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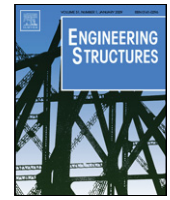

On strain change of prestressing strand during detensioning procedures

Do Young Moon [a], Goangseup Zi [a,*], Jang-Ho Kim [a], Seung-Jung Lee [a], Gyuseon Kim [b]

[a] *Department of Civil, Environmental & Architectural Engineering, Korea University, 5 Ga 1, Anam-dong, Seongbuk-gu, Seoul, 136-701, Republic of Korea*

[b] *Korea Infrastructure Safety and Technology Corporation, Daehwa-dong, Ilsan-gu, Goyang-si, Gyeonggi-do, 411-758, Republic of Korea*

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ABSTRACT

The strain change of a seven-wire strand is experimentally investigated for two different detensioning procedures of a pretensioned concrete bar: flame-cutting and hydraulic-jacking. Based on the results of strain changes, it is confirmed that the prestressing force was stepwise transferred to concrete for several seconds according to the individual cut of different wires in the flame-cutting procedure. In the hydraulic-jacking procedure, the detensioning was smoothly accomplished in a time of about one second shorter than that of flame-cutting. It seems that the pattern of strain changes during the detensioning procedure is more important than the elapsed time for detensioning. In addition, the drop in the strain of each wire at the moment of flame-cutting was reduced by the installation of the debonded region. Moreover, the test results showed that the placing of stirrups has an insignificant effect on the strain change. In particular, the initial prestressing force was estimated simply from the elastic recovering strain of the strand after detensioning. The prestressing force obtained from the procedure was very close to that obtained from a load cell.

1. Introduction

Most of the prestressed concrete structure systems can be classified into one of the two categories of the pretensioned system and the post-tensioned system according to when the prestressing force is introduced. In the pretensioned system, the prestressing force is transferred to the concrete by detensioning the prestressed strands. Strands are typically detensioned by means of flame-cutting or hydraulic-jacking.

The flame-cutting procedure is generally applied to a single-strand release and completed within a few seconds. The time for the procedure strongly depends on the workers' skill. On the other hand, the hydraulic-jacking procedure is simultaneously applied to a multiple-strand release and is completed within a few seconds. For both detensioning procedures, the force transfer results in a very rapid strain change of strands. However, the patterns of strain change greatly depend on the type of method used for the detensioning procedure. The method chosen to release strands is one of the primary factors influencing the structural integrity of a pretensioned concrete member as well as the bond integrity between the strands and concrete.

Cracks may develop due to an undesirable tensile strain at the ends of the pretensioned members during the detensioning procedure [1–4]. Russell and Burns reported that the dynamic shock effect due to the sudden transfer of prestressing force can create a transverse crack perpendicular to the strand axis [1]. In Nanni et al.'s work [2], splitting cracks were caused by the strand wedge effect, although the prestressing force was transferred by hydraulic-jacking. These cracks that form near the ends of the pretensioned members may jeopardize the structural integrity of the pretensioned concrete structures. Namely, the cracks reduce the load resistance of the pretensioned concrete member and provide a path for moisture transfer, causing strand corrosion and concrete frost damage.

The detensioning procedure obviously influences the bond integrity of the strands as well as the transfer length, as reported in several works [1,2,5–11]. The transfer length is the length required for the complete transfer of the prestressing force to the concrete. It is reported that sudden prestress release often results in a longer transfer length than that of gradual prestress release. This phenomenon has generally been considered to be due to the dynamic effects of the detensioning procedure carried out in a relatively short period. Such a dynamic effect is also found in post-tensioned structures when the tendon is cut for various reasons [12,13].

Seven-wire strands are more frequently used than bars for prestressing reinforcement in pretensioned concrete structures. Because seven-wire strands are comprised of seven twisted wires [14], it seems reasonable to consider that each wire of the seven-wire strand behaves differently during the detensioning procedure. However, few studies have been carried out on the strain changes of individual wires during the detensioning procedure. Most of the studies for prestressed structures are about the structural behaviors after they are constructed [15–19, etc.].

* Corresponding author. Tel.: +82 2 3290 3324; fax: +82 2 928 7656.
E-mail address: g-zi@korea.ac.kr (G. Zi).

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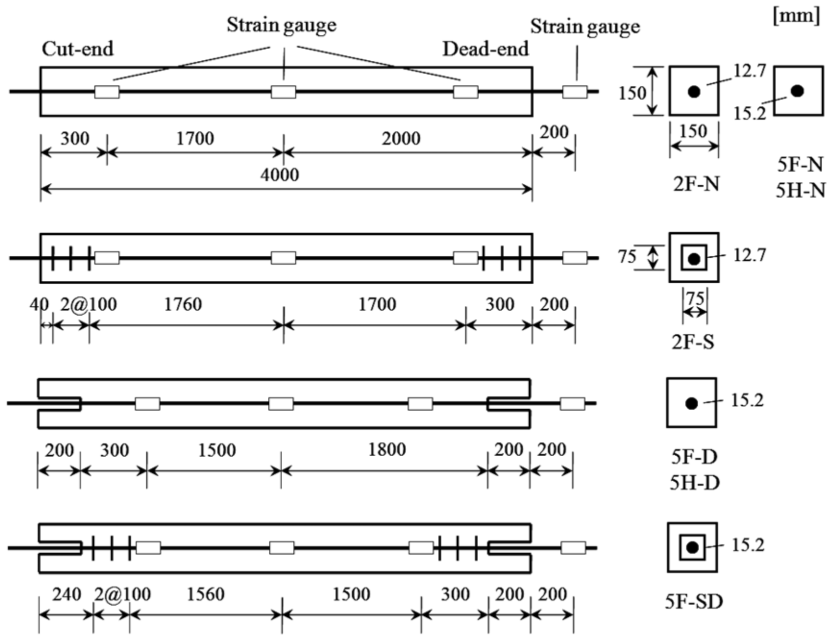

Fig. 1. Test specimens.

Table 1
Outline of the experimental program.

Specimen ID	Diameter of strand (mm)	Release method	Stirrups	Debonded length (mm)
2F-N	12.7	Flame-cutting	None	None
2F-S	12.7	Flame-cutting	Yes	None
5F-N	15.2	Flame-cutting	None	None
5F-D	15.2	Flame-cutting	None	200
5H-N	15.2	Hydraulic-jacking	None	None
5H-D	15.2	Hydraulic-jacking	None	200
5F-SD	15.2	Flame-cutting	Yes	200

This study presents the strain changes of a seven-wire strand during the detensioning procedure. An experimental program was carefully designed to statically and dynamically measure the strain during two different detensioning procedures: flame-cutting and hydraulic-jacking. In addition, investigations were carried out on the effects of confining reinforcements and the effects of installing a debonded region at the cut- and dead-end regions. The residual force at both ends and at the center of the strand after prestressing force transfer was measured and compared. Here, the authors used a new simple method to measure the prestressing force. The method is based on the plasticity theory. The prestressing force measured by the new method was compared with that obtained from the conventional method using load cells.

2. Experimental program

2.1. Test specimens

Seven single-strand pretensioned specimens were cast. A 12.7 mm or 15.2 mm strand was embedded in the center of the specimens as shown in Fig. 1. Each specimen has a square cross section of 150 mm × 150 mm and is 4 m in length. The confining reinforcement such as stirrups and the debonded region were included as test variables in this experimental program, as shown in Fig. 1.

Table 1 shows an outline of the test specimens. Each specimen is identified by a label that represents the diameter of the strand, the release method, and the type of end reinforcement; 2 and 5 stand for 12.7 and 15.2 mm, respectively, F and H flame-cutting and hydraulic-jacking and S and D stirrups and debonding region, respectively. N refers to a region with neither reinforcement nor debonding.

2.2. Materials

A low relaxation seven-wire strand was used. The elastic modulus, ultimate and yield strength of the strand were 194 GPa, 1860 MPa and 1710 MPa, respectively. The areas of the strand were 98.71 mm^2 and 138.7 mm^2 for 12.7 mm and 15.2 mm strand respectively. Steel reinforcement bars for the stirrups were No. 4 reinforcement with a diameter of 10 mm and the yield strength of 400 MPa.

Table 2 shows the concrete mix design. The concrete mix was chosen for a 28 day strength of 45 MPa. The maximum size of aggregate was 25 mm. All the specimens were cast with the same concrete from a single batch. After casting the concrete, the concrete strength was measured by the standard method using 15 by 30 cm cylinders every day to check whether the strength had reached the minimum value for a detensioning procedure. The average strength of the concrete was 38.7 MPa at the test date which is five days after casting the concrete.

2.3. Test procedures and instrumentations

The experimental procedure was conducted as follows. The prestressing frame is made from a heavily reinforced I-shaped steel bars. Concrete formworks were set on the frame. Strands were placed in all specimens, while PVC pipes and stirrups were installed in selected specimens. PVC pipes were installed at both ends of the strands of specimens 5F-D, 5H-D and 5F-SD. Three No. 4 steel