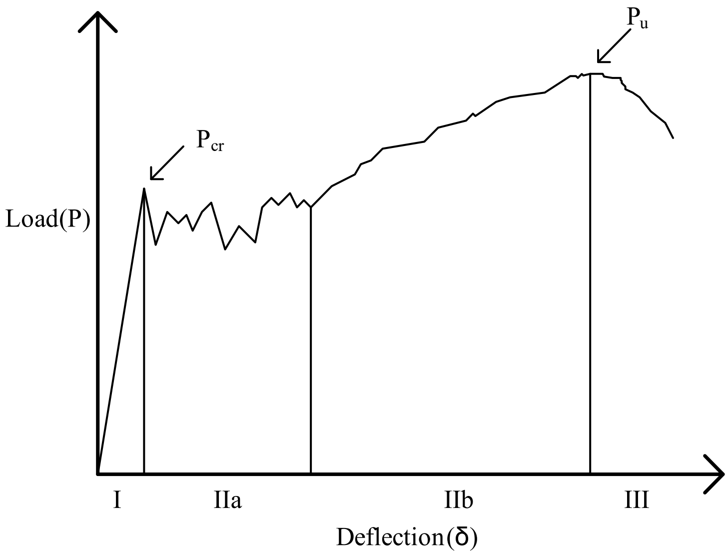

Fig. 7 General behavior of thin TRC member

Table V shows the deflection of the test result. For the H-PS specimen, the deflection at crack occurred was 1.666 mm and the deflection at break was 7.465 mm. For the L-PS, the deflection at crack was 0.977 mm and 1.99 mm at the fracture. For the L-NPS, it was confirmed that the deflection at fracture was 1.282 mm. Until brittle fracture occurred, H-PS specimen has shown like behavior of RC, which increased deflection after cracking constantly. However, L-PS and L-NPS tend to break rapidly without deformation after cracking.

TABLE V
DISPLACEMENT OF SPECIMENS

Name of Specimen	Deflection [Load at occurred, kN] (mm)	
	At initial crack	At Fracture
H-PS	1.666 [20.34]	7.465 [31.19]
L-PS	0.977 [8.63]	1.990 [10.48]
L-NPS	-	1.282 [7.03]

IV. CONCLUSION

In this study, the flexural behavior of TRC with only textile reinforcement was analyzed by using the amount of textile and the presence of textile prestressing.

1) The H-PS with 1.86 times the amount of reinforcement of the textile compared to L-PS showed a flexural strength as high as 298%. The difference in load capacity compared to the amount of reinforcement was bigger because load capacity of L-PS was smaller than expected due to reinforcement of L-PS was not uniform.
2) L-PS showed 149% greater load capacity than L-NPS, which is a non-prestressing. As a result of analysis of the fracture section, if the prestressing is not applied, textile laying position is not done according to design. Therefore, it is important that textile prestressing when manufacturing TRC member with only textile reinforcement.
3) In the H-PS, the load and deflection curve were similar to reinforced concrete. However, L-PS and L-NPS, which are experiments with small amount of textiles and tend to be destroyed without occurrence of large deflections after cracking. Therefore, it is considered that more than adequate textile should be placed in the design of the textile concrete composite.

ACKNOWLEDGMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. 2011-0030040).

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