International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:11, No:4, 2017

Adhesion Performance According to Lateral Reinforcement Method of Textile

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Abstract**—**Reinforced concrete has been mainly used in construction field because of excellent durability. However, it may lead to reduction of durability and safety due to corrosion of reinforcement steels according to damage of concrete surface. Recently, research of textile is ongoing to complement weakness of reinforced concrete. In previous research, only experiment of longitudinal length were performed. Therefore, in order to investigate the adhesion performance according to the lattice shape and the embedded length, the pull-out test was performed on the roving with parameter of the number of lateral reinforcement, the lateral reinforcement length and the lateral reinforcement spacing. As a result, the number of lateral reinforcement and the lateral reinforcement length did not significantly affect the load variation depending on the adhesion performance, and only the load analysis results according to the reinforcement spacing are affected.

Keywords**—**Adhesion performance, lateral reinforcement, pull-out test, textile.

I. Introduction

REINFORCED concrete is widely used as a construction member which has excellent durability and can complement each other in compression and tension. However, there is a problem that the durability is deteriorated due to the enlargement of the structure, the increase of the self-weight due to the superstructure, and the crack due to the external force. Especially concrete cracks have been increasing rapidly due to a wide range of temperature changes and a change in weather conditions in the world nowadays. When a crack occurs in the reinforced concrete, the reinforcing steel is corroded by the moisture that flows into the generated crack. This results in a decrease in the durability of the reinforced concrete. Therefore, researches for increasing the durability of reinforced concrete are actively underway [1]. In order to reinforce the durability of the structure, repair and reinforcement methods using corrosion resistant fiber reinforced plastic (FRP) are widely used. External repair and reinforcement methods FRP sheet, plate and gird type products were mainly used. Recently, internal repair and reinforcement methods are being used while developing FRP bar type products. Recently, researches are underway to reduce cracks in concrete itself and to improve durability. Examples include self-healing concrete that automatically restores cracks and smart concrete that restores automatically through self-diagnostics [2]. Particularly, the prefabricated structure using this structure has the easiness of maintenance through replacement of damaged part, overcoming the durability problem of the existing structure. However, the above is basically a research method used in the absence of reinforced concrete. As a result, the problem that the reinforcing steels are corroded and the durability is lowered still occurs. As a result, researches on replacing reinforcing steel have been actively carried out in Europe.

Textile is used as a representative material. Textiles have the same strength as reinforcing steels but have the advantage that they do not cause corrosion, which is a disadvantage of reinforcing steels. However, since the textiles are thin, it is difficult to fix them. Textile Reinforced Concrete (TRC), which replaces reinforcing steels with textiles, has been actively studied for 15 years in the United States, China and Spain, mainly in Germany [3]. Especially, it has been proved that the adhesive property of concrete and textile is satisfactory through the study. In particular, Germany has generated a report defining TRC and standardizing testing methods with RILEM [3]-[5]. Especially, it has been proved that the adhesive property of concrete and textile is satisfactory through the study. However, in past studies, adhesion performance of textile and concrete materials has been mainly verified, and Park et al. have verified the change in adhesion performance of longitudinal direction length [6]. Therefore, in this paper, we have experimented on the change of the adhesion performance according to the variables of the lateral reinforcement number, reinforcement spacing, and reinforcement length of the textiles.

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II. TRC

A. Textile

Textile, which is mainly used in TRC, is mostly carbon. Recently, researches on textiles made of glass and aramid are underway. Such thin fiber strands are processed into bundles to produce a fabric shape, thereby increasing tensile strength and refractory performance. Also, molding is free [7].

B. Concrete

Textiles are usually produced in the form of a grid of about 6 to 8 mm. However, the aggregate used in concrete is generally used around 25 mm, which is not suitable for application to textiles. Therefore, it is necessary to use fine aggregate less than the spacing of the textile and to increase the adhesive force by facilitating the input into the textile. Fine aggregate of 0.6 mm or less is used, and an admixture such as silica fume or fly ash is used in order to prevent the strength reduction.

C. TRC

TRC is a composite material of textiles and concrete. TRC is produced by replacing reinforcing steels with textiles. Therefore, it is not necessary to use coating thickness for corrosion prevention and it is possible to manufacture even very thin layer, so that the weight of the concrete is reduced and the weight of the member is reduced. In addition, since it has a large surface area compared to ordinary reinforcing steels, it has strong adhesion with concrete and can be formed freely. Therefore, various types of concrete composite members can be manufactured. The most significant effect is to prevent the durability from decreasing due to the corrosion caused by replacing the reinforcing steels with textile. Currently, the TRC has confirmed its academic content through RILEM's report, and research is underway to expand it.

III. Experiment Plan

A. Test Set-up

Pull-out test was carried out to determine the adhesion performance between the concrete and the textiles. A 2000 kN Universal Test Machine (UTM) was used for the load test. An epoxy with a diameter of 8 mm and a height of 100 mm was installed in the outer textile (excluding the attachment length) to prevent slippage and material damage during loading. The strength of the concrete was 50 MPa. Displacement control was carried out at 0.5 mm/min until breaking or pulling down.

B. Textile

Textile used in the experiment was Taishan Fiberglass Inc. of China. We used a mesh product made of a lattice of Alkali-Resistance (AR), containing more than 16% zircon and a single roving. The tensile strength and the modulus of elasticity of the AR-glass fiber are 130 MPa and 72 GPa, respectively. The specifications are shown in Table I. Fig. 1 is the Textiles.

TABLE I
SPECIFICATION OF TEXTILE OF AR-GLASS FIBER

Diameter (μm)	Tensile strength (MPa)	Modulus of elasticity (MPa)	Specific Gravity (g/cm^3)	Softening Point (°C)
27	1700	70	2.68	860

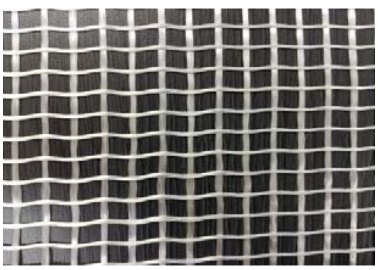


Fig. 1 Textile

C. TRC

Textile Reinforced Concrete (TRC), when used in general concrete, is difficult to attach between two materials due to coarse aggregate larger than the size of the lattice of the textile. Therefore, it is necessary to use aggregate smaller than 6-8 mm, which is the spacing of textile. Therefore, silica sand of 0.1 ~ 0.35 mm and 0.35 ~ 0.7 mm was used in this experiment and silica fume and fly ash were added to improve the strength. In addition, SP agent was added to ensure fluidity. On 28th, the target design strength was 50 MPa, and a circular specimen of 100 × 200 mm was manufactured according to KS F 2403. The concrete specimens are shown in Table II and the compressive strengths exceeded the target design strengths of 46.1Mpa for 14 days and 56.3 Mpa for 28 days. The parameters of the test specimens are shown in Table III. S is the concrete strength, D is the textile embroidered length, TR is the number of lateral reinforcement, T is the lateral reinforcement length, and C is the lateral reinforcement spacing. For example, in the case of the test specimen S3-S60-TR2-T40-C15, the test specimen consisted of concrete with a blend ratio of Table II, a length of 60 mm, a number of lateral reinforcement of 2, a lateral reinforcement length of 40 mm, lateral reinforcement spacing of 15 mm.

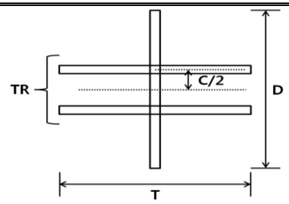
TABLE II
CONCRETE MIXING RATIO

W/B ratio	SP(%)	Unit weight (kg/m^3)					
		Water	Cement	Fly-ash	Silica fume	No.6 sand	No.7 sand
0.40	0.7	280	490	175	35	500	713.75

TABLE III
VARIABLE ACCORDING TO SPECIMEN NAME

S-D-TR-T-C

S : concrete strength
D : textile embroidered length
TR : number of lateral reinforcement
T : lateral reinforcement length
C : lateral reinforcement spacing



IV. Experiment Result

Table IV shows the respective parameters for the lateral reinforcement number, lateral reinforcement spacing, and lateral reinforcement length. The number of lateral reinforcement was increased by 1, 2, and 3, and the lateral reinforcement spacing was varied from 10 mm to 25 mm by 5 mm, and lateral reinforcement length was varied from 20 mm to 20 mm by 100 mm.

TABLE IV
VARIABLE

TR(EA)	1	2	3		
C(mm)	10	15	20	25	
T(mm)	20	40	60	80	100

A. Number of Lateral Reinforcement

As shown in Fig. 2 and Table V, the load according to the number of lateral reinforcement is 990 N for one lateral reinforcement, 990 N for two, and 870 N for three lateral reinforcements. The stresses were similar at 1081 MPa, 1081 MPa when the number of reinforcement is 1 and 2, 950 MPa when the number of reinforcement is 3. As a result, it was found that the number of lateral reinforcement does not affect the adhesion performance.

TABLE V
NUMBER OF LATERAL REINFORCEMENT

S3-D60-T60			
Categories	TR1	TR2	TR3
Load (N)	990	870	990
Stress (MPa)	1081	1081	950

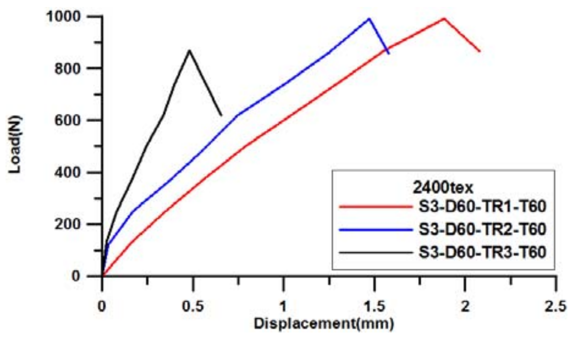


Fig. 2 Load according to number of lateral reinforcement

B. Lateral Reinforcement Spacing

As shown in Fig. 3 and Table VI, the experimental results on the lateral reinforcement spacing were increased to 740 N at 25 mm, 620 N at 20 mm, 990 N at 15 mm and 1480 N at 10 mm, stress was also increased to 808 MPa at 25 mm, 677 MPa at 20 mm, 1081 MPa at 15 mm, 1616 MPa at 10 mm, the load and stress increased significantly as the lateral reinforcement spacing decreased.

TABLE VI
LATERAL REINFORCEMENT SPACING

S3-D60-TR2-T60				
Categories	C10	C15	C20	C25
Load(N)	1480	990	620	740
Stress(MPa)	1616	1081	677	808

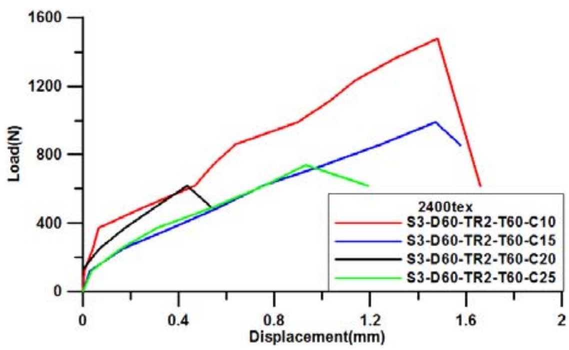


Fig. 3 Load according to lateral reinforcement spacing

C. Lateral Reinforcement Length

As shown in Fig. 4 and Table VII, the maximum load per lateral reinforcement length is 1480 N at length 40 mm, 990 ~ 1110 N at rest, The maximum stress is 1616 MPa at 40 mm and 1081 ~ 1212 MPa at the other variables. It was found that the lateral reinforcement does not affect the adhesion performance.

TABLE VII
LATERAL REINFORCEMENT LENGTH

S3-D60-TR2-C15					
Categories	T20	T40	T60	T80	T100
Load(N)	1110	1480	990	1110	1110
Stress(MPa)	1212	1616	1081	1212	1212

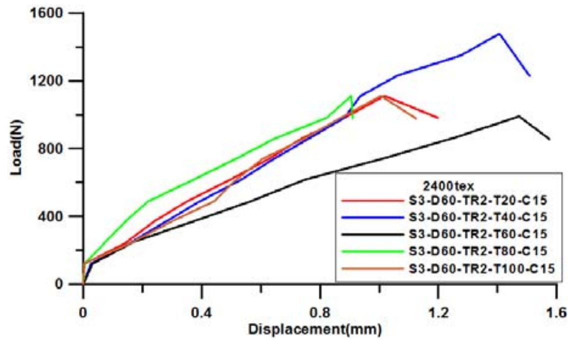


Fig. 4 Load according to lateral reinforcement length

V. CONCLUSION

In this study, it was confirmed that as the lateral reinforcement spacing narrows through the pull-out, the load and stress increase and the adhesion performance improves.

1) Experiments on the number of lateral reinforcement results showed that the load was 990 N for one lateral reinforcement, 990 N for two lateral reinforcement, 870 N for three lateral reinforcement, stress was 1081 MPa for one lateral reinforcement, 1081 MPa for two, 950 MPa for three, the adhesion performance did not increase significantly.
2) Experiments on lateral reinforcement spacing showed that load and stress were the largest at 1480 N and 1616 MPa when the lateral reinforcement spacing was 10 mm. In the other variables, it was confirmed that the load and stress increased as the reinforcement spacing decreased from 740 N and 808 MPa at 25mm, 620 N and 677 MPa at 20 mm, and 990 N and 1081 Mpa at 15 mm, respectively.
3) Experimental results on the lateral reinforcement length showed that the maximum load and stress were 1480 N and 1616 MPa at 40 mm and 990 ~ 1110 N and 1081 ~ 1212 MPa at the other variables, respectively.
4) In this paper, we investigated the adhesion performance between textile and concrete according to various parameters. Experiments on the number of lateral reinforcement, lateral reinforcement spacing, and lateral reinforcement length confirmed that the adhesion performance depends on the lateral reinforcement spacing. Therefore further study will make various experiments by changing the variables.

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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