Predicting the Slump of Concrete Using an Artificial Intelligence System

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Introduction

Recently, the shortage of workers in Japan's construction industry has led to the demand for increased productivity during the concrete production stage. Concrete slump is controlled via sampling inspection using a slump test and visual inspection of the mixing conditions by production personnel. In particular, the visual inspection depends significantly on the judgment of experienced engineers; however, the transfer of such skills is challenging.

To address this issue, Taiheiyo Cement Corporation has developed and implemented a system, called the "AI slump-prediction system," which can predict the slump of concrete from mixing images using artificial intelligence. This system is unique in its ability to predict the slump of concrete with high accuracy in real time by integrating AI technology into the concrete manufacturing process. This paper presents an overview of the AI slump-prediction system.

Overview of the AI Slump-Prediction System

1. System Configuration and Predicted Performance

This system is applicable to ready-mixed concrete, precast concrete, and onsite plants. Image recognition and deep learning with AI are applied for slump prediction. In general, supervised learning of AI involves preparing training data in advance and preparing an AI model that has been tuned and constructed to generate results that correlate with the training data. AI learning is equivalent to human beings gaining experience and refining their skills; this system can predict slumps, even under new formulations and environments, by learning from accumulated data.

The configuration of the AI slump-prediction system is shown in Fig. 1. An analysis camera that is installed on top of the mixer for mixing the concrete acquires images of concrete kneading. The system instantly analyzes images and predicts slump on a PC. The predicted slump is automatically transmitted to the chapter synthesizer and displayed on an existing monitor that monitors the interior of the mixer. This enables the production personnel to determine the predicted slump results on a normal monitoring monitor of the kneading situation. A dedicated tablet terminal and an application are provided to collect the data and reduce the burden on the operator. The data can be input at any place and time using a tablet terminal, and the relationship between the input-measured slumps and the corresponding kneading videos can be determined automatically.

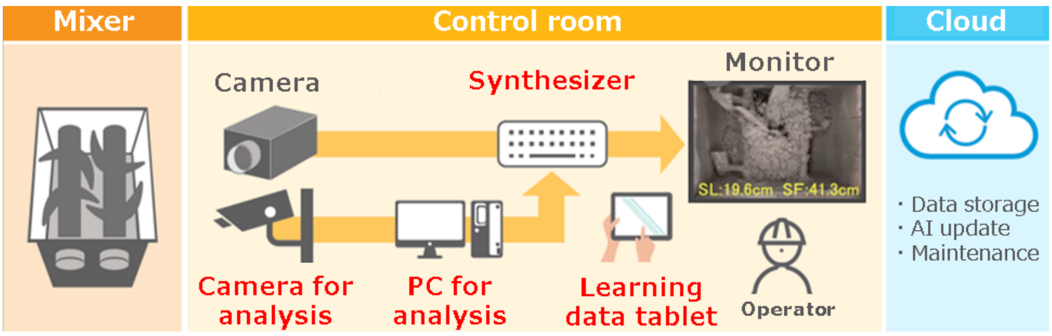

Fig. 1 Configuration of the AI slump-prediction system

Demonstration tests for the slump-prediction performance of this system were conducted in several ready-mixed and precast concrete plants. The relationship between the percentage of correct answers and slump tolerance is shown in Fig. 2. The percentage of correct answers was calculated as the difference between the actual value measured by the examiner and that predicted by the AI, and the number of correct answers within each tolerance level was counted. The percentage of correct responses was calculated as the percentage of correct responses within the tolerances for accuracy using formula [1].

$$A = \frac{n_D}{n} \times 100 \qquad [1]$$

where A is the accuracy (%), n_D is the number of data, $|x_p - x_a| \leq D$, n is the total number of verification data, x_p is the predicted slump value (cm), x_a is the measured slump value (cm), and D is the tolerance (cm).

A high prediction accuracy of 99% (tolerance: ±2.5 cm) was achieved after the AI was updated twice following its initial introduction. At the time of its initial implementation, the correct response rate (tolerance: ±2.5 cm) was only 78%, highlighting the importance of continuous learning in improving forecast accuracy. For practical use, it is desirable to begin slump prediction with the minimum amount of training data and then improve accuracy through repeated AI updates, given the time and effort required to collect training data in actual concrete production.

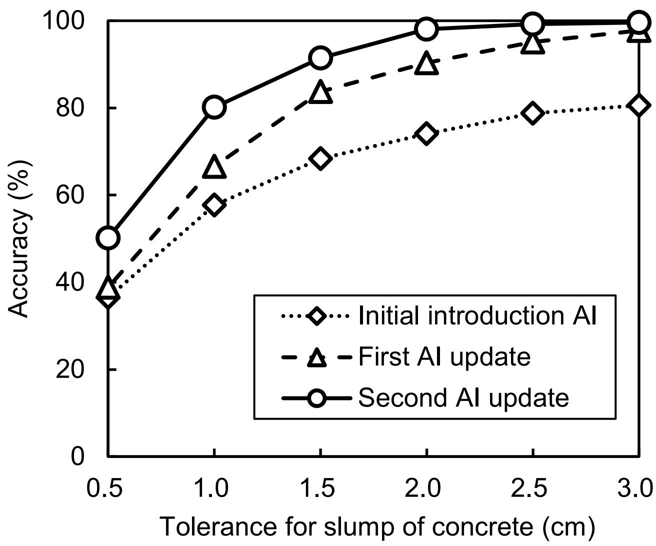

Fig. 2 Variations in accuracy and slump tolerance

2. Application of the system to manufacturing process control

The use of an AI slump-prediction system for process and quality control during concrete production was also investigated. The operational status of the AI slump-prediction system is depicted in Fig. 3. The predicted values are displayed at one-second intervals, with the lower left and lower right sections of the screen showing the predicted values for slump and slump flow, respectively.

A control chart of the slump between batches of concrete with the same mix is shown in Fig. 4. The predicted slumps represent values for each of the 10 batches, while the measured slumps correspond to values for each of the three batches. The centerline indicates the mean value of the predicted slump, with the "+2.5 cm line" and "−2.5 cm line" representing 2.5 cm above and below the centerline, respectively. The predicted slump closely matched the measured slump and was accurately predicted during continuous production (Fig. 4). As shown in Fig. 3, this system can predict the slump in real time during concrete production, simplifying the process of determining the slump value. This allows variations among multiple batches, which are challenging to detect using conventional sampling inspections, to be identified at an early stage. For instance, as illustrated in Fig. 4, the transition of the predicted slump relative to the centerline helps determine whether the slump can be adjusted for subsequent batches.

Fig. 3 AI slump-prediction system in operation

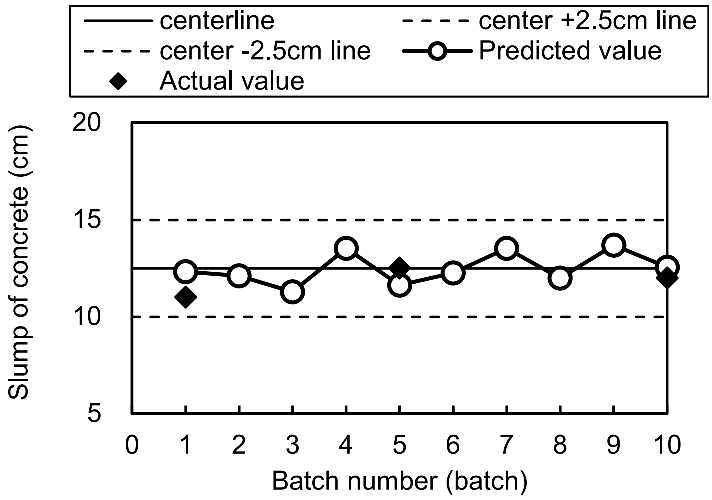

Fig. 4 Slump control chart

3. Expectations of introducing this system

The effects of introducing this system into concrete production, as determined through demonstrations at ready-mixed concrete and concrete product plants, are as follows.

(1) Standardization of concrete manufacturing process

The assessment of concrete mixing depends significantly on the skill of the person in charge of production, and sometimes experienced workers are unable to accurately determine when the concrete exhibits high viscosity or low fluidity. Slump prediction with this system is conducted quantitatively based on a defined standard, contributing to the standardization of the manufacturing process.

(2) Quality controls

This system is capable of real-time slump prediction. The system can calculate the total number of slumps effortlessly and detect abnormal products immediately. Consequently, it contributes to stabilizing concrete quality and enhancing quality control.

(3) Quality assurance

This system stores all data on a hard disk or in the cloud. In other words, the system has a traceability function that strengthens the quality assurance system.

(4) Effective education

In the concrete industry, it is difficult to recruit young engineers when skilled engineers eventually retire. The excellent skills of skilled engineers cannot be acquired overnight; even if new young engineers are hired, it takes time for them to acquire these skills. Using this system, young engineers can take charge of concrete production as soon as they begin to work and improve their skills through production work. This significantly reduces the time required for young engineers to acquire the necessary skills. In addition, this system is expected to reduce the mental load on the person in charge of concrete production by assisting with the production of concrete.

(5) Labor and manpower savings

This system is not affected by working hours, overtime, sudden absences, or medical leave due to illness or injury. In times of labor shortages or when changes to work practices are required, the system significantly contributes to reducing labor demands and improving efficiency in concrete production and construction.

Conclusion

In Japan, with the anticipated shortage of engineers and technicians, it is necessary to reduce human involvement in the field. Discussions are underway regarding quality control and inspection methods, such as comprehensive slump inspections. In light of these trends, there is increasing momentum for adopting new technologies related to digital transformation in the concrete sector. The AI slump-prediction system is a technology developed to address these societal conditions. The proposed system contributes to stabilizing quality and improving the productivity of concrete production. Taiheiyo Cement aims to accelerate the adoption of AI and other technologies to develop innovative methods that will contribute to improving concrete production and construction in the future.