

Automatic Surveying System of the Geographical Feature Utilizing Newly Developed Long-distance and Angle Measuring Instrument without Target Prism

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ABSTRACT

The Public Works Research Institute of the Ministry of Construction, having developed an automatic measuring system of construction progress amount in the earth work together with the Advanced Construction Technology Center, Aoki Corporation and Kawasaki Heavy Industries, Ltd., herein reports it.

- In the conventional method, measurement technicians are obliged to move with carrying a target prism in measuring site and to measure and collect the distance and angle data of many points by the TOTAL STATION. This paper is to report our newly developed NON-PRISM distance and angle measuring instrument, the total measuring system with automatic scanning method and several effects for man-power saving and also securing the safety with using this system.

1. INTRODUCTION

Recently in the earth work, while size-enlarging and performance-improving of construction machines are being promoted, the technical development for work management and quality control is not enough and it causes that much time and labor are required still now. Therefore, in the General Technology Development Project "The Development of New Construction Process Technology", we have been engaged in the technique development aiming at automating and rationalizing in this field. We have developed the distance measuring

instrument without the target prism and integrated the measuring system, which is the automatic measuring system of the construction progress in the earth work and enables automatization and labour-saving.

In this paper, we report on confirmation of its applicability and the results compared with the conventional TOTAL-STATION, based on the performance confirming test on a single unit and the proof experiment using the NON-PRISM experimental model.

2. OUTLINE OF SYSTEM CONFIGURATION

2-1 System Configuration

The automatic measuring system is composed of the distance measuring and angle measuring instrument (hereinafter called NON-PRISM), a portable computer which controls the automatic scanning and collects measuring data, Joy Stick which is to operate the angle measuring instrument manually, the power source battery and the tripod. (Fig.2-1-1)

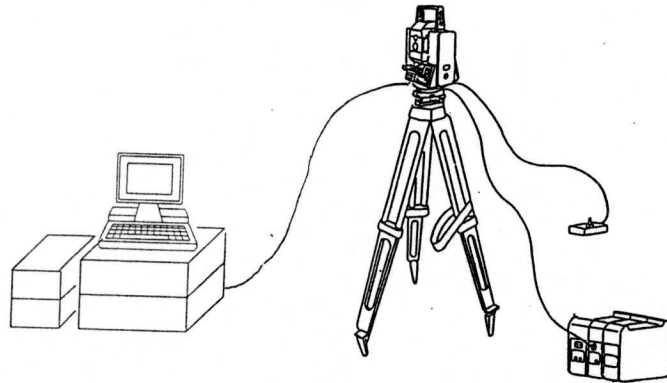


Fig. 2-1-1

Table 2-2-1 Setting of Automatic Measurement

Setting Item	Contents of Setting	Setting Method
Setting of measuring shape	① Polygon ② Rectangle ③ Segment	Selection
Setting of measured region	Collimation range of telescope of an angle measuring instrument	Joy Stick Operation
Setting of scanning type	① Angle ② Distance on ground surface	Selection
Setting of measured pitch	Angle : 10' , 30' , 1° , 2° , 3° Distance : 0.3m, 1.0m, 2.0m, 3.0m, 4.0m	Selection

2-2 Outline of Automatic Measuring

- Brief procedure for measuring and its function are as follows;
- (1) A operator will set the initial data to the computer listed up on Table 2-2-1 on previous page.
 - (2) The computer starts and continues the automatic scanning for both horizontal and vertical direction respectively and successively.
 - (3) The computer will gather the inclined distance data, vertical angle and horizontal angle data for each measuring point per about five to eight seconds.

3. PERFORMANCE OF DISTANCE AND ANGLE MEASURING INSTRUMENT

Item	Specifications	Remark
Distance measurement section :		
Distance	20~1,000m	Reflection ratio: 10%, Visibility:7 km, Vertical incidence σ -value Reflection ratio:10%, Visibility:7 km, Vertical incidence
Accuracy	under ± 50 mm	
Time	under 0.4 sec.	
Angle measurement section:		
Accuracy	Altitude : under $\pm 15''$ Horizontal : under $\pm 15''$	Rotation in vertical direction is possible.
Range	Depression: more than 45° Elevation: more than 45° Horizontal : Multi-rotation	
Time	under 0.4 sec.	
Remote operation	Interface : RS232C Baud rate : 9600 bps	
Manual operation	Joy Stick	with ENTER KEY
Electric power source	12 V DC, 8A	Portable Battery
Weight	13 kg	Main body only

4. PERFORMANCE OF SINGLE UNIT

4-1 Distance Measuring Accuracy

(1) Test Contents

In a field circumstance, distance measuring accuracy of the NON-PRISM has been confirmed.

(2) Measuring Method

In the test field, a target plate (a white board of A2 size) was placed at the arbitrary position about 50~800 m distance from the NON-PRISM.

The number of the measurement was about 100 times for each point and the average of those was converted to the horizontal distance. For the comparison with the true value, the horizontal distance between the same spots was also measured by the TOTAL-STATION (SET4DS made by SOKKIA Co.) and one element prism (APS-12S made by SOKKIA Co.), and used those data as the true value.

(3) Measured Result

The measured results concerning the distance measuring accuracy are shown in Table 4-1-1.

Table 4-1-1 Distance Measuring Accuracy

NON-PRISM				TOTAL STATION	Error		
Oblique distance m	Vertical angle			Converted horizontal distance m ①	σ value m ②	Horizontal distance (true value) m ③	m
	°	'	"				① - ③ + ②
45.638	92	07	37	45.606	0.005	45.583	0.028
85.500	91	28	36	85.472	0.004	85.448	0.028
163.580	91	14	45	163.541	0.011	163.532	0.021
196.591	91	04	32	196.557	0.008	196.533	0.032
300.319	90	15	06	300.316	0.011	300.299	0.028
399.805	90	09	58	399.803	0.009	399.773	0.039
498.628	90	11	28	498.626	0.003	498.604	0.024
598.686	90	10	00	598.684	0.006	598.675	0.015
699.515	90	09	19	699.512	0.003	699.482	0.034
802.472	89	34	30	802.450	0.004	802.437	0.017

4-2 Distance Measuring Characteristics due to Inclined Surface Difference and Surface Material

(1) Test Contents

To investigate the influence which the difference of inclined surface and its material has on the distance measuring performance, the distance measuring characteristics were investigated by varying the incline angle versus to the laser axis of the sample plates made of different material.

(2) Measuring Method

The inclinable pedestal was used for the measurement. This pedestal enable to incline the sample plate at arbitrary angle, and the sample plate was placed at 100 m distant from the NON-PRISM. Eight kinds of sample plates shown in Table 4-2-1 were prepared. The distance at the angle of 0° , 30° , 60° and 75° were measured for each sample plate.

Table 4-2-1 Sample Plates

Name of Sample	Material and Shape adhered on wooden panel
White board	White decorative sheet, highly mirror-like
Black board	Black decorative sheet, highly mirror-like
Earth	Earth, dry and wet condition prepared
Sand	Sand, dry and wet condition prepared
Stone	Stone, dry and wet condition prepared
Artificial lawn	Lawn, yellow green, thickness about 1.5 cm.
External wall material	Black external wall materia, like mortar finish.
Plaster board	White plaster board, like mortar finish.

(3) Measured Result

Based on a standard value at the inclin angle of zero degree, the difference of the measured distance in case of having varied the incline angle and the kind of the sample, are shown in Table4-2-2.

Table 4-2-2 Distance Measuring on Verious Sample Plates

Name of Sample	m	Difference measured m				Remarks
		Inclined angle (degree)				
		0	30	60	75	
White board	100	0.00	0.00	0.00	0.00	
Black board	100	0.00	0.00	0.00	0.00	
Earth (Dry)	100	0.00	0.00	0.00	0.00	
Earth (Wet)	100	0.00	0.00	0.00	0.00	
Sand (Dry)	100	0.00	0.00	0.00	-0.01	
Sand (Wet)	100	0.00	0.00	0.00	0.00	
Stone (Dry)	100	0.00	0.00	0.00	0.00	
Stone (Wet)	100	0.00	0.00	0.00	0.00	
Artificial lawn	100	0.00	0.00	0.00	0.00	
External wall material	100	0.00	0.00	0.00	0.00	
Plaster board	100	0.00	0.00	0.00	-0.04	
White board	340	0.00	0.00	0.00	0.00	

Although this is the example of the considerably ideal object such as the flat plate, the variation of the measured distance due to the difference of the beam incidence angle (incline angle of the sample) were not found. And influences due to the difference among eight kinds of the prepared sample, were not also observed.

5. PROOF EXPERIMENT

The proof experiments were executed, for the purpose of carrying out the performance estimation by the measurement accuracy and to get the necessary man-power amount and also obtaining the basic data to analyze the measurement characteristics and operational requirement for this system through the measurement by the experiments in the fields.

In this paper, we pick up only the experimental result in which the comparison measuring was carried out with the TOTAL-STATION.

In addition, measured data collected by the NON-PRISM automatic measuring system, were converted to the coordinate data by the data managing program which had been developed at the same time, the coordinate data were separated into the elements of the triangle, using backup system of the civil engineering design which is placed on sale, the geography data were made and earth amount was calculated.

5-1 Object Geography and Measurement Contents

The experiments were executed as shown in Table 5-1-1 on next page.

5-2 Earth Amount Measuring Accuracy

In the NON-PRISM measuring system, many random points are automatically measured and after we can get the geography model (linear approximate model of the ground surface) by the element separation method which makes the measured points as nodal points. The earth amount before and after the geography variation can be obtained by quadrature between the geography model measured before and after the variation. The calculation accuracy of the earth amount by this method, depends on the accuracy of the geography model. In a common sense, the smaller the interval of the measuring point at the uniform distribution is made, the better becomes the accuracy of the geography model. The average section method and column state method and such are the same as this method on the basic concept.

In the experiment of this time, the estimation of the measured earth amount before and after the geography variation could not be done, from the restriction by the field and etc. However, it was considered that the earth amount measuring accuracy can be verified indirectly, by estimating the approximate-accuracy of the geography model made from the result of the automatic measurement of the static geography. Then, on four cases of fairing face of slope (Data 1), created inclined face (Data2 and 3) and plain ground (Data 4), the approximate-accuracy of the model was estimated by the earth amount difference from the geography model measured by TOTAL-STATION (comparison object). However, the geography model by total station is not more than those which represents the measured amount accuracy by the conventional method, and not the geography model of the true value which 100 % approximates to the object geography.

The earth amount between the geographic model by the automatic measurement and total station are shown collectively in Table 5-2-1 on next page. In the table, the earth amount error per unit area is obtained. This is the same with the vertical error as a meaning, and the value of earth amount error is used to obtain the approximate calculated value of the measured earth amount error in case of measuring the similar geography.

Table 5-1-1 Object Geography of Experiment and Measuring Item

Object Geography	State of Geography	NON-PRISM				TOTAL STATION
		Distance m	Measured Points	Measured Pitch HA/VA	Data No	Measured Points
Fairing Face of Slope	Inclined face of cut ground arranged in L letter form Inclination : 1: 0.8 Height : 20 m Width : 80 m Berm is of five-stage and face of slope is faired.	140	718	30' /30'	Data 1	150
Created Inclined Face	Oblong inclined face under creation (Right side two third of inclined face) Inclination : 1: 1 Height : 20 m Width : 150 m Being faired roughly with heavy machine (Left side one third of inclined face) Slope unable to access	500	486	30' /10'	Data 2	63
		500	2 13	30' /10'	Data 3	50
Plain Ground	Work yard under rough stone mining surface Plain surface of which area is about 100 × 80m State such that base rock is slightly covered by sand.	150	1002	30' /10'	Data 4	-----
Accumulated Wood Chip	Heap of accumulated wood chip . Bottom area: 100 x 30 m. Height: 10 m	40	2475	3° /30'	Data 5	aerial photograph

Table 5-2-1 Earth Amount Measuring Accuracy by Automatic Measurement

object geography	Cut Ground ① m ³	Fill-up Ground ② m ³	Total ③ ③ = ① + ② m ³	Plain Area ④ m ²	Volume Error ⑤ = ③ / ④
Fairing face of slope Data 1	42.65	39.41	82.06	1171.795	0.07
Created inclined face 1 Data 2	386.82	316.47	703.29	5088.161	0.14
Created inclined face 2 Data 3	229.94	179.57	409.69	2443.761	0.16
Plain ground Data 4	11.88	3.22	15.10	1483.121	0.01
Accumulated wood chip Data 5	Automatic Measurement 35,741 m ³		Analysis from Aerial Picture 37,371 m ³		

5-3 Object Geography

The state picture of created inclined face of Data 2 and 3 (Picture 5-3-1) and the aerial view made from the measured value of accumulated wood chip Data 5 (Fig. 5-3-2) are shown below.



Picture 5-3-1

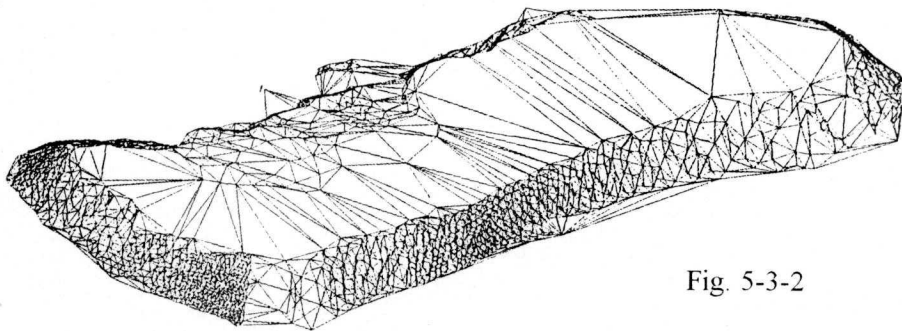


Fig. 5-3-2

6. EFFECTIVENESS OF SYSTEM 《 MAN-POWER REDUCTION 》

6-1 Unit Working Hour

Throughout these experiments, a certain knowledge concerning the required hours of measuring work could be gotten. The required hours and required number of worker for each work item are shown collectively in Table 6-1-1.

Table 6-1-1 Comparison Table of Work Man-hour

Work Item	Required Time	Required Man Power	Remarks
Measurement Preparation	15 ~ 20 min.	1 ~ 2 workers	<ul style="list-style-type: none"> • Installation of instrument • Collimation of known point • Setting of measurement range and measuring pitch
Automatic Measuring	5 ~ 8 sec/ point	Not required	Measuring time per one point changes depending on measuring pitch
Battery Chang	3 ~ 5 min/ change	1 worker	Duration of battery is 1.5 ~ 2 hours.
Clearing After Work	5 minutes	1 ~ 2 workers	Removing equipment and etc.

6-2 Comparison of Work Man-hour

The comparison between the man-hour of the automatic measuring by NON-PRISM measuring system and the one by the existing method is made. The results of the work man-hour of the fairing face of the slope and creating inclined face in which the comparison measurement is executed, are shown collectively in Table 6-2-1 on next page. Comparing with the existing method, the large number of the measured points (random points) could be obtained in the short time. And since no workers were needed to attend the measured spot, only a worker for operation of the instrument was required as the required number of the worker. Furthermore, this worker could be engaged in another work during the automatic measurement.

It was confirmed that the measurement could be performed by man-hour of about a third, comparing with the conventional method. It is clear that the larger the range of the measurement becomes, the more remarkable becomes the effect of man-hour reduction.

7. CONCLUSION

Although we could not report in this paper, we have performed analysis also on the instrument installing accuracy, the error characteristics depending on the geography, measurement characteristics depending on the measuring position and the measurement pitch and the earth amount measuring accuracy etc.,. We can judge that this system gets basically required performance which is necessary and sufficient for many fields.

Especially for the measurement on the dangerous place such as the steep slope and the place unable to access, this system is one issue which displays might, and makes the safe measuring work possible.

Lastly, we would like to express many thanks to every member of ASCODE (Automatic Survey Co-operated Development Association) who carryout detail design and tests.

Table 6-2-1 Comparison Table of Work Man-hour

Fairing face of slope (Data 1)

	Form of Measuring	Required Time (hr)	Number of Worker	Remarks	Man-hour ratio
NON-PRISM	Automatic random measuring	1.5	1*	measuring points = 718 including preparation time etc. 0.5hr	0.375
TOTAL-STATION	Section measuring	2.	2	measuring points = 150	1

Created inclined face 1 (Data 2)

	Form of Measuring	Required Time (hr)	Number of Worker	Remarks	Man-hour ratio
NON-PRISM	Automatic random measuring	1.2	1*	measuring points = 486 including preparation time etc. 0.5hr	0.267
TOTAL-STATION	Section measuring	1.5	3	measuring points = 63 including section determination time, etc. 0.5hr	1
GPS (Reference)	Section measuring	0.75	2	Same points as the TOTAL-STATION	0.333

Created inclined face -2 (Data 3)

	Form of Measuring	Required Time (hr)	Number of Worker	Remarks	Man-hour ratio
NON-PRISM	Automatic random measuring	0.8	1*	Measuring points = 213 including preparation time etc. 0.5hr	0.4
TOTAL-STATION	Section measuring	1.0	2	measuring points = 50 including section determination time, etc. 0.5hr	1
GPS (Reference)	Section measuring	0.5	2	Same points as the TOTAL-STATION	0.5

* No men are required during automatic measuring