AN AUTOMATED CONSTRUCTION SYSTEM FOR HI-RISE BUILDINGS: AN EXAMPLE OF COMPUTER INTEGRATED CONSTRUCTION

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I feel it a great pleasure to be given this opportunity to present our current technology developments in automated construction systems. I would like to begin my presentation by briefly describing computer integrated construction, that is, CIC. Application of innovative computer technologies to architecture, engineering, construction industry is viewed as a major factor to improve productivity and efficiency in these disciplines.

The recent improvement on computer technologies in such areas as computer-aided design, computer-aided engineering, database management systems, knowledge based systems, and automation and robotics have expanded the spectrum of potential applications. Remarkable progress in the application of computer technologies in the manufacturing industry have been made, through the development of computer integrated manufacturing systems, that is, CIM.

This technology, when adapted to construction, is known as computer integrated construction, CIC. It promises to allow the construction industry to reach higher levels of sophistication.

Let me introduce one approach to computer integrated construction and present current examples in Shimizu. Current approaches to develop CIC are generally classified into the following three aspects. The first approach to develop CIC is to integrate computer-aided design and computer-aided engineering systems for the improvement of design and engineering productivity. The second approach is to integrate planning and management systems, such as concurrent design and construction planning and real time monitoring of the project. The third approach is to integrate the building systems and construction systems, such as industrialized composite and automated systems and robotics.

CIC consists of these three systems by utilizing innovative computer technologies such as ARA, database, hypermedia, computer graphics and robotics. This scheme shows conceptual bill of CIC at Shimizu. CIC is realized by efficiently integrating these systems. Design and engineering system and planning and management system in the previous slide are integrated into one concurrent design and construction planning.

On the other hand, the construction system is divided into two separate systems. One is site automation systems and the other is the factory automation system. Common database plays an important role for exchanging design and construction information throughout these three systems. As management of logistic information really becomes more important, due to the decomposition of construction functions.

I would like to offer an example of CIC systems in Shimizu. Shimizu Corporation has been developing an automated high-rise building construction system. The system is called SMART Shimizu Manufacturing System with Advanced Robotics Technology. This system is being applied to a real office building construction project in Japan. SMART system is a part of Shimizu strategy for developing construction systems which integrate the high-rise construction process from the foundation to the site management, including structuring, finishing and installation work. By introducing a SMART system, the amount of labour required in the construction period is reduced significantly and the poor image of a construction site is dispelled. This one shows the Durok Bank Building in Navoya City in Japan. To reach a SMART system is really a pride.

I would like to briefly explain this building. The site area is about 2 000 m², the total floor area is 20 665 m², the standard floor area is 900 m², the height is 80 m with 20 stories and the main structure is steel. The construction period
is 28 months, including 11.5 months of construction work by the SMART system.

In this project the SMART system automates a wide range of construction procedures, including the erection and welding of steel frames, replacement of previous concrete floor panels, exterior and interior wall panels and installation of various units. The system utilizes pre-fabricated components extensively, including columns, beams, floors and walls, and the assembling of these components is simplified by the use of specially designed joints.

The heart of the SMART system is composed of the lifting mechanisms and automatic conveying equipment, installed on the operating platform, which is ultimately to reach to the roof of the building. Steel frame columns, beams, floor and walls are automatically conveyed to designated locations, where they are effectively assembled and mounted with specially made joints.

Our steel frame process is also automated with the invention of an automatic welding machine. When one of the floors of a building is completed, the entire automated system is lifted vertically and the work for the next floor commences immediately. Thus construction work proceeds systematically, floor by floor, until the whole building is completed.

The SMART system also provides complete all weather enclosure for a site, accommodating satisfactory working conditions and safety, and leading to higher quality for the product.

Let me show the first application of SMART, especially the automated erection system, to construct one of our laboratory buildings. Through this experimental application we investigated the efficiency of automatic conveying and assembling system by computer control and we also evaluated availability of special joints of steel frames and lifting mechanisms of operating platform.

This slide shows the conveying and setting of steel columns. Both conveying and setting of steel columns were controlled by the computer, based on the operator's instructions. The entire process is displayed on the screen on real time.

Control on the management of construction was conducted from the computer in this control centre. The design of steel column joints were developed so that assembly can take place without workers' help. Also beams, joints were developed to allow for automated fabrication. After the completion of installation of steel frames on one floor, the entire steel erection machine was lifted up smoothly to the next floor, using the step lock of the jack. This process is also controlled by the computer in the control centre and was displayed on the screen in real time.

The steel frame erection of floors in this building was repeated four times and was finally found to be completed, the entire erection process, in a four day cycle without any delay.

After examining data collected through experiments, we improved the lifting mechanisms to be applied without design constraints. We also developed automated building systems and automated transportation system of building elements and the materials based on the experiment.

This slide shows the automated building machine. This machine determines the building conditions using laser sensors and database in positioning of building equipment. This system allows only one worker to control and transport two or three machines. This automatic material transportation system is also introduced as a component of the SMART system. In contrast with automatic conveying systems, which mainly transfer building elements such as steel columns, beams and previous concrete panels, this system mainly transports materials and parts for fitting, decorations, which are not fully automated at present.

Several information systems have been developed and tested as sub-systems for SMART in a lot of ordinary construction projects. This slide shows a current architecture of information management system applied to SMART, which includes not only real time monitoring but management of design information, construction process information and logistic information, utilizing several kinds of media and network.
In addition, the sophisticated simulation and real time computer control orchestrates the whole assembling process, resulting in construction site operation in a highly automated way.

This slide shows a meeting board system which utilizes drawing boards as an input and display of computers. The meeting board system incorporates the production and the process information at site and improves efficiency of communication in site management. Thus, information management at the site is made efficient with the SMART system as well, thereby reducing the amount of waste and improving overall site management and scheduling.

I would like to summarize the efficiency and productivity of SMART system at the present. Through simulation using the data, corrected through the experiment on construction and applications of sub-systems, we plan to reduce 20%, both in productivity and construction period, in the Durok Bank project in Japan. With steel frame erection activities, we forecast labour reduction by 35% and time saving by 35% compared to ordinary tower/crane erection system, because in SMART we can utilize synthesized and simultaneous application of assembling systems and transportation systems. With steel column joint activities, we forecast 100% to 200% increase in labour productivity by introducing automated building machine.

With efficiency of SMART always a condition, it makes the construction process more stable. Prefabrication and automated construction system increase, reliability of quality and synthesized and simultaneous application robots, the machines improve their efficiency.

We plan to develop the SMART system even further, by developing more effective information management system for SMART, an automated construction system for underground. In the not-so-distant future, we plan to reduce labour and construction period to half of the present time.

In conclusion, I would like to say that the greatest impact of higher efficiency, the productivity and the safety in AEC industry will be brought by construction process innovation, that is, CIC. Shimizu is trying to establish CIC efficiently now. One of the key applications of CIC is the SMART system. The SMART system is to be applied to actual construction projects, defining its sub-systems and the functions to a real integration of computer and robotics.