CONSTRUCTION MANAGEMENT USING POSITION MEASURING TECHNOLOGY OF CONTRUCTION EQUIPMENT IN PAVING WORK

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Abstract: Ministry of Land, Infrastructure and Transport has been promoting computerized construction for the purpose of rationalization of construction and improvement of supervision and inspection work with regard to improvement of efficiency of construction, enhancement of safety, quality assurance and conservation of environment, etc. by effective use of information in relation to construction where IT (information technology), such as positional data acquisition technology, communication technology, and information processing technology is applied.

This report describes the construction and construction management method using IT for asphalt paving work which has a predominant portion in public work projects and the results of trial work based on the method.

Keywords: Computerized construction, earth work, paving work, construction management

1. INTRODUCTION

The construction management items of the existing paving work are working-form and quality. As for the working-form, standard height management is required for up to the lower sub base, while thickness management for the range from the upper sub base upon the lower layer to the surface layer.

For the paving work, material cost occupies an approximately 60 to 70% of the entire construction cost and, the higher the layer (closer to the surface layer), the higher the material cost. Further, flatness of surface layer is important as management item at the final stage of paving work. Therefore, management of exact finish thickness and height is required at each construction stage.

As the form accuracy of sub base directly affects the working-form and quality of base layer and surface layer, many finishing stakes are installed as the target of finished height in the existing construction method, and the construction accuracy of sub base is ensured by repeated work of shaping by means of a motor grader and height inspection measurement. Therefore, the shaping work of sub base requires much labor and time and, in addition, high-level technique of operators is required for finishing the section between finishing stakes where there are no height indicators.

Meanwhile, the working-form and quality after paving construction work is confirmed by destructive inspections, such as dig-up and core sampling. Such inspections inevitably involve problems, including a small spot management over the entire worked area and a decrease in partial pavement quality as a result of destructive inspection.

Work A

Work B

Photo 1 Target site of trial work

In order to solve these problems, computerized construction system using IT was established and “IT-assisted pavement procedure (draft)” was prepared in the form of operation manual. The system was applied to 2 sites as shown in Photo 1. Based on the result of the test construction at these sites, this report describes the effectiveness and subjects to be reviewed on the IT-assisted construction and its management method.

2. THE OUTLINE OF IT-ASSISTED CONSTRUCTION SYSTEM

The IT-assisted paving work and its management method and the computerized construction system was configured as shown in Figure 1. This system consists of 3 subsystems which are described below.

2.1 3D Heavy Equipment Control Grader System

This system consists of an automatic tracking Total Station (hereafter referred to as “auto tracking TS”) provided with optical communication function, a control PC (directly connected to auto tracking TS) automatic hydraulic control unit which installed on the grader.

The operation procedure of this system is as follows:

(1) Input the design data(design height, cross sectional inclination) into the control PC.
(2) Collimate a target prism which is installed on the grader blade, using the auto tracking TS, and measure the plane position and traveling direction of the blade.
(3) Calculate the design height and the cross-sectional inclination at plane position of the blade, utilizing the control PC, and transmit them to the grader side utilizing optical transceiver at intervals of 10 times/sec.
(4) On the grader side, receive the design data, and automatically control the blade in line with the design data utilizing automatic hydraulic unit.
(5) The operator just have to steer and back and forth operation to form a road surface. Operator also can switch from automatic operation to manual operation with a toggle on the operation panel.

2.2 Compaction Frequency Management System

This system is intended to perceive the present number of times of compaction continuously and concurrently with construction work and to manage the quality of a compaction target soil layer.

The system consists of an RTK-GPS mobile station mounted on the compacting equipment and the personal computer (hereafter referred to as “onboard PC”), an RTK-GPS base station and radio equipment.

The quality management procedure of paving using this system is as follows:

(1) Confirm the appropriate number of times of compaction in the test construction.
(2) At the beginning of each compacting work, input the compaction area appropriate number of times of compaction into the onboard PC.
(3) The onboard PC divides the compaction area into square meshes which have a side of 0.25m (referred to as “management block”).
(4) During compaction, measure the position coordinates of the compacting equipment with the aid of the RTK-GPS continuously.
(5) The onboard PC decides that the compacting equipment has compacted the block when the equipment has run past the management block based on the movement locus of compacting equipment and displays the

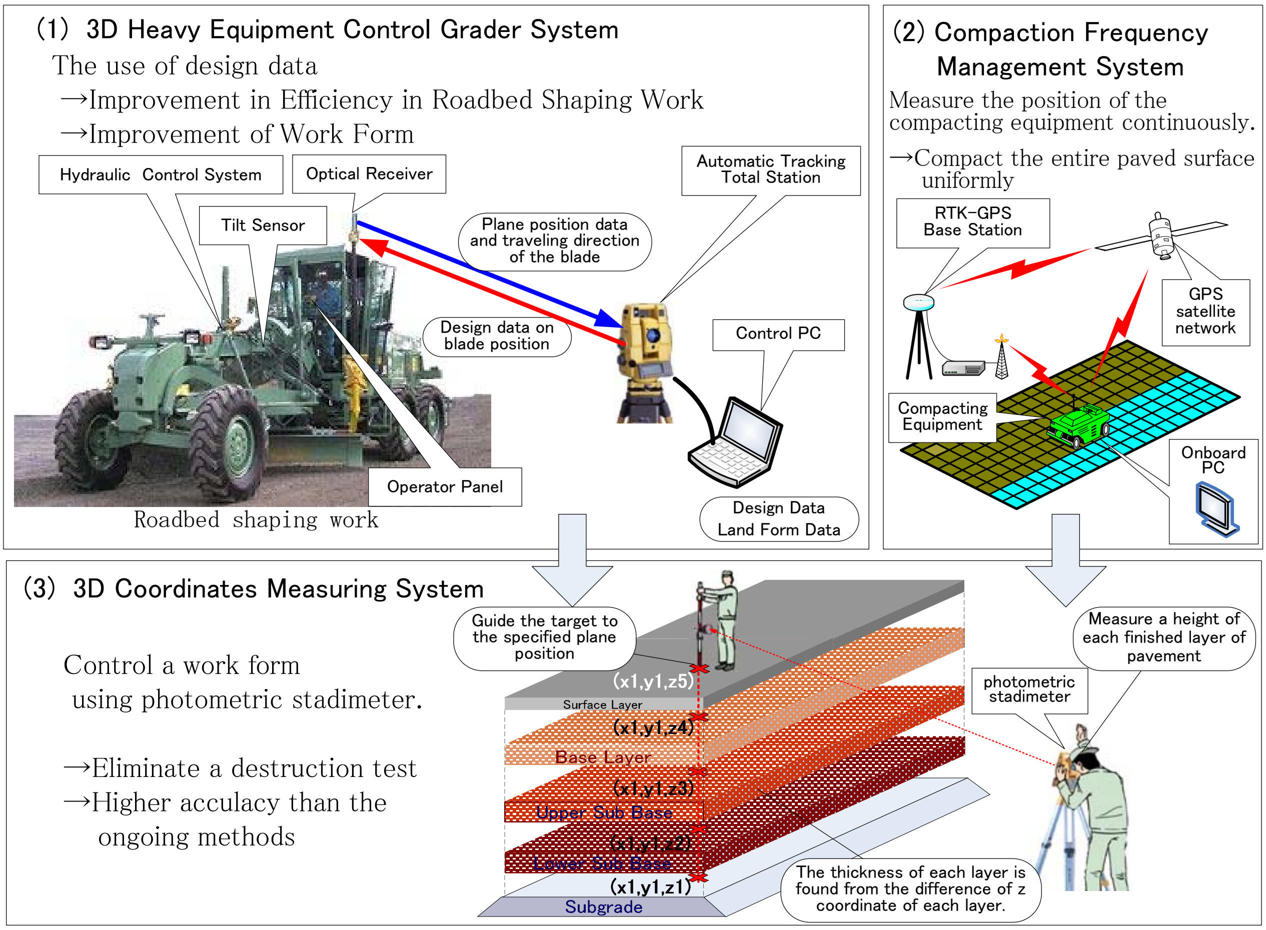

Figure 1 IT-assisted paving work system

cumulative number of times the compacting equipment has traveled past each block that is color-coded.

(6) The operator is engaged in the compaction work while viewing the map of sections that are color coded by the number of times of compaction on the display of the onboard PC.

(7) Operator compact until the entire area of work field with certain color which indicates appropriate times of compaction has done.

A macadam roller and a tire roller were used as compacting equipment in the trial sites.

2.3 3D Coordinates Measuring System

A photometric stadimeter (hereafter referred to as the "TS") was used to output 3D coordinates of measuring target points. This system has the function to guide the target to the specified plane position, enabling fixed point measurement of a height of each finished layer of pavement. In the trial work, 3D position coordinates (x, y, z) of specified management point were surveyed from the TS after compaction work of each layer is finished based on that function. The thickness of each layer was found from the difference of z coordinate of such points. The measurement target was the thickness of sub base, base layer, and surface layer.

3. RESULTS OF TRIAL WORK

The application test at an actual site was conducted to compare with the construction work based on the IT-assisted construction system and the current construction work. The test results and the effectiveness derived in the test are described below.

3.1 Efficiency Improvement in Sub Base Shaping Work

In the current construction work, the sub base is made to approach the target height during the sub base shaping work by using the motor grader and by repeating confirmation jobs about working-forms many times at the site where finishing stakes as shown in Photo 2 were located.

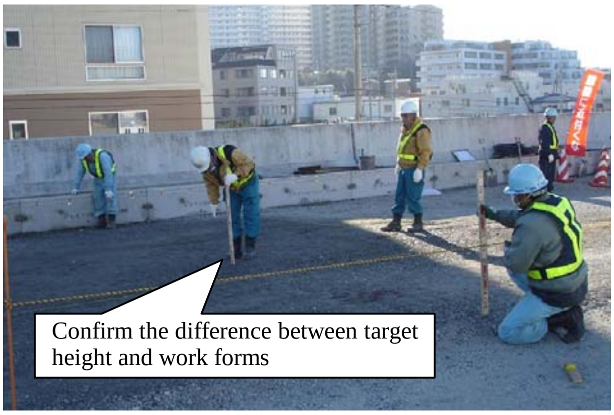

Photo 2 Confirmation of working-form of sub base in the current construction

On the other hand, as shown in Photo 3, this system allows real-time measurement of the altitude of the blade which shapes the sub base surface. During construction, the altitude of the blade is measured by means of the target which is mounted on the blade and the auto tracking TS which is installed at the road side. Since the system automatically controls the height of the blade until it reaches the target height, frequency of the interruption of construction work for confirmation of working-forms can be reduced and the target height can be reached in a shorter time.

As a result of employing this system, the work efficiency was improved by approximately 50% compared to the current construction method. As the work efficiency was improved, approximately 30 to 40% fuel consumption was reduced, achieving a reduction in environment load. At the same time, safety is ensured since chances for manual work around the heavy machinery for checking the working-forms can be reduced.

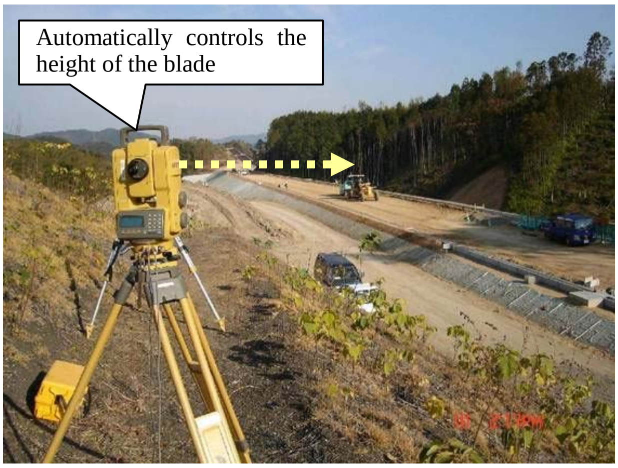

Photo 3 IT-assisted sub base shaping work

3.2 Improvement of Working-form

The difference between the design altitude and the altitude of sub base was fed back to the motor grader and the up-and-down motion of the blade as well as the cross-sectional grade were automatically controlled so that the working-form may be approached as desired altitude.

As a result, it was found that finished work quality improved and that surface smoothness was satisfactory as is clear from Figure 2 and Table 1. IT-assisted construction section showed better results also in terms of flatness of the surface.

Construction time required for the IT-assisted construction section to achieve the working accuracy shown in Figure 2 and Table 1 was significantly shorter due to improvement in work efficiency as described in the preceding section.

In addition, improved finished work quality is likely to reduce the amount of material waste, in relation to the base layer and surface layer which requires a relatively high unit cost of material.

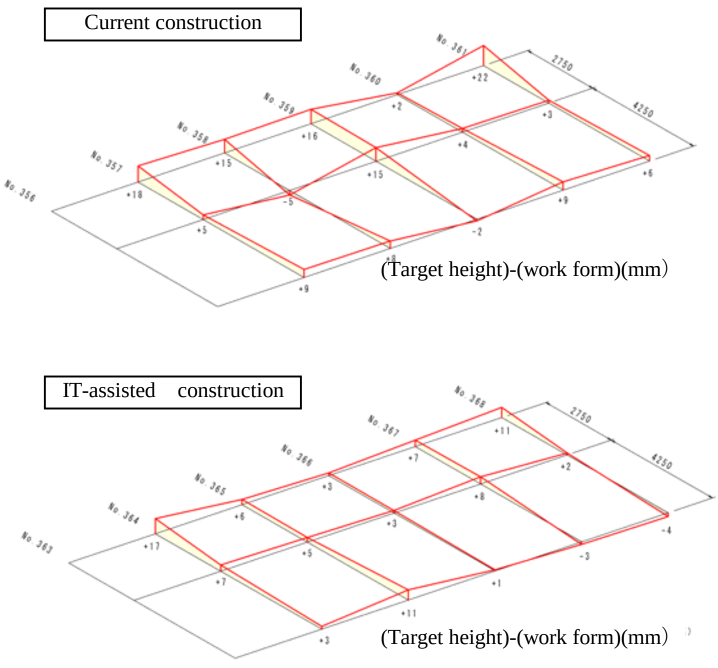

Figure 2 Comparison of finish accuracy (sub base)

Table 1 Comparison between design and finish altitude

(unit: mm)

Section	Average value	Standard deviation	Minimum value	Maximum value
Current construction	8.3	6.4	2	22
IT-assisted construction	5.1	4.3	1	17

3.3 Uniform Construction Quality

Figure 3 shows a color-coded compaction frequency distribution map divided into square control blocks each having an area of 0.25 m by 0.25 m. An entire pavement area shown in figure 3 is about 8 m wide by about 100 m long. A cumulative number of times compaction was done is indicated on a bloc-by-block basis. As is clear from this map, there are areas (other than colored black) where the required frequency of compaction is not reached when it is the operator's task to count the number of times compaction is performed. Such areas are found to account for approximately 4 to 10% of the entire construction area. This range of percentage remains unchanged as to the sub base as well as the base and surface layers alike.

On the other hand, it is found that there remain little or no areas in the IT-assisted construction field where the compaction frequency is placed under continual control of the onboard PC monitor. In this case, the entire paved surface is uniformly compacted and fulfill current quality standards at all density measurement point. This fact most likely testifies to the effectiveness of the IT-assisted construction in achieving a satisfactory level of construction quality.

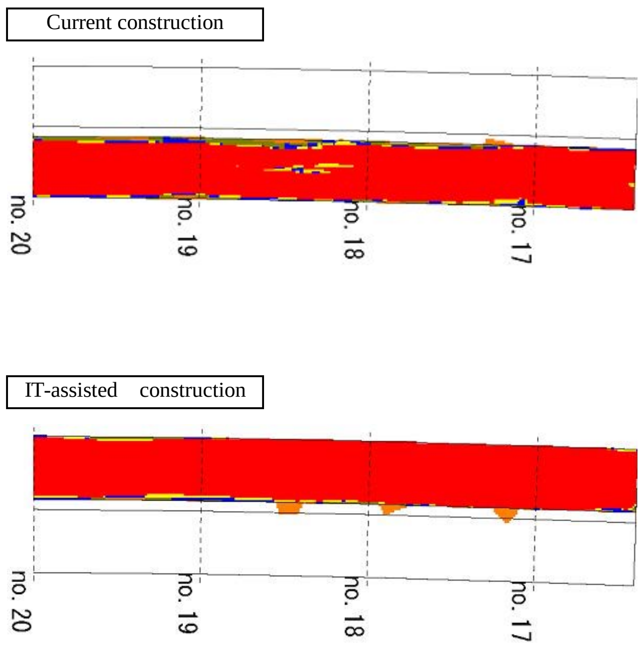

Figure 3 Compaction frequency distribution map

3.4 New Management Method of Working-form

Figure 4 represents a histogram in which the difference between the pavement thickness measured by the TS and thickness measured by means of core sampling. Former one is calculated from the finished base layer and surface layer's altitude which was measured at the fixed point by the TS. Latter one was average value of measured pavement thickness made at 4 points at the core periphery using a scale. The core was obtained at the same points where have been measured the altitude by TS. As is shown in this figure, there are maximum and average differences of about 6 mm and about 0.9 mm, respectively, in thickness between the base and surface layers measured by the TS at the fixed points and those of the samples cored. In view of the fact that there are variations in thickness ranging from 2 to 3 mm among the samples cored since they were collected at different points, the TS measurement is considered to be an effective means for controlling the layer thickness.

It is arguable that replacing the ongoing pavement layer thickness control method dependent on sub base digging-up or core sampling with a new method. Because new method takes advantage of the TS could lead to elimination of a destruction test which damages the pavement or of restoring job that is inevitably called for after core sampling. Furthermore, the TS-based measurement is possibly one of working-form control methods with higher accuracy than the ongoing one since it is easy to handle and to increase the number of measurement points as compared to the destruction method.

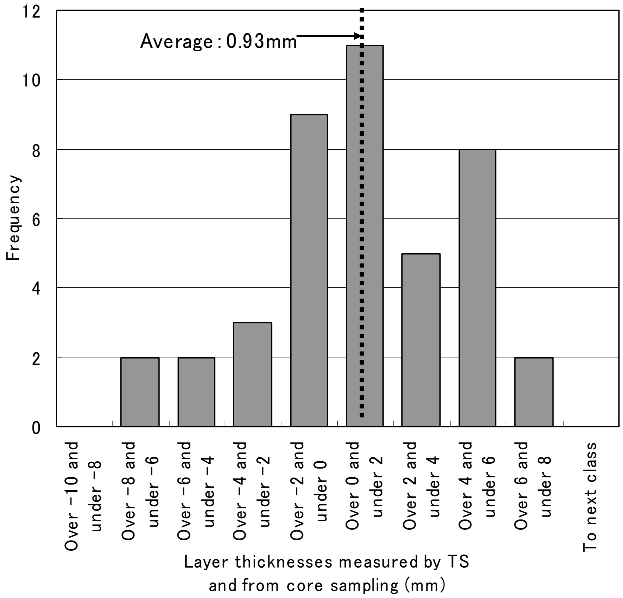

Figure 4 Difference of values measured by TS and from core sampling

4. FEASIBILITY OF IT-ASSISTED CONSTRUCTION AND CONSTRUCTION MANAGEMENT

Several findings were obtained from the test construction. One of them is that the IT-assisted construction has proven effective and advantageous in many respects, including efficiency in sub base shaping, construction accuracy, safety, and environment preservation. As to the IT-assisted work control method, it is found that working-form and quality control is achievable without destruction test. In addition, it is confirmed that progress of the work can be checked during construction in real time and in a plane view. And that the working-form as well as quality is equal or superior to that obtained from the current construction method.

It should also be noted that the construction data could be rendered serviceable for future maintenance since it can be stored as electronic data related to positional information. The IT-assisted construction shows promise of streamlining the work processes and improving the tasks of supervision and inspection since it could minimize the frequency of job interruptions which required for overseeing or checking purposes.

The test construction under study was conducted referring to "IT-Assisted Pavement Procedure (Draft)" that was prepared earlier.

As described in the preceding sections of this paper, the concepts contained in the foregoing procedure suggest introduction of an IT-assisted construction system consisting of "3D Heavy equipment Control Grader System", "Compaction frequency management System", and "3D Coordinates Measurement System". With the help of such systems, it is intended to attain the following:

(1) Heightened construction efficiency
(2) Omission of destruction tests involving digging-up or core sampling
(3) Uniform construction quality achieved by plane work control
(4) Improvement in supervision and inspection
(5) Enhanced safety and environment preservation

To sum up, findings from the present test construction lead us to believe that the IT-assisted pavement could satisfactorily achieve the foregoing goals.

5. TASKS

Based on the knowledge gained from the present test construction, the authors cite the following as tasks to be taken up for more effective implementation of the IT-assisted construction and construction management.

(1) Distribution of 3D CAD data

The control data for the 3D heavy equipment control grader system was first acquired by plotting 3D coordinates of the road center with 10-m pitches in the longitudinal section (5-m pitches at sharp bends) and by reading the cross-sectional gradient, referring to the alignment calculation sheet, drawing of longitudinal section. Since then the obtained data was manually inputted for control software.

Originally created through the 3D CAD, the design documents were re-processed into 2D CAD data or appear as drawing print-outs before delivery to the orderer in the form of standard delivery procedures. Once the 3D CAD data on design drawings that are prepared according to the public coordinate system could be desirably accepted, a customarily time-consumed job of creating the control data could be eliminated.

(2) Establishment of construction management standards compatible with multi-point control

The current criteria for point-to-point control (admission decision on layer thickness that is represented by points over a wide range of area) are used without any modifications as the standard values applied to the thickness control by use of the TS.

Since the layer thickness control in the IT-assisted construction takes a form of the TS-based multi-point control, there may be larger amounts of data than before that is outside of the range of current specifications. If such is the case, admission decision will be rigorous excessively. That is the reason for the necessity of defining the construction management standards and specifications that are adaptable to multi-point control.

[Current construction: core sampling]

[IT-assisted construction: TS-based survey]

Photo 4 Comparison of layer thickness inspection

6. CONCLUSION

Successful completion of the test construction indicates that the IT-assisted construction and construction management that are described in the “IT-Assisted Pavement Procedure (Draft)” are feasible to an appreciable extent.

It is intended to continue test constructions until sufficient amounts of data are accumulated so as to carry out re-verification and other tasks. Discussion will be devoted to the process of preparing the “IT-Assisted Pavement Procedure (Draft)” that is expected to constitute guidelines on an effective use of IT.

REFERENCES

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