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Probabilistic inference on corrosion configurations based on tensile test results of corroded strands

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ABSTRACT

Prestressing strands are frequently affected by pitting corrosion. A new method was recently proposed to evaluate the effects of corrosion on the mechanical characteristics of strands in a probabilistic manner. By employing the proposed method inversely, we suggest a new inference method to examine corrosion variables in corroded strands, such as the pit depth and loss of sectional area, based on the tensile tests (i.e., ultimate load-displacement tests). The inference method requires solving an optimization problem using a cost function, which was defined as the difference between the experimental results and the predicted values from a previous study. As a result, corrosion configurations are inferred based on the pit configuration and tensile tests. The proposed inference method was verified when applied to three specimens of corroded strands from an existing prestressed concrete bridge in South Korea, and the relation between corrosion configurations and mechanical properties of corroded strands is discussed.

1. INTRODUCTION

Prestressing strands are used as important structural elements in bridges but they are exposed to pitting corrosion; yet many studies have focused on non-corroded steel strands (Jeon *et al*. 2019). In addition, assessing the mechanical characteristics of corroded strands involves uncertainties, e.g. the material structural properties, wire size, and corroded area. Lee *et al*. (2020) recently suggested a method to assess the mechanical characteristics for specific corrosion configurations of strands in a probabilistic manner. However, the corrosion configurations are frequently unknown when the prestressing strands are structural components in bridges. In such cases,

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predicting the mechanical characteristics is challenging; we have addressed this herein.

2. PREDICTION OF MECHANICAL CHARACTERISTICS OF CORRODED STRANDS

Strands are vulnerable to pitting corrosion, which affects mechanical characteristics, such as ultimate load and displacement. To quantify the impact of corrosion, Jeon *et al*. (2019) proposed a finite element (FE) method to model corroded wires with pitting corrosion by categorizing the pit shape into three types (Fig. 1). The simplified FE model for each of the three types can be constructed from this assumption, and the ultimate load and displacement of corroded wires can be obtained for a given corrosion type, from the pit depth (d_p), and the wire diameter (R).

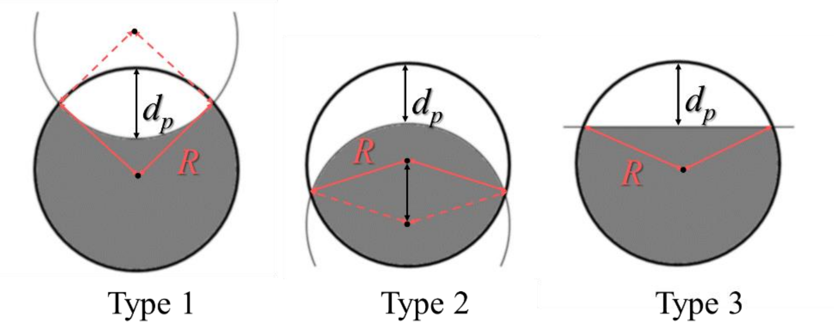

Fig. 1. Pit shapes for FE analysis (Jeon *et al*. 2019).

In the Costello's model (Costello 1997), a load-displacement curve of corroded strands can be estimated by summing the forces and moments acting on the core wire and helical wires (Lee *et al*. 2020) as follows:

$$F_{z,strand} = F_{z,core} + \sum_{i=1}^{M} F_{z,hel,i} \quad (1)$$

where $F_{z,core}$ is the force of the core wire in the z direction, M is the number of helical wires, and $F_{z,hel,i}$ is the force of the i^{th} helical wire in the z direction. In the core wire, only the tangential force is present; in contrast, $F_{z,hel,i}$ is calculated by considering both tangential and binormal forces (Lee *et al*. 2020).

3. INFERENCE MODEL FOR THE PIT CONFIGURATIONS

3.1 Test specimens of corroded strand

Three 100 mm-long specimens (i.e., S1, S2, and S3) of corroded strand were extracted from a prestressed concrete bridge in Korea. The specimens consisted of one corroded helical wire and six non-corroded wires, as shown in Fig. 2. The strands had a nominal diameter of 15.2 mm while the core wire and helical wires had radii of 2.58 mm and 2.5 mm, respectively. Tensile tests were conducted for the three specimens using the displacement control method at a speed of 5 mm/min, until any of the wires failed. The measured ultimate load and displacements for the specimens are presented in Table 1.

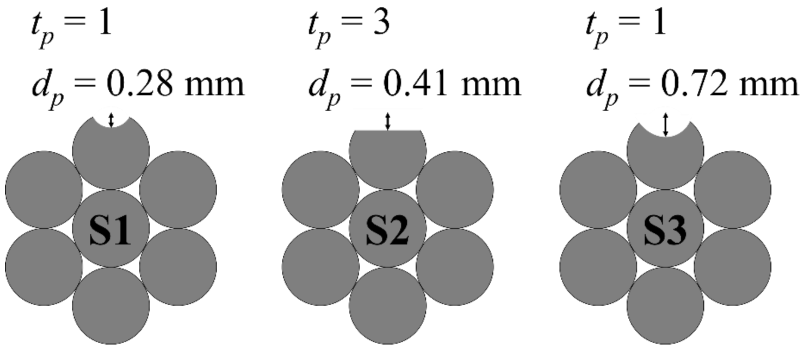

Fig. 2. Test specimens of corroded strands.

Table 1. Tensile test results.

Specimen	Sectional area loss	Ultimate load	Ultimate displacement
S1	0.3097 mm^2	205652.56 N	6.6787
S2	0.7632 mm^2	261504.02 N	4.0269
S3	1.2598 mm^2	237793.51 N	2.0484

3.2 Optimization of the inference model of the pit configurations

In this study, an inference method is proposed to predict corrosion configurations, such as pit depth and sectional area loss, based on the ultimate load and displacement of the corroded strands, as shown in Fig 3. The cost function (L) was defined as the difference between the experimental values for ultimate load and displacements from the tensile test (*ans*), and the predicted values (*pred*(d_p,t_p)) for a particular pit depth (d_p) and pit type (t_p) were estimated by the method described by Lee *et al*. (2020). The optimal-pitting corrosion configurations were the ones that minimized the cost function, L.

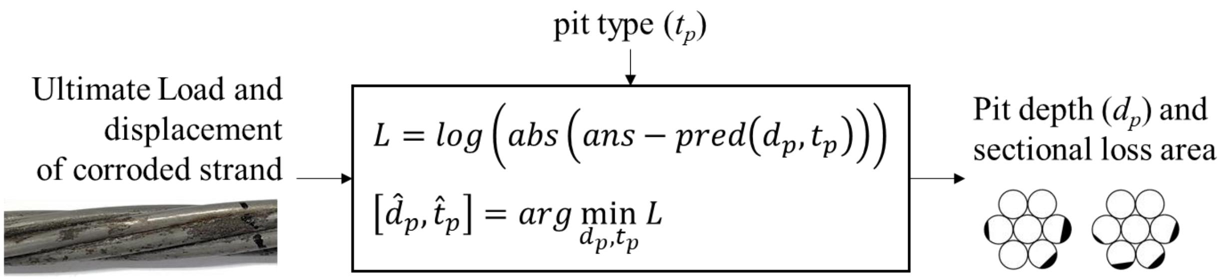

Fig. 3. Inference method to evaluate the corrosion configurations.

Table 2 shows the predicted values of the pit depth and sectional area loss, considering pit shape types 1, 2, and 3, for each specimen. The estimated pit depths for S1 were 0.2804, 0.0837, and 0.2237 mm, assuming that the pit shape was type 1, 2, and 3, respectively. From these results, we observed that all the predicted results were close to the experimental value for sectional area loss; moreover, Table 2 demonstrates that S1 exhibits a type 1 pitting corrosion because its pit depth was 0.2800 mm. A comparison of inferred and experimental values of the pit depth is presented for each specimen. We may state that the sectional area loss is a dominant factor on the mechanical variables of the corroded strands.

Table 2. Predictions versus experimental data.

Specimen		Pit type	Pit depth	Sectional area loss
S1	Inferred	1	0.2804 mm	0.3104 mm^2
		2	0.0837 mm	0.3139 mm^2
		3	0.2237 mm	0.3112 mm^2
	Experimental	1	0.2800 mm	0.3097 mm^2
S2	Inferred	1	0.5137 mm	0.7641 mm^2
		2	0.2059 mm	0.7721 mm^2
		3	0.4132 mm	0.7720 mm^2
	Experimental	3	0.4100 mm	0.7632 mm^2
S3	Inferred	1	0.7248 mm	1.2982 mm^2
		2	0.3402 mm	1.2754 mm^2
		3	0.5912 mm	1.3061 mm^2
	Experimental	1	0.7200 mm	1.2598 mm^2

4. CONCLUSIONS

We propose a new inference method to predict the variables for the corrosion configurations of corroded strands, such as pit depth and sectional area loss, based on tensile test results. The proposed method was verified using three test specimens of corroded strands that were collected from an existing prestressed concrete bridge in South Korea. The comparison of the predicted and experimental values shows that the inference method may estimate the sectional area loss of the corroded strands, which was found to be a dominant factor that influences the mechanical characteristics.

ACKNOWLEDGEMENT

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