IPA News Letter
Volume 4, Issue 4 December 2019

Special Contribution

Technology Developments in Japanese Construction Industry

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ABSTRACT: The major Japanese construction companies have their own research and development (R&D) institutes as well as the design and engineering divisions, which is very different from the construction contractors outside Japan and one of the unique characteristics of the construction business in Japan. Such in-house research capability allows them to meet a wide variety of technical, social demands, and customer requirements in the world. It is also very important for their research institutes to develop new technologies in view of future trends in the business markets in the world. This report will introduce the recent activities of technology developments in such research institutes of one of Japanese contractors, i.e., Taisei Corporation which the author belongs to, with much focus on the technologies using recent ICT & AI technologies.

Key Words: Construction industry, Technology Development, Research Institute, Robot, ICT

1. INTRODUCTION

Major Japanese construction contractors have their own research institutes to enhance and expand their business markets. The topics of their research fields are significantly varied to cover the social and technical demands raised by our social lives and business activities of clients, as well as global trends. Selections and prioritizations of research and development topics are one of the major important duties of the author.

Major topics of research and development currently are
i) Technologies to cope with major future earthquakes and other natural disasters,
ii) Renovation and replacement of old existing infrastructures and buildings, especially in urban areas such as Tokyo,
iii) Environment-friendly construction to meet corporate social responsibility,
iv) Application of advanced technology such as use of ICT and AI to enhance productivity,
and
v) New construction technologies required for major projects in Japan.

Sustainable Development Goals (SDGs) which was proposed by the United Nations in 2015 are also important issues which we surely need to follow as the current and future global trends. Among the topics of the above, the recent advanced technologies which use ICT are introduced in this report after the brief introduction of the recent trends in Japanese construction industry.

2. RECENT TRENDS IN JAPANESE CONSTRUCTION INDUSTRY

It is necessary to first give an outline of overall trends in the Japanese construction industry. The Japan Federation of Construction Contractors (JFCC) publishes an annual handbook giving the latest data on the Japanese construction industry (JFCC, 2019). The author combines the data by referring the past issues of the handbooks.

Fig. 1 shows the overall trend in Japanese Gross Domestic Product (GDP) alongside investment in the construction market. It is revealed that GDP has remained almost unchanged for the past twenty years, with a slight increase up to about JPY 550 trillion (equivalent to USD 5.1 trillion at the latest exchange rate of 108 JPY/USD). At the same time, despite the unchanged trends in Japanese GDP, the investment in construction had halved by 2010 from a peak value of JPY 84 trillion in 1992 after the collapse of the Japanese bubble economy in 1989. After the investment hit the bottom value, the investment in construction has crept upward by 1.5 times to about JPY

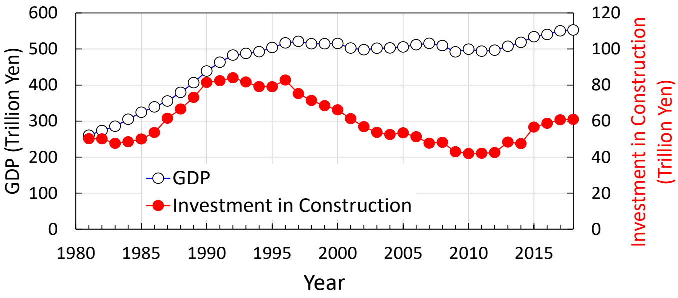

Fig. 1. Investment in construction in Japan
(Data from JFCC handbook)

60 trillion in 2018, which increase is thought to be attributed to rehabilitation and reconstruction work following the 2011 Tohoku Earthquake and a construction boom related to the upcoming 2020 Tokyo Olympic and Paralympic Games, and other big projects in Japan.

Fig. 2 shows the overall trend in the number of construction companies operating in Japan and employees in the industry. The number of construction companies has decreased by 22% from the peak of 601,000 in 1999, while employment has fallen by 25% from the 1997 peak of 6.85 million. Although the investment has increased by about 1.5 times in the last five years, the number of construction companies as well as the number of employees have not increased at all, which means that a significant lack of labor in the construction industry has been experienced. Fig.2 clearly shows that once left the industry, it is not easy to return. Owing to the lack of labor, the construction workers have been busier and busier, which leads to the work of the construction industry less attractive for young engineers.

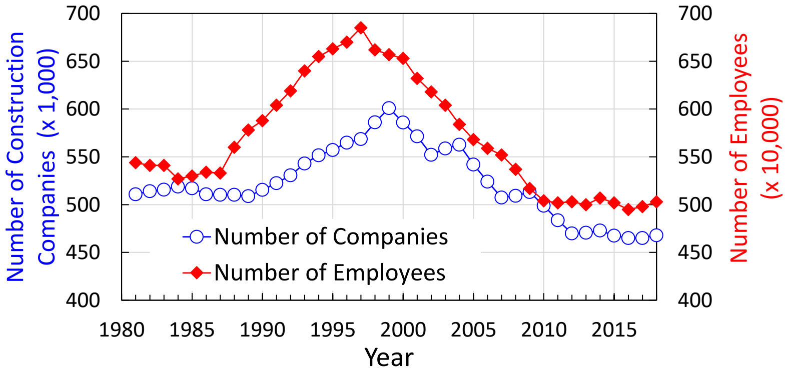

Fig. 2. Number of construction companies & employees in construction industry

Fig. 3 shows the percentage of workers in different age in the construction industry compared with that for all industries in Japan. It shows the significance of rapid aging in the construction industry compared with other industries in Japan. At present, more than one third of employees in the industry exceed 55 years old, with only about 10% being less than 29 years old. Attracting young engineers to the construction industry is a very urgent issue.

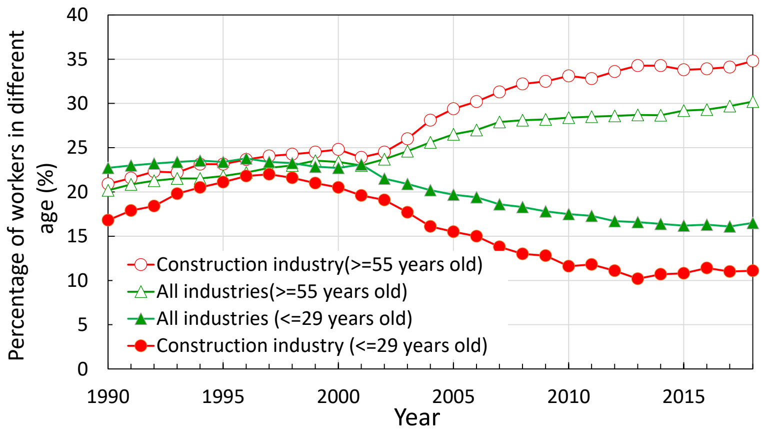

Fig. 3. Percentage of workers in different age in construction industry compared with that for all industries

Considering the above situations in the construction industry, it is very important for us to develop new technologies to cope with the shortage of labor and skilled workers in construction, as well as more advanced technologies using ICT and AI which are attractive to young engineers, and which will change the negative image of '3D' in the industry, i.e., Difficult, Dangerous, and Dirty. Improving productivity in the industry will surely be one of the solutions.

3. IMPROVING PRODUCTIVITY IN CONSTRUCTION INDUSTRY

Unmanned construction system

In 1991 one of Japan's most active volcanoes erupted and generated an enormous pyroclastic flow that killed 43 people (Fig. 4). The site at Mt. Unzen remained in dangerous conditions, but the disaster recovery efforts had to go on, so the government decided to use unmanned construction systems for the work. Following the successful application of unmanned construction system at the Mt. Unzen site, the technology has been improved and used for many other natural disasters. These include the sites of landslides resulting from earthquakes, heavy rains and other natural occurrences. It is worth noting, also, that unmanned construction systems played an important role when the Fukushima nuclear power plant was severely damaged in the 2011 Tohoku Earthquake (Fig. 5). The unmanned machines removed rubble and debris immediately after the accident to allow rapid and problem-free commencement of other recovery work. Initially, the unmanned machines were controlled from a site house located at the nearest safe place for the work. Remote control of construction machinery requires particular skills that differ from those needed to operate the machines directly. Work was carried out step by step under manual control, using many monitors set up in the site house to observe the operation.

Fig. 4. Pyroclastic flow occurred at Mt. Unzen in 1991 (https://en.wikipedia.org/wiki/Mount_Unzen)

Fig. 5. Unmanned construction systems at Fukushima nuclear power plant https://www.nikkei.com/article/DGXNASFK11034_R11C13A2000000/

More than 25 years have passed since the first application of unmanned construction. Advanced technologies related to real-time positioning systems, monitoring systems, highly accurate sensor systems, communications, and other recent ICT and AI techniques ensure more accurate work with more automatic and autonomous control. Unmanned construction technology also contributes to reduce demand for workers. Two autonomous unmanned construction machines have been developed, a vibration roller system and a breaker system (Katayama and Ishii, 2016, Katayama et al., 2015). These machines can complete an assigned task without further human control once the initial conditions and target results are entered.

Fig. 6 shows the autonomous unmanned vibration roller named as 'T-iROBO Roller'. It is fitted with a number of sensors needed for autonomous operations. Fig. 7 shows the machine undergoing verification tests. After an operator enters data specifying the area requiring compaction, the machine completes the work, autonomously keeping track of the number of compactions. Since the machine accurately tracks its own position, construction work can continue even in poor visibility, such as with fog, and at night. Operational data can be linked with data from Building Information Modeling (BIM) or Construction Information Modeling (CIM) systems and linked to quality control data. An autonomous unmanned breaker machine (Fig. 8) named as 'T-iROBO Breaker' is able to detect a target object, such as a mass of rock, from a distance, approach the target, and break the up target while determining the best breaking position.

Fig. 6. Autonomous unmanned vibration roller

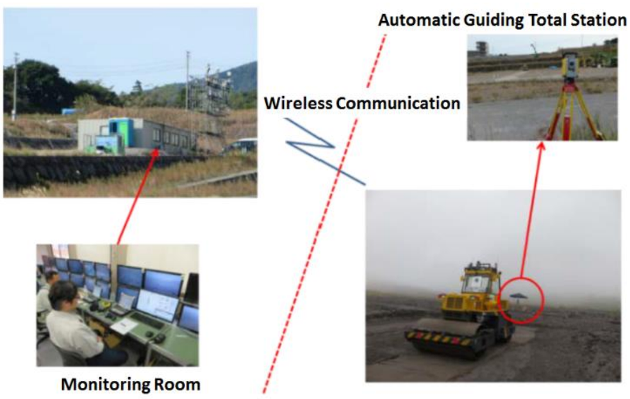

Fig. 7. Verification test of autonomous unmanned vibration roller

Fig. 8. Autonomous unmanned breaker

Automatic concrete slab finisher and cleaner

Manual slab finishing just after casting is hard work for a construction worker as shown in Fig. 9. It is slow work in a difficult posture that places a heavy burden on the body. An automatic finishing machine was then developed for concrete floors. An attempt was made to improve work conditions and efficiency in this concrete finishing work by developing a light-weight construction robot named as 'T-iROBO Slab Finisher' (Nakamura, 2016), as shown in Fig. 10. The machine does the work of three construction workers. Operation is done by a single worker with a controller like the one used for computer games, leading to a reduced workforce and easier work. The machine is battery-operated and weighs 90kg, of which 25kg is a battery weight. Continuous operation for 3.5 hours is possible. Battery performance and weight still leave room for improvement. In addition to the types of automatic machine described above, an automatic cleaning machine for construction sites has been developed (Kato, 2016) named as 'T-iROBO Cleaner' as shown in Fig. 11. It can recognize safety cones and barriers marking off-limits areas.

Fig. 9. Finishing cast concrete is hard & time-consuming work

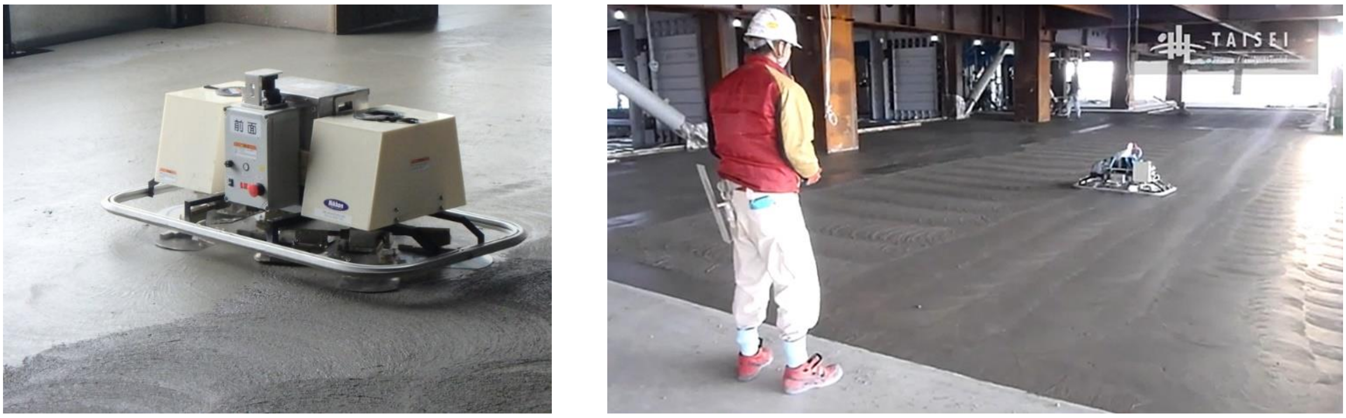

Fig. 10. Automatic concrete slab finisher

Fig. 11. Automatic cleaner for construction sites

Advanced positioning system for pile installation

Work of accurately marking the specified locations for piles generally requires at least two people, one stationed by the measuring system (total station theodolite) and the other moving around into the exact pile positions. An advanced positioning method named 'T-Mark Navi' that can be operated by just one person has been developed (Tanaka and Sueda, 2016). The operator wears a pair of wearable (smart) glasses that include a display system. Fig. 12 compares the operation of the system with the conventional method. A specially designed measurement device is used instead of the conventional total station theodolite. The operator carries a smart phone that communicates with the measurement device via wireless LAN and uses voice control technology to determine precise pile positions. Positioning data is visible on the display of the smart glasses, as shown in Fig. 13. This system reduces the number of workers required for pile positioning by half.

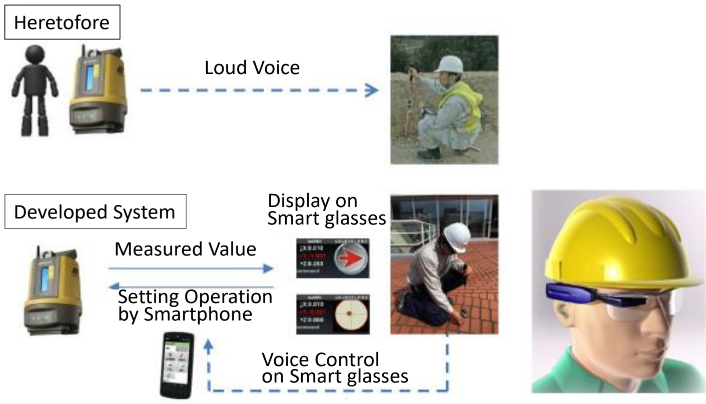

Fig. 12. Precise positioning system operated by only one person

Fig. 13. Display of positioning data via smart glasses

Systems developed for safer tunnel construction

Tunneling in complicated geotechnical conditions is one of the difficult constructions. Safe and secure tunneling is always desired. A technology used projecting mapping was developed for tunnel construction (Fig. 14) (Tani et al., 2019, Nikkei Construction, 2019). Once drilling was finished at the tunnel face, the face is covered with shotcrete quickly for safety and protection. Therefore, it is important to share the information on the face with all workers and operators. The system projects the necessary information directly on the runnel face so that all workers and operators can share the technical information easily. Examples of the projected information are shown in Fig. 15.

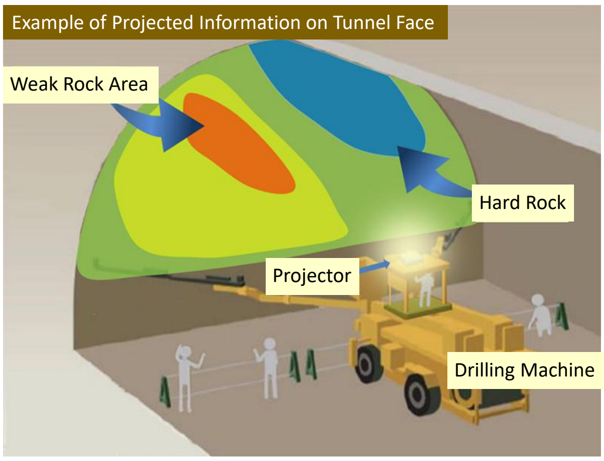

Fig. 14. Projection mapping system on tunnel face

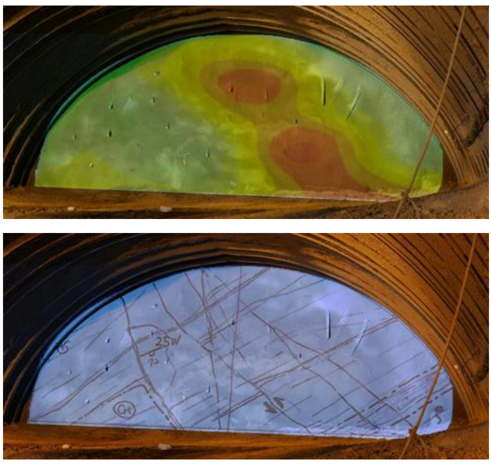

Fig. 15. Examples of the projections

4. SUMMARY

Some of the research and development activities at Taisei Advanced Center of Technology (TAC.T) was briefly introduced with focus on technologies to cope with the shortage of labor and skilled workers in the construction industry. Most technologies use advanced ICTs, and more AI technologies in the future. Implementation of ICT and AI in construction technologies will enhance the productivity of the construction industry as well as attract more young engineers to the industry. Please note that the contents described in this report are only a small part of the results. Further information can be available on the website of Taisei Corporation, and Report of Taisei Advanced Center of Technology, or please contact the author.

'Open innovation' has become a major keyword in the recent research and development activities. Collaborative work on a global scale with a wide variety of fields beyond the scope of construction is more necessary for further development of the construction industry in near future.

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◆ A brief CV of Dr. Kenichi Horikoshi

Kenichi Horikoshi is the general manager at Taisei Advanced Center of Technology, Taisei Corporation, Japan. After completing the Master's degree from Kyoto University in 1987, he joined Taisei Corporation. In 1996, he received PhD degree from the University of Western Australia for the thesis of 'Optimum Design of Piled Raft Foundations'. Since then he has engaged in a number of research projects and consulting works on a wide variety of geotechnical engineering fields. Currently, he is responsible for technology development strategy in Taisei Corporation. He is also the Secretary General of Asian Civil Engineering Coordinating Council (ACECC), as well as the vice president of Japanese Geotechnical Society.