Visualization Technology for Concrete Construction Using AI and Image Analysis

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1. Introduction

Concrete construction has been to slow to evolve with the times, continuing to rely on the knowledge, experience, and skills of workers to ensure quality. Therefore, there is a need for new and enhanced techniques for assessing on-site work utilizing AI trained on digitized knowledge and experience, which in turn will enable anyone to ensure and improve quality. In this context, we are working on the development of a system called CONCRETE＠i, which employs AI and image analysis to visualize the condition of concrete and operation status in real-time, ensuring and improving the quality of concrete structures.

This newsletter provides an overview of the CONCRETE＠i system and the various technological elements employed in visualizing the entire process, which encompasses concrete production, transportation, acceptance at the site, pumping, placing and compaction, treatment of construction joints, and assessment of surface quality.

2. Data Platform

The data platform (Figure 1) employs AI and image analysis tools to provide a visual representation of the concrete construction process, thereby facilitating real-time information sharing and data-driven quality management through the utilization of information and communication technology (ICT) tools. In the future, the organization of information collected from each process into a database and its analysis will facilitate the improvement of subsequent processes based on the status of those prior, thereby facilitating a spiral-up of the PDCA cycle for each process.

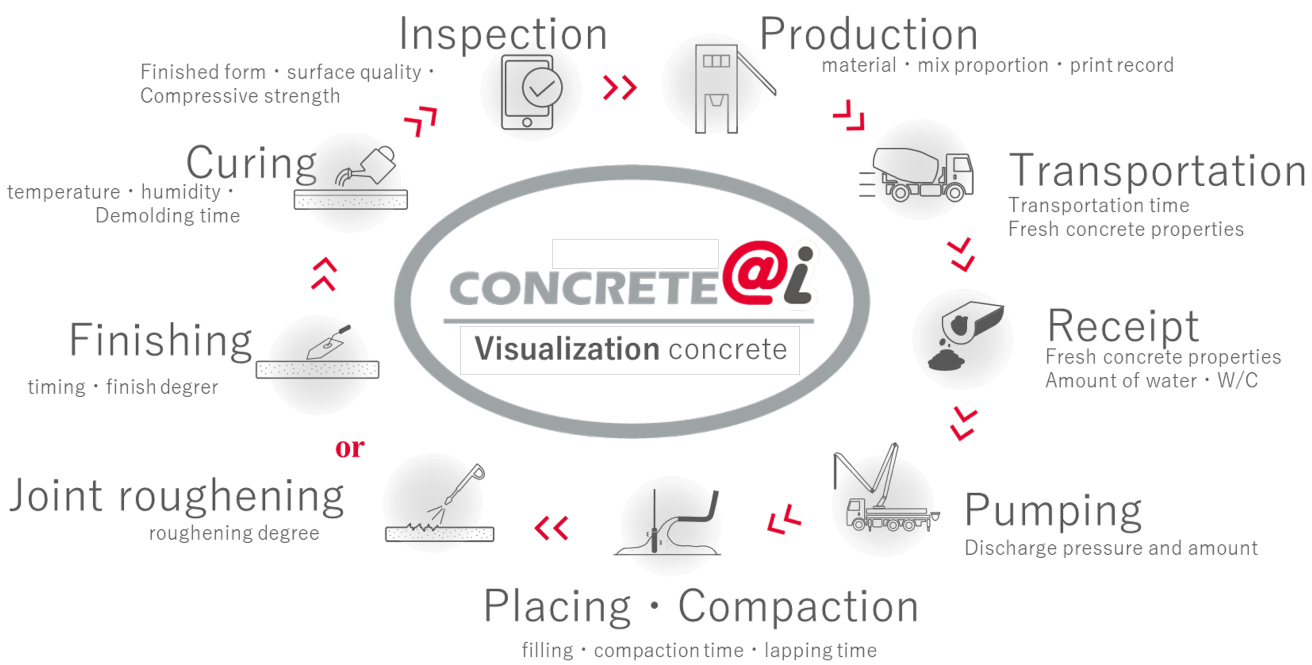

Figure 1. Visualization of the CONCRETE@i data platform

3. Various Technological Elements

3.1 Transportation Management

A cloud-based integrated vehicle operation management system (Figure 2) has been developed and put into practical use. This system estimates slump, concrete temperature, and load using probes and sensors (such as strain gauges and thermometers) that have been pre-installed in the drum of an agitator truck.

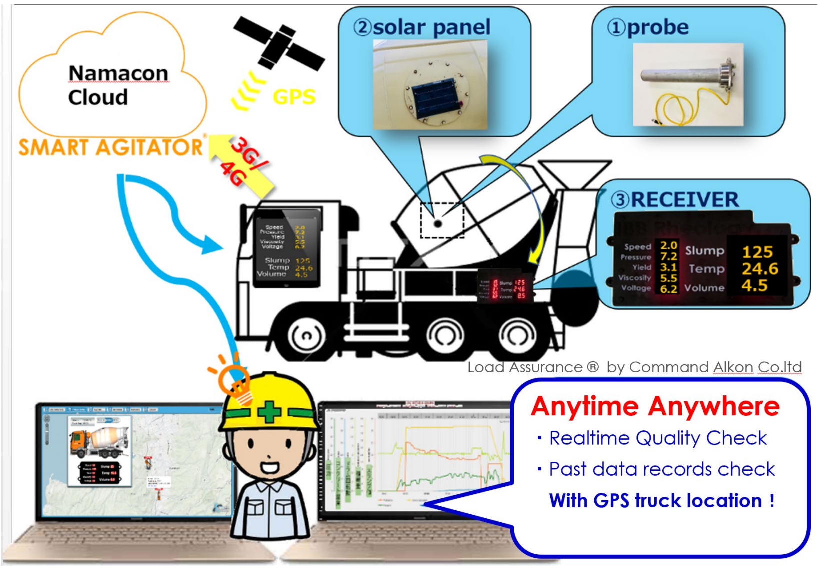

Figure 2. Cloud-based integrated vehicle operation management system

3.2 Pumping Management via IoT Vehicle Management System

A concrete pump equipped with an IoT vehicle management system (hereinafter referred to as the "IoT pump") gathers data in the cloud on the fluctuating discharge volume (theoretical discharge volume) and principal hydraulic pressure resulting from the operation of pistons during pumping, enabling near real-time monitoring remotely.

3.3 Total Acceptance Management

A total acceptance management system (Figure 3) has been developed with the objective of automatically detecting and eliminating concrete with poor workability (so-called harsh concrete) without human intervention. This system captures video footage of the concrete as it flows down the agitator truck chute and automatically estimates the slump and slump flow in real time.

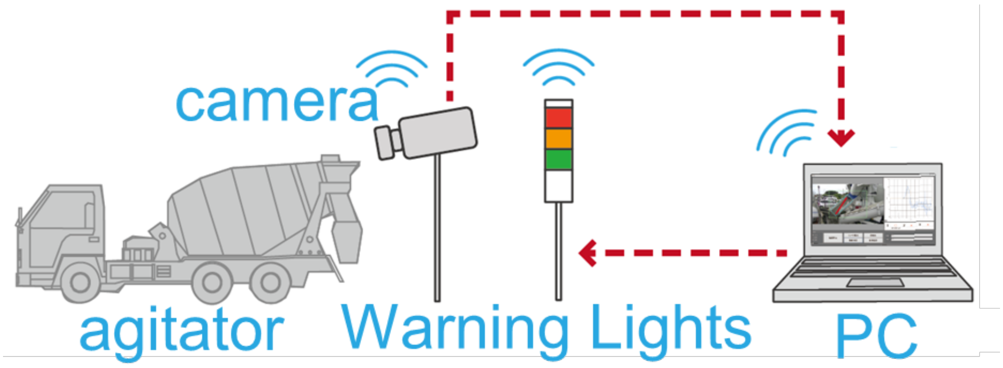

Figure 3. Total acceptance management system

3.4 Pouring Management

A concrete pouring management system manages the pouring time and the elevation of the point from which concrete is poured. The system consists of a laser displacement meter, a tablet for remote control, and a tablet for centralized management of measurement points.

3.5 Compaction Management

An AR compaction management system (Figure 4) records the duration and location of concrete compaction while concrete is being pouring. This system is comprised of a mobile device equipped with a camera worn on the arm of a construction worker and a computer. The point of compaction is detected by reading AR markers pre-installed around the pouring area using the mobile device. The progress of concrete pouring and finishing can thereby also be monitored on a continual basis.

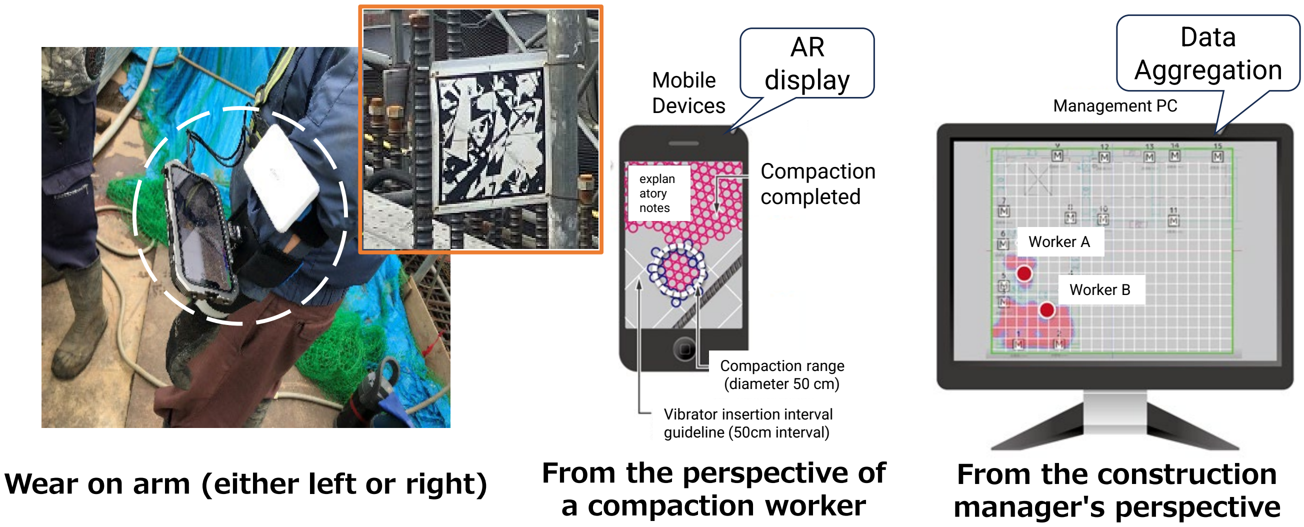

Figure 4. AR compaction management system

3.6 Joint Surface Treatment Management

A joint surface evaluation system (Figure 5) has been developed to enable a simple, quantitative, and objective assessment of the quality of a surface roughening treatment for a wide range of construction joints on site. This system focuses on the luminance distribution, which varies according to the unevenness of the joint surface and the exposure of the coarse aggregate, and quantitatively assesses whether the joint is good or bad based on the degree of luminance distribution.

Figure 5. Joint surface evaluation system

3.7 Concrete Finishing Management

A concrete finishing robot (Figure 6) has been developed to significantly reduce the needed manpower and labor when finishing concrete floors. This robot is able to change the angle and movement of the trowel according to the specification of the finishing operation, mimicking the skills of a human worker. In addition, the robot's movements can be tracked and recorded, helping to visualize the progress of the work.

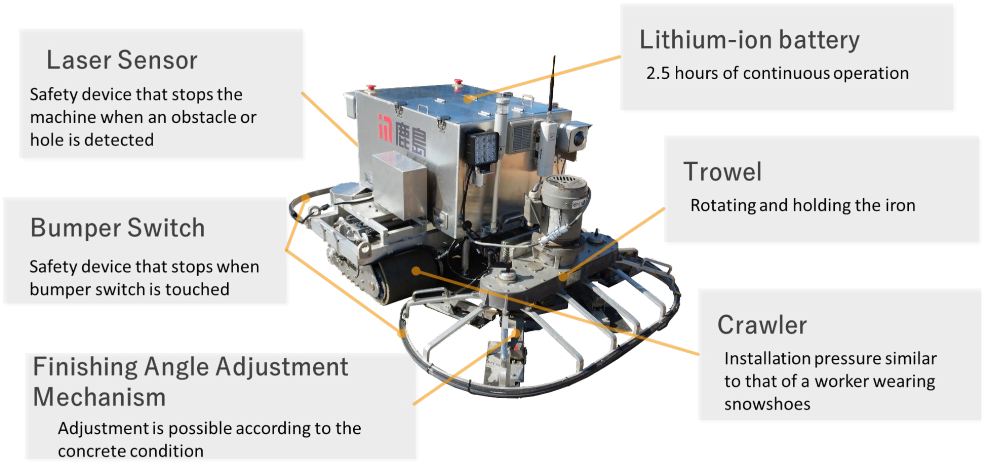

Figure 6. Concrete finishing robot

3.8 Inspection and Surface Quality Management

A system has been developed to enable on-site engineers with limited knowledge and experience to make the same evaluations as expert engineers through use of an AI that assigns points to the quality of construction, learning from the visual evaluations made by expert engineers (hereinafter referred to as the "AI surface quality evaluation system") (Figure 7). The AI surface quality evaluation system maps the variation in points on the surface being inspected as work is being performed, thus enabling the system to identify risks and take corrective action before quality defects occur.

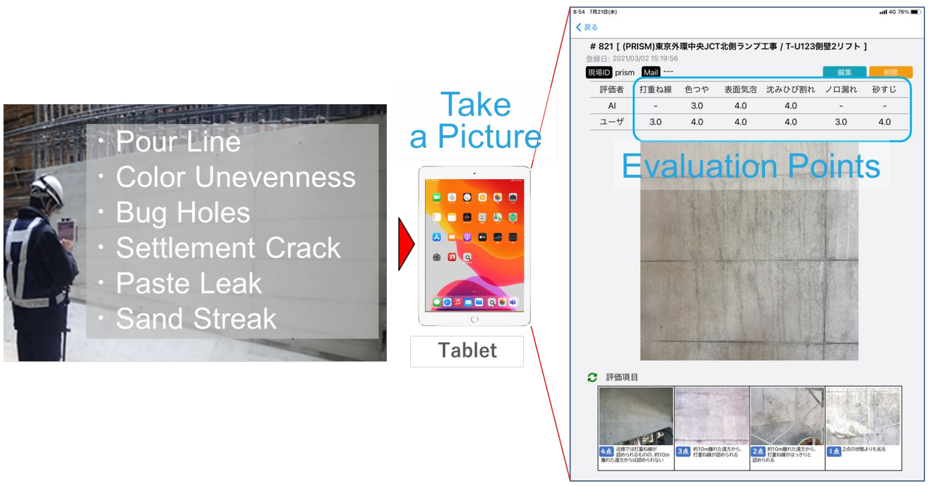

Figure 7. AI surface quality evaluation system

4. From Data to AI Development

The data platform aggregates data obtained through the aforementioned elementary technologies. The real-time access and sharing of the data acquired by each technology allows on-site construction workers to take prompt action to ensure quality and avoid loss of profit due to problems, thus facilitating the timely implementation of corrective measures. Moreover, the consolidated data provides a correlation between the construction management, quality control, and inspection outcomes of each site. By analyzing and reviewing the data as it continues to learn, the AI is able to suggest improvement activities for the next construction project. Conversely, such efforts can also be developed and used to improve the efficiency of the client's inspection work.

5. Conclusion

In the future, a range of technologies, including AI, image analysis, AR, sensors, and ICT, will be employed to visualize the quality of concrete and work conditions. The implementation of these technologies will facilitate the real-time monitoring of concrete structures and work environments, thereby enabling the development of automated solutions.