Current Status of and Problems with Information Technology Construction Technology for Road Construction Work in Japan

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ABSTRACTS: Information technology construction (hereinafter “ITC”) has been rapidly promoted in recent years as an engineering solution to various construction-related problems such as improving productivity, improving safety, improving quality, and dealing with the lack of veteran workers following the mass retirement of the baby-boom generation. The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) set up the Information Technology Construction Promotion Committee in February 2008 in an effort to promote information technology construction and put together the Strategy for Information Technology Construction Promotion to support strategic diffusion of information technology construction in July 2008. In response to those movements, the Japan Road Contractors Association surveyed the present status of information technology construction, the techniques used for ITC, and the records of ITC applications and gathered together the problems identified from such survey. ITC is best used when it is applied to all processes of construction work including survey, design, and maintenance. But at the moment, the “informatization” part of ITC alone is promoted, and it is hoped that there are early implementation of ITC in its true sense.

KEY WORDS: Information technology construction, application records of information technology construction.

1 OUTLINE OF INFORMATION TECHNOLOGY CONSTRUCTION

In actual information technology construction (ITC) for road construction, three-dimensional coordinates (X, Y, Z) of a design plan are input in a memory unit, the position of a construction machine (Xa, Ya, Za) is measured on a real-time basis, and the amount of (Z − Za) is automatically controlled so as to make a working device become the design plan height data (Z) at that position. This basic idea applies even for different machines or different position detection methods.

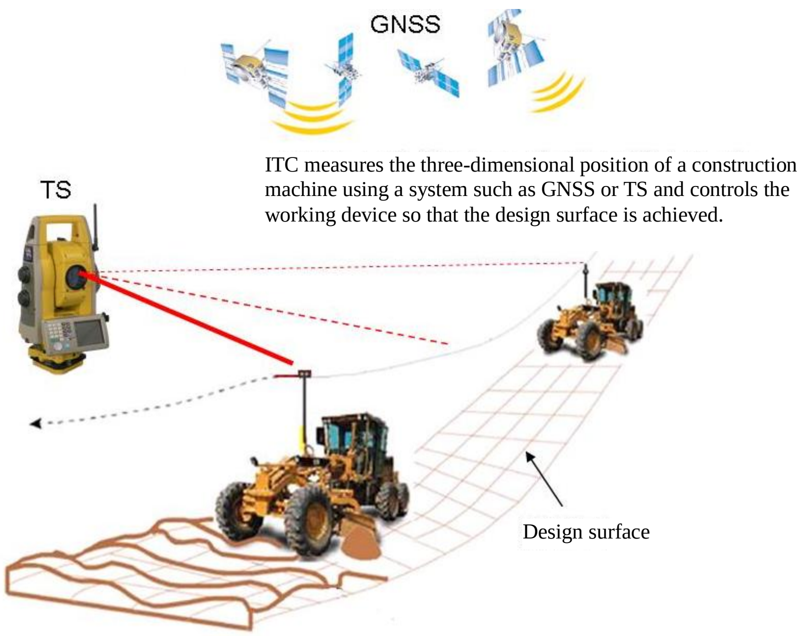

Figure 1: Concept of three-dimensional machine control

An outline of three-dimensional machine control (3D-MC), as the ITC technology used in the construction stage of road construction work, is explained in the following, and a conceptual diagram is shown in Figure 1.

A few 3D-MC systems have been commercialized by conducting real-time measurements on the position of a construction machine and the height of a working device.

1.1 3D-MC by Global Navigation Satellite System (GNSS)

GNSS is a positioning system using US satellites and other positioning satellites of Europe and Russia. Since the system uses many satellites that provide supporting data, it can provide more accurate pieces of data than those provided by a single GPS.

GNSS-based 3D-MC acquires 3D coordinate information of a construction machine and a working device from GNSS. The controller installed in a construction machine conducts control so that the difference between the design plan data at the position of the machine and the height of the working device is compensated for. Use of GNSS creates big measurement errors, but an actual construction machine control system uses real time kinematic (RTK) method, in which a base station at a fixed point whose installation position is known is set up, and the measurement error is sent to the mobile station put on the construction machine for compensation (Figure 2).

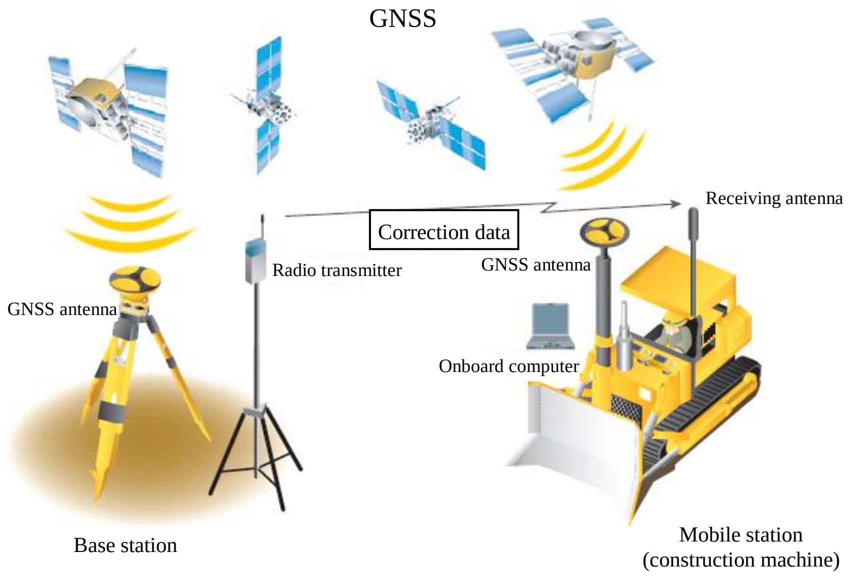

Figure 2: GNSS-based 3D-MC

1.2 3D-MC Made Up of GNSS and Laser System

Since GNSS-based 3D-MC creates errors in the height direction, a combination of GNSS-based 3D-MC with a laser system guarantees a higher precision. To be specific, the horizontal position (Xa, Ya) of a mobile station (construction machine) is measured with GNSS, while the vertical direction (Za) is detected by the laser system.

The laser used here is not a standard one that makes a horizontal reference surface with simple rotational laser light; it is a zone laser, which is a rotational laser that has a certain width in the vertical direction. If a construction machine or surveying device equipped with a sensor to receive zone laser light is in this zone laser range, a level of precision as high as that of a rotational laser can be obtained. Since there is no limit to the number of light receiving sensors that can be used, it is possible to simultaneously control two or more construction machines during the surveying work, which is one advantage of this combination system (Figure 3).

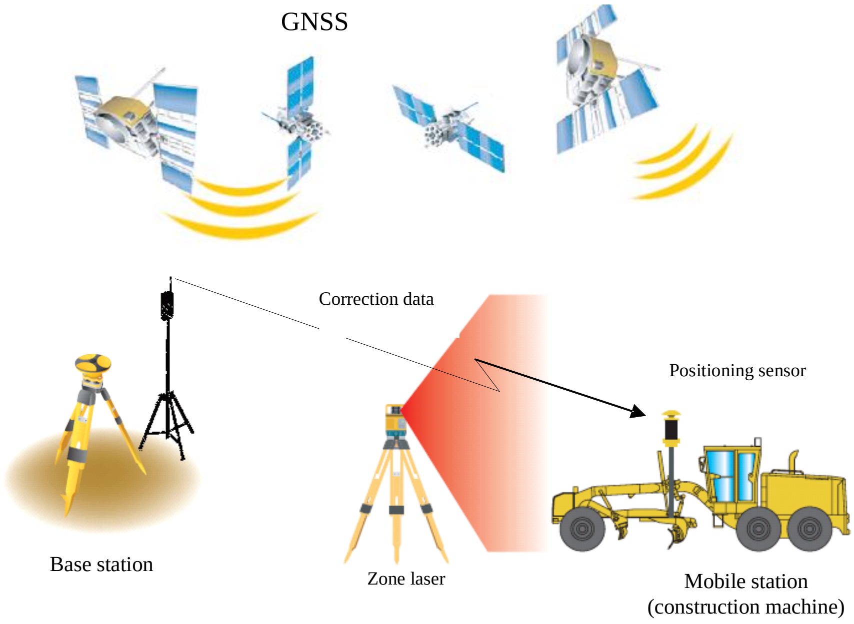

Figure 3: Combination of 3D-MC with GNSS and laser

1.3 3D-MC with Automatic Tracking Total Station

A total station (TS) is a surveying device that simultaneously measures the angle and distance, which are the basic elements of survey. When the angle and distance are measured from observation, the three-dimensional coordinates of a target (in this case a surveying prism) can be obtained (Figure 4). This system conducts 3D-MC of a construction machine using an automatic tracking total station additionally fitted with the capability to automatically track a target.

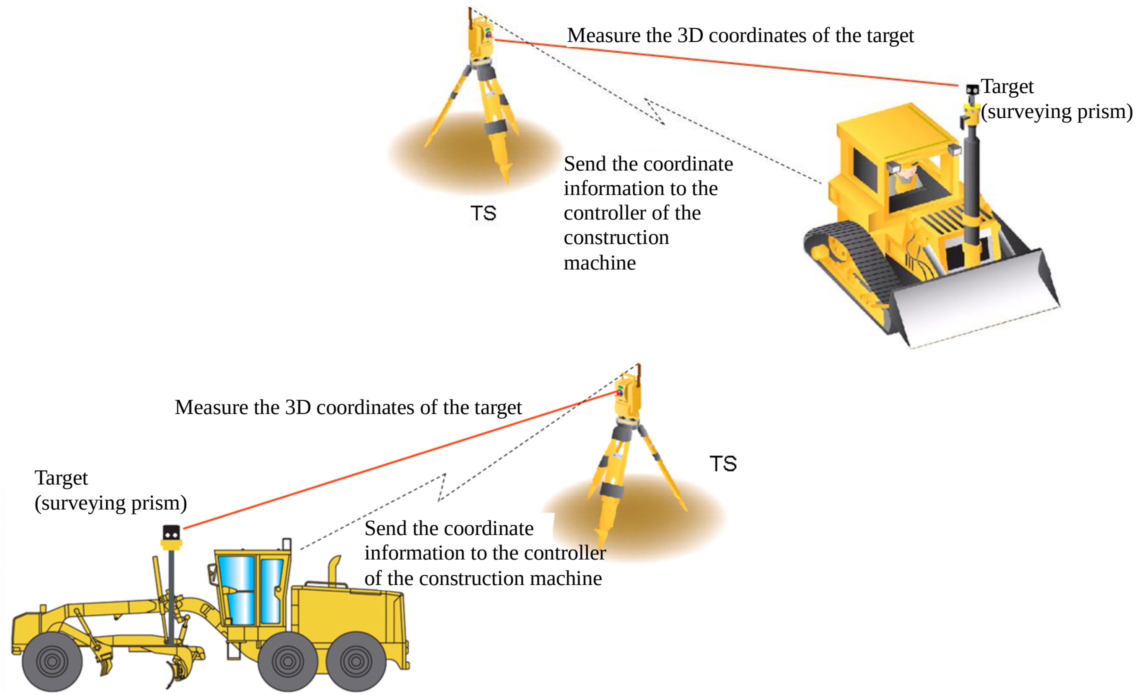

Figure 4: 3D-MC using automatic tracking total station

This system does not need a base station to be set up, unlike GNSS. Therefore, it is relatively easy to make preparations for the work. Because of this feature, the system is currently enjoying a rapid diffusion.

As the relationship between TS and the survey target is one to one, the number of TS's required is the same as the number of machines to control.

1.4 Rolling Management System

A system of rolling management has been developed that measures the location of a roller with GPS or TS to manage the rolling locations and the number of passes. In this system, the rolling locations and the number of roll passes are shown on a monitor attached to the roller to inform the operator of the conditions on a real-time basis. A system that incorporates the data on the degree of compaction by combining an accelerograph or radiation thermometer attached to the roller is also used.

As mentioned above, the technique of not controlling the machine itself but providing the operator with information on the location of the work device to enhance execution efficiency and precision is called "machine guidance." This concept is applied to excavation and slope trimming in addition to rolling management.

2 APPLICATION RECORDS OF INFORMATION TECHNOLOGY CONSTRUCTION

A questionnaire was given to the eight member companies of the Working Group (WG) 6 of the Subcommittee on Pavement Technology and Construction Management of the Japan Road Contractors Association in order to investigate the present status of information technology construction in the road pavement industry and its problems. The questionnaire particularly focused on the results of application, the type of work to which ITC was applied, and the construction machines used in ITC-based execution.

Figure 5 shows the number of projects in which ITC has been used since FY 2006. The figures indicate that every company has increased the number of ITC applications in their work projects, with the number of applications rapidly increasing from 24 in FY 2006 to 114 in FY 2007 and 221 in FY 2008.

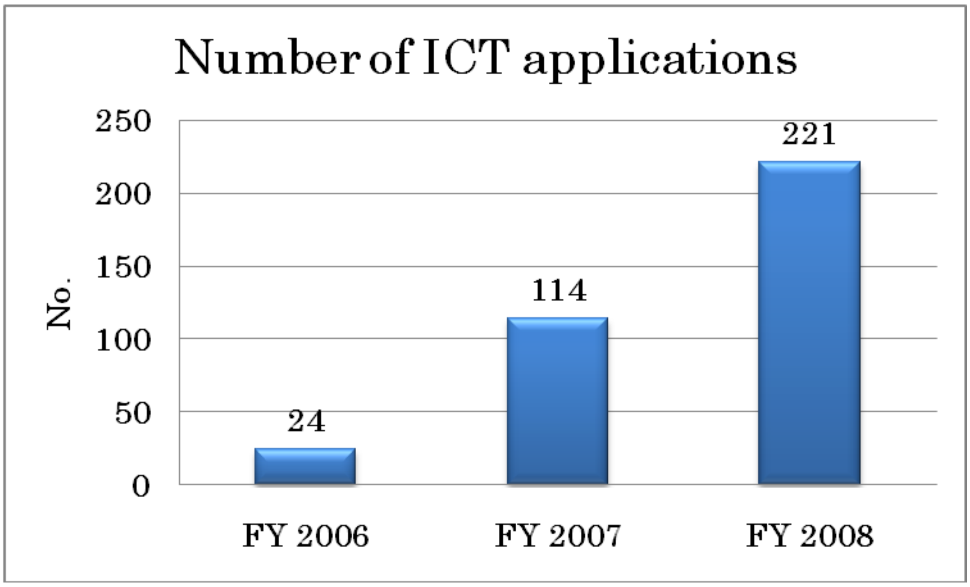

Figure 5: Number of applications of ITC

The details of ITC applications in FY 2008 are shown in Figures 6 through 8. The usage percentages of TS, mmGPS and rolling management are shown in Figure 6. TS-based 3D-MC occupies 83% of the total. Since it is relatively simple to install the system for TS compared with mmGPS, and also because it can flexibly cope with changes due to local conditional changes, TS-based 3D-MC has been rapidly diffused particularly in private projects. Meanwhile, mmGPS systems are often applied to large-scale projects such as construction of airports or expressways.

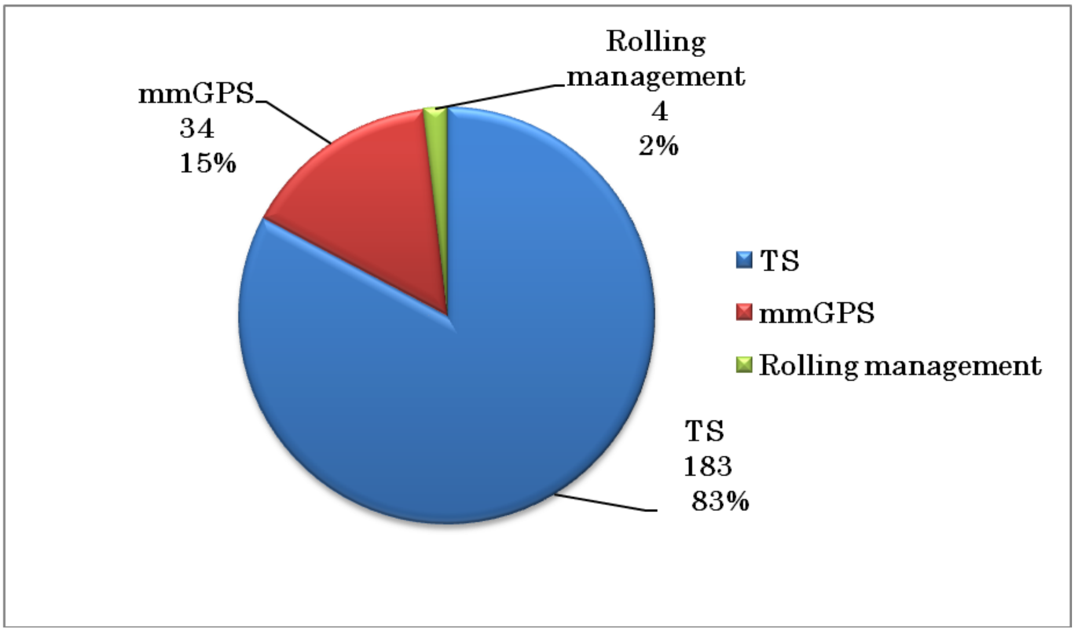

Figure 6: Breakdown of ITC system applications

Figure 7 shows a breakdown of the types of work to which ITC was applied. Subgrade work occupies 21%, and base course work 66%. Of the total types of work, 87% were occupied by subgrade and base course work. Use of ITC now allows a very precise finish of subgrades and base courses. An asphalt finisher, one of the machines used for asphalt paving, was originally designed to level the road surface. If the subgrade and base course are applied with high precision, the flatness and workmanship will eventually improve even if only the finisher is properly operated.

Asphalt paving accounts for 9% (25 applications). In detail, ITC was mainly used for asphalt-treated base courses and binder courses. This statistic suggests that an accurate finish of subgrades, base courses and subbase courses allowed construction of surface courses not by 3D-MC but by the interpolation technique of ITC or the thickness management process using the leveling capability of the finisher. In conclusion, finishing the subbase course with high precision to finish the surface course with a high level of flatness by thickness management is the system of construction that satisfies all requirements of workmanship, precision and flatness.

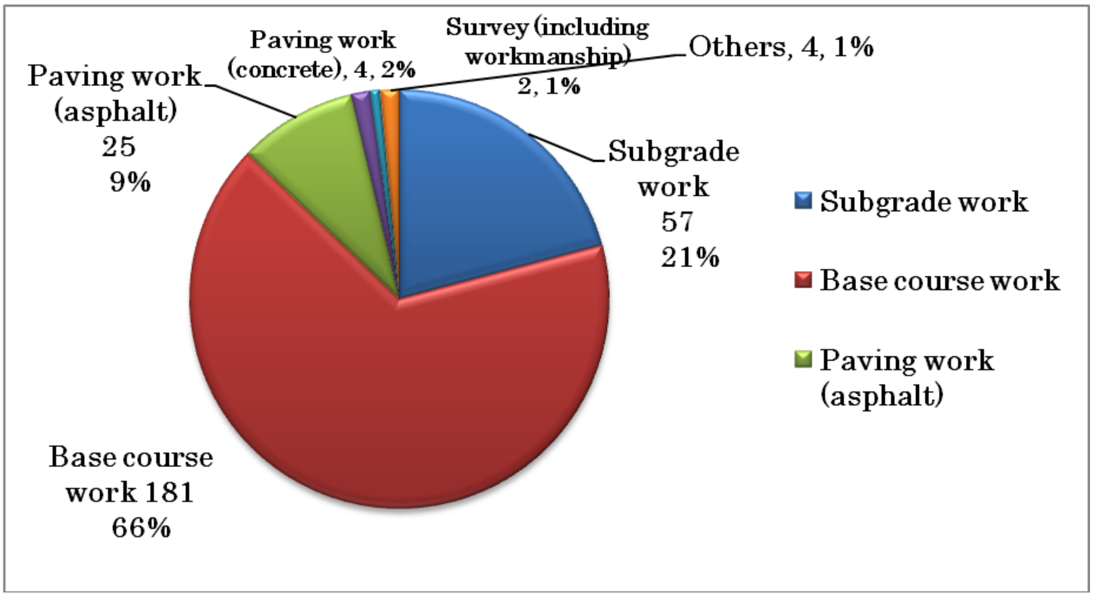

Figure 7: Breakdown by the type of work

Figure 8 shows a breakdown of the use of construction machines. Since ITC is mainly applied to subgrades and base courses, the kind of construction machines used for ITC are mainly those for subgrades and base courses. Two machines occupy 87%, with bulldozers accounting for 62% and motor graders 25%.

ITC was applied to three slipform projects. More use in this genre is expected in the future.

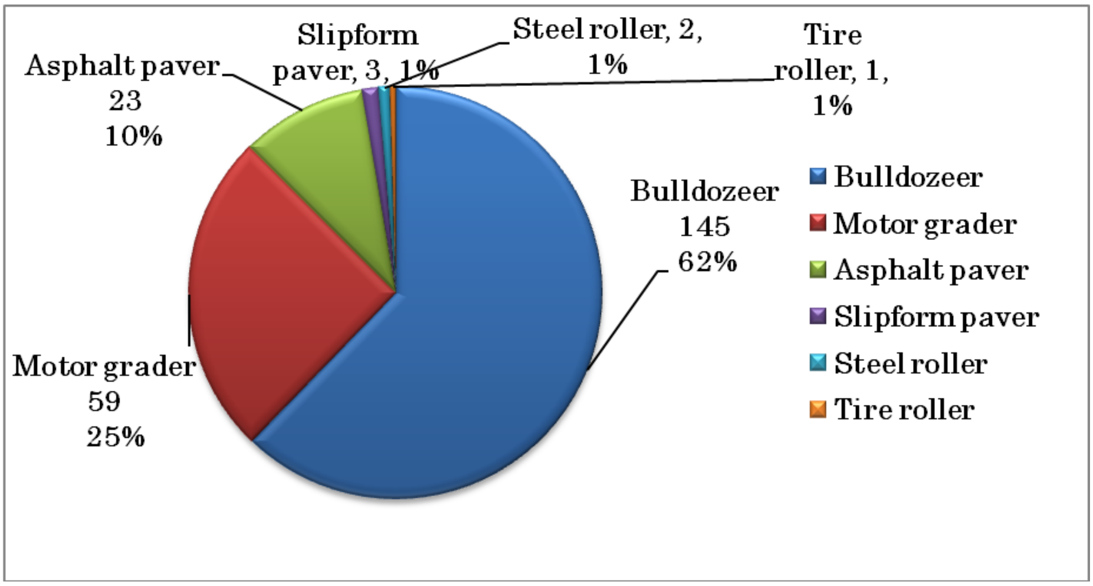

Figure 8: Breakdown of construction machines

3 FUTURE TASKS TO SOLVE BASED ON THE PAST APPLICATION RESULTS

Amid a rapid increase in the number of ITC applications, various problems have come up at construction sites. We conducted a questionnaire on the eight members of WG 6 to determine their opinions and requests. The results of the survey are summarized as follows, with typical problems and opinions arranged by item:

3.1 Cost Estimation and Production Rate

The development cost is enormous, and the rental and transportation costs are high because of the scarcity of the machines. At present, those high costs are covered by contractors thanks to their corporate efforts. Further diffusion will require those costs to be included in the construction cost.

3.2 Coordination of Design Data

Reading the coordinates of Z from the paper drawings and inputting it together with two-dimensional coordinates (X, Y) is an inefficient way of working. Isn't it possible to ask contractors to provide the drawings and coordinate data (change point data) in digital format?

3.3 Execution

Data collation is necessary in ITC for paving work, while it is in the stage of paving that data collation is necessary in the conventional method of structure construction. It is irrational to ultimately match the surface course of the pavement to a structure built using the conventional method.

3.4 Construction Management

The present 3D-MC system conducts height control in line with the pavement design and is not very suitable for work that needs thickness management such as applying a surface course or base course. It is basically used as a system that enhances the construction precision of the base course to enhance the precision (flatness) of the upper courses (asphalt pavement). If the 3D-MC system needs to be applied to the stage of asphalt pavement, use of a paving management technique has to be considered.

3.5 Quality Control

Workmanship management at arbitrary survey points is permitted to simplify conventional survey points for workmanship management (Expansion of the tolerable range of errors of positions on a flat surface).

3.6 Construction Machines and Control Devices

Control devices quickly become outdated, and this prevents operators from receiving an appropriate payback on their investment in the equipment. Therefore, the spread of ITC to smaller businesses has stagnated.

3.7 Personnel

Compared with the conventional method of machine control, use of ITC in pavement work eventually results in more advanced functions and capabilities of machinery and equipment. This consequently means there is a need for personnel who are qualified to operate them. To develop such personnel, companies and manufacturers should provide education, which will logically require extra time and cost.

4 CONCLUSION

It is estimated that the concept of ITC in road construction was first introduced by one of the Ministry of Construction's general technology development projects, "Development of Construction Rationalization Technology in the Construction Industry," conducted for seven years from October 1990 to March 1997.

In this project, an asphalt finisher designed to conduct automatic control of three-dimensional positions was developed. This system used an automatic tracking total station, originally designed for surveying, to measure the three-dimensional position of a finisher on a real-time basis and simultaneously conducted traveling route control and three-dimensional position control on the finisher using road design plan data that had been previously input in the computer as reference data. Since the design plan data served as the construction reference data, it eliminated the need for setting up reference lines and finishing stakes for control and continuously recorded the measurement data and control data during the work. Those data are therefore applicable as management data after the completion of the work. This concept is roughly the same as the ITC that is currently in place. The said project also developed a prototype asphalt finisher that makes automatic control of three-dimensional positions, and conducted trial work on an experimental field in six locations.

As explained above, incorporating ITC into road construction work in Japan started almost 20 years ago. In addition to this history, the Strategy for Information Technology Construction Promotion of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) aims to establish ITC-based road construction as a standard construction (management) method by 2010 for large-scale projects under the direct management of the MLIT, and by 2012 for smaller-scale projects. These moves will promote the further diffusion of ITC use in road construction projects in Japan.

The authors hope that solving the current problems one by one will help promote the full diffusion of ITC.

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