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Data-based post-tensioning system with application in Internet of Things

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ABSTRACT

In present post-tension construction, the force in tendons is measured through analog methods. A worker reads the pressure gauge from a hydraulic pump and the elongation of the stressed tendons, writing them down on paper by hand. Furthermore, it is hard to give tendons accurate tensioning stress due to the time lag between measurement and control. Kang and Jeong (2016) applied an IoT system in the post-tension method. It accomplishes more accurate stressing of tendons, which is based on sensor data including pressure and elongation. A device receives data from the sensors, and updates the real-time stressing force and elongation. The sensor data is transmitted to a mobile application, and stored in the database server automatically. This paper has the purpose of improving the proposed IoT system for post-tension.

1. INTRODUCTION

In the post-tension construction, it is important to apply uniform tension to the tendons by minimizing the deviation of the force in multiple single-strand or multi-strand tendons. These forces have been traditionally manually managed by, for example, reading the pressure gauge value from a hydraulic pump and the extent to which the hydraulic jack piston moves. The allowable error range between the measured tension force and the design tension force is within the average of 7%. Generally, the manually measured elongation of tendons falls within the acceptable error range. However, the accuracy depends heavily on the competence of the measurer. There are physical causes that make it difficult to accurately measure the tension, including the fact that the critical measurement and the pump control do not happen at the same time.

Accordingly, Kang and Jeong (2016) developed an IoT system for controlling of prestressing force in post-tension method. The operator can check the calibrated elongation of tendons based on data from sensors. The system performs real-time

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analysis of data from elongation sensor and pressure sensor based on its internal algorithm. Also, a mobile application can be used to monitor the system. In other words, this is the IoT system that can accurately and uniformly control tension in tendons. The purpose of this study is to extend and improve the proposed IoT system.

2. SMART PRESTRESSING SYSTEM IN POST-TENSION METHOD

2.1 System

The purpose of the system is to control the tension in the post-tension members. Fig. 1 shows the plan of the novel system that resembles that of the previously proposed one. The elongation sensor is installed in the hydraulic jack that applies tension to the tendon to measure the distance length of its piston. The pressure sensor is installed in the pipe of the hydraulic pump that supplies pressure to measure the applied pressure. The measurements are transferred to the data logger in real-time. The logger calculates the corrected elastic modulus of the tendon based on the internal algorithm. Finally, it derives the tension in each tendon. This force is calculated by taking into account the slack that occurs early in the application of the tension, the wedge slip after the application, and the correction value assumed as a measurement error.

Data is transmitted to the mobile application through the wireless communication module, and the application provides an interface as shown in Fig. 2. The operator can visually check the critical data value on the screen. Measurement data is transmitted to the main server through the application and is accumulated in the database.

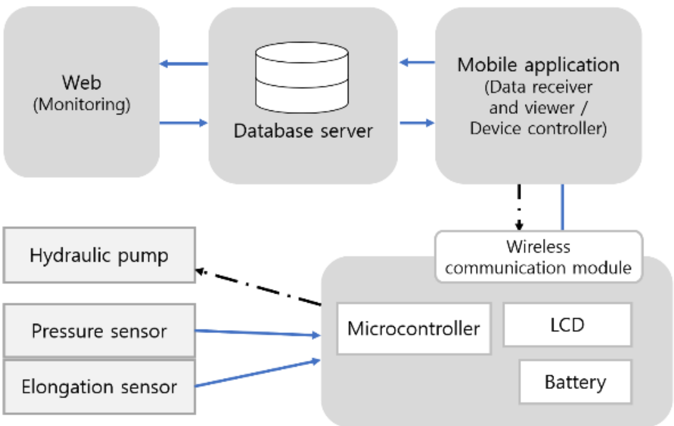

Fig. 1 System plan

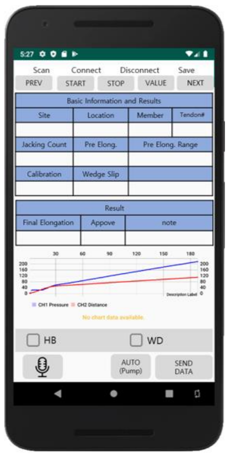

Fig. 2 Application interface

2.2 Algorithm

A novel algorithm for calculating the corrected tension force is designed by referring to the construction data collected by the previous system. It grasps the tendency of elongation and pressure data in the process of tensioning. The algorithm can determine the effective maximum pressure, elastic modulus for each tendon, and the amount of wedge slip after release. The tensioning work is performed by one jacking or two jackings when it is difficult to tension at a time, and an algorithm for each type of work has been implemented. During construction, the worker selects the jacking count and the logger operates on the corresponding algorithm. Besides, to account for situations where the desired tension is not achieved, the algorithm for additional tension work is also implemented in a separate mode to increase the convenience of work in the field.

2.3 IoT application in the future

IoT technology is specialized for controlling the equipment based on sensor data. It can be utilized for this system to be more convenient and accurate. Specifically, in the future system, the hydraulic pump can be stopped automatically at the moment when the pressure or elongation reaches the design value. It gives tendons target tension and prevents tendon failure. Additionally, voice recognition in the mobile is expected to offer another method to control the equipment.

3. ALGORITHM TEST

3.1 Test with the construction data

The developed algorithm has been tested with the construction data collected by applying the previously proposed system in the field. Fig. 3 shows the data graphs of two tendons and there are the critical points, for example, the final points where the pump stops applying pressure. Table 1 shows that the internal algorithm finds the final point where the valid max pressure is applied and calculates the corrected elastic modulus. It also finds the value of wedge slip and calculates the correct final elongation.

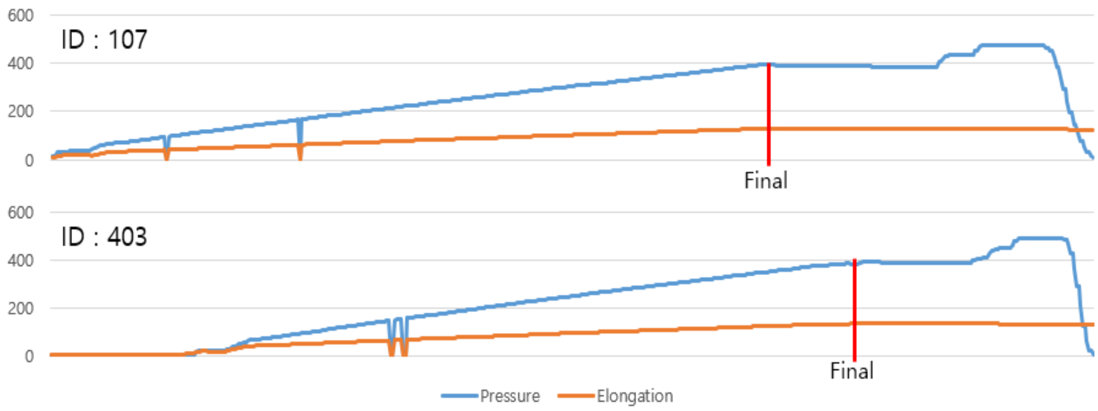

Fig. 3 Pressure and elongation data in real-time

Table 1 Raw measurements and corrected results based on actual data

ID	Final		Wedge Slip Value (mm)	Corrected Final Elong. (mm)
	Pres. (bar)	Elong. (mm)		
107	396.4	130.2	7.6	100.5
403	391.6	135.5	6.4	96.1

3.2 Mock test of the system

Using a mobile application, the mobile and the data logger are capable to communicate with the BLE command. The mobile sends the start command with some initial information, for example, tendon number, jacking count, and correction value. The logger measures data and, after the application, sends the corrected final elongation to the mobile. In this mock test, instead of pressurizing the pressure sensor, the control of input current changed the pressure value in the system. Specifically, by increasing the current from 4.00mA to 20.00mA, the system simulated the action of controlling the hydraulic pressure from 0 bar to 600 bar in the data logger. Fig. 4 shows data recorded in the mock test, and Table 2 shows the critical values and final elongation of this test. The system works without error and recognizes the critical values well.

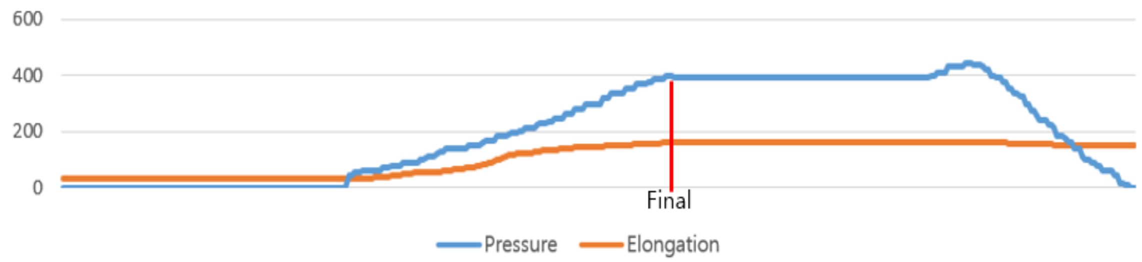

Fig. 4 Pressure and elongation data in real-time

Table 2 Raw measurements and corrected results during mock test

ID	Final		Wedge Slip Value (mm)	Corrected Final Elong. (mm)
	Pres. (bar)	Elong (mm).		
1	397	159	7	127

4. CONCLUSIONS

The purpose of this study is to apply the IoT technologies in the construction field to solve the difficulty of measurement and management in the traditional post-tension method. The smart prestressing system in the post-tension method offers the correct measurement of tension and elongation of each tendon and convenient construction. Additionally, on the internet network, it is possible to manage the construction data and monitor the system.

REFERENCE

Kang and Jeong (2016), *System for controlling of prestressing force in post-tension method*, 10-1643732. (in Korean)