The 9th International Symposium on Automation and Robotics in Construction June 3-5, 1992 Tokyo, Japan

A New System for Marking off on The Face in a Tunnel

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ABSTRACT

Amid the pressing need for automation and labor-saving due to the shortage of construction laborers and skilled workers, we developed a new tunnel face marking system, which automatically computed the coordinates of tunnel face center and marks the excavating plofile. Consisting of a survey instrument incorporating the latest electronics technology and a computer, the system projects the required point for tunnel excavation with laser beam onto the tunnel face. Together with high precision hardware, this system features software which serves the general purposes of various tunnels and provides easy operation by unskilled workers. This system has obtained satisfactory results, adopted for a Shinkansen tunnel. This type of technology provides valuable opprtunities for improved automation of tunnel construction and other underground works.

1. INTRODUCTION

In line with the recent aggressive development of electronic technologies, various industries have adopted computers and robots to automate and speed-up their processes. This is not only for the benefit of technical innovation but is also the fruit of quick response to a changing industrial environment with a decreasing industrial labor population and an aging society. This trend also applies to the construction industry, for automated in execution and other forms of work.

In Japan, NATM which employs shotcrete and rockbolts as the primary support has spread widely, making large scaled tunnels or intricately configured tunnels possible. Accordingly, the accurate instruction of excavation profile has become increasingly important, in line with the development of automatic face marking systems. In this situation, we developed a new general purpose, high precision face marking system applicable to general survey and field measurement for tunnel construction. This new system irradiates the excavating plofile determined by the up-to-date survey instrument and computer with laser beam.

2. THE SYSTEM COMPOSITION AND FUNCTION

Fig-2.1 shows the system composition. This system consists of a marking device which irradiates the excavating profile, and a controlling computer. The marking device consists of a total station drived by pulse motors, and a laser oscillator. Specifications are shown in Table-2.1. This device irradiates laser beam in any direction instructed by the computer. The available laser beam range is over 200 meters.

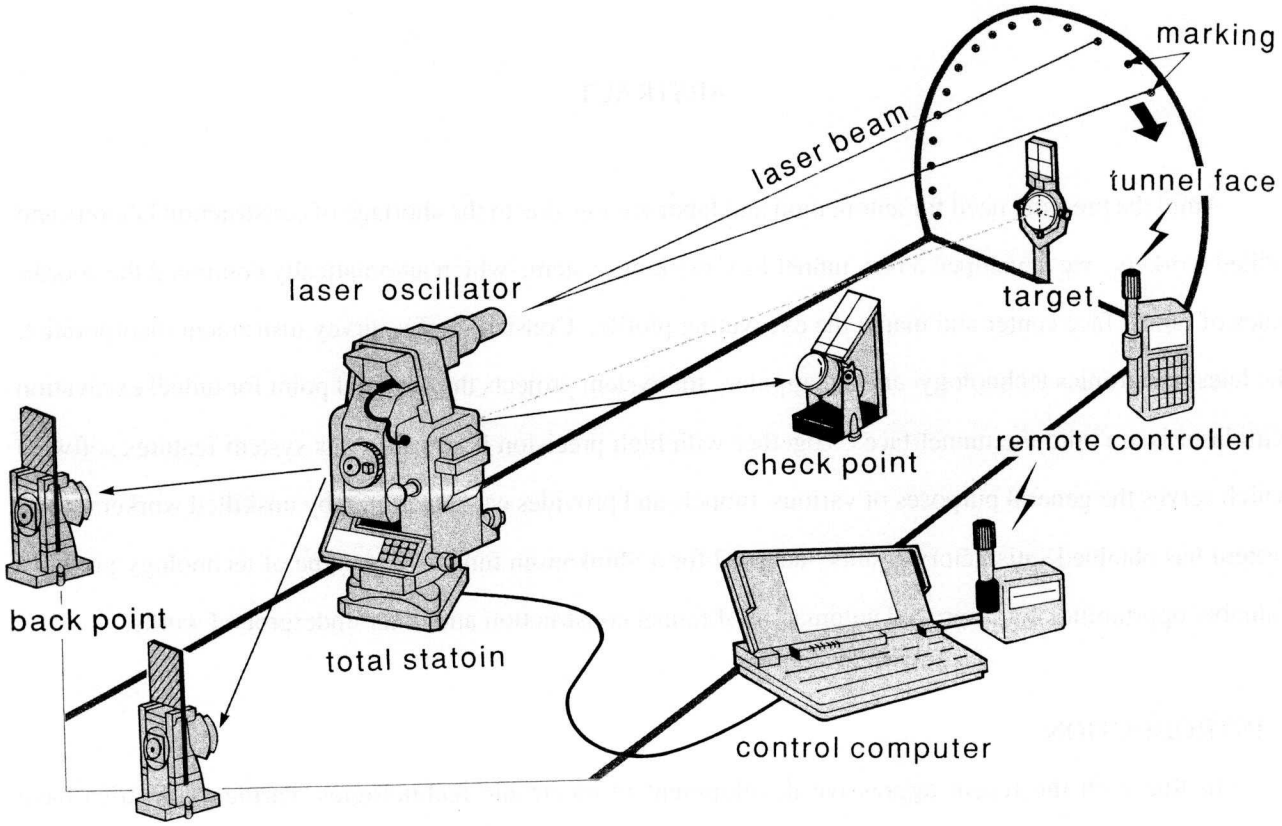
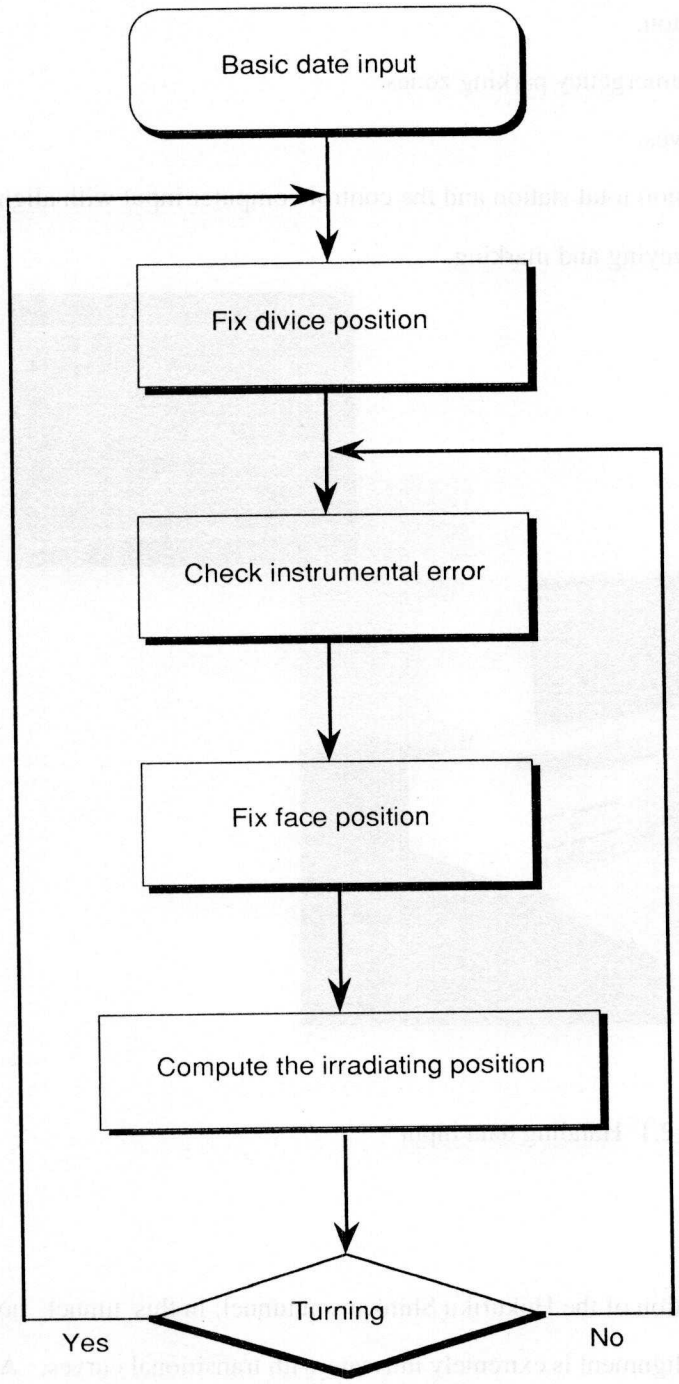


Fig-2.1 System composition

Table-2.1 Spesifications

Angle measurement		Distance measurement	
Measuring time	Less than 0.5 seconds	Measuring time	4 seconds
Smallest unit in display	5"	Smallest unit in display	1 mm
Horizontal accuracy	7"	Distance accuracy	±(5 mm + 2 ppm*D)
Vartical accuracy	7"	Maximum range	1,000 m
Laser osciiiator		Remote controller	
Power consumption	0.5 mW	Operating temperture	0 to +40℃
Power supply	9 V DC	Power supply	Ni-Cd battry 4.8 V
Wavelength	632.8 nm	Weight	700 g
Arrival distance	200 m	Service area	In radius of 300 m

The control computer three-dimensionally processes tunnel alignment and cross-section configuration from stored data. Fig-2.2 shows the operation flowchart.



* Tunnel plane alignment data
* Tunnel vertical alignment data
* Tunnel cross-section data
* System data

* Determine self-position from 2 known points by computer.

* Check self-position or mechanical discrepancy by projecting the laser beam to check point.

* Measure the distance between the apparatus and face to determine the coordinate at tunnel center.

* Compute the irradiating position from the present tunnel plan data, and the face position

* Project the irradiating position calculated by computer with laser beam.

Fig-2.2 Operation flowchart

The software features the following functions:

* Easy to handle dialogue-type data input. (Photo-2.1)
* Handles 5 different alignments:

  Straight lines, circular curves, clothoid, cubical parabola, and SIN diminishing curves.

* Responds to free cross-section configuration.
* Marks off-center cross sections, such as emergency parking zones.
* Accurate marking available, even on curves.

Thus, this system provides a high precision total station and the control computer input with alignment data, allowing easy application to general surveying and marking.

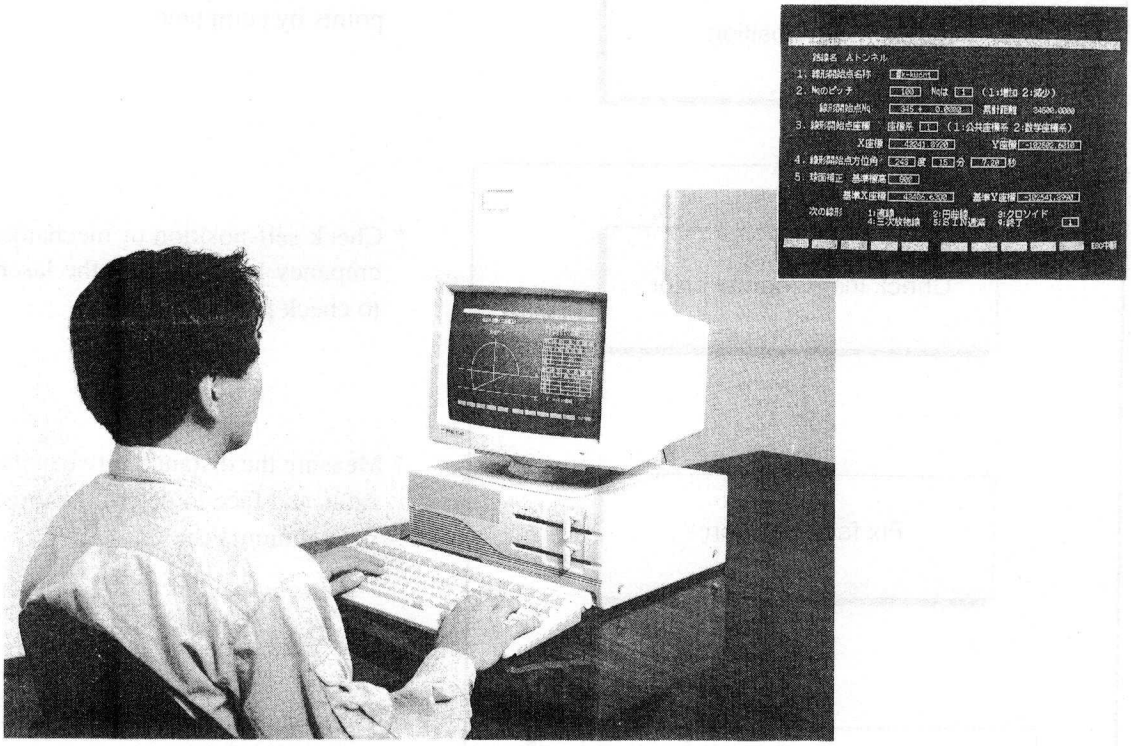


Photo-2.1 Handing data input

3. APPLICATIONS

This system was applied to the construction of the Hokuriku Shinkansen tunnel. In this tunnel, no steel ribs are used as the primary support, and its alignment is extremely intricate with transitional curves. Applying the mini-bench excavation method, the excavated face is large, requiring markings at high location. Therefore, the conventional method of manually marking the excavation plofile on the face would be inefficient, inaccurate, and unsafe.

The marking device is set about 100 meters from the face, as shown in the Photo-3.1. The back point to determine its own position for the marking device, and the check point to detect errors is respectively set on the tunnel side wall about 30 meters from the marking device towards the portal, and toward the face. Housed in a dust shield, the control computer is installed immediately underneath the marking device.

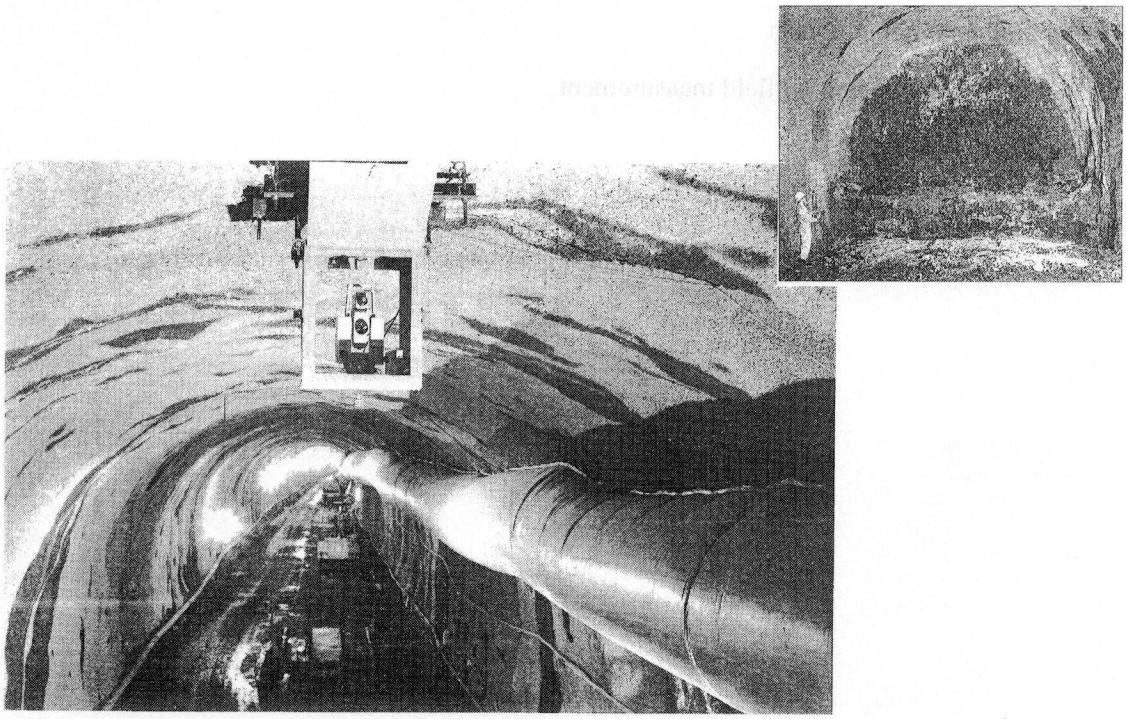


Photo-3.1 Marking device in Shinkansen tunnel constraction

The new marking system has the following proven advantages:

*Precise excavation profile marking:

Precise projection of excavating profile, regardless of irregular face . Particularly, on this tunnel, the structure center sifts from the surveying center on curves. The new system follows such as compricate alignment and enables accurate excavation.

*Enhanced safety:

With the new system, tunnel workers are reliesed from the conventional manual marking and they don't have to work close to the face.,

*Enhanced economy

The new system enables precise instruction of excavation profile, for accurate excavation, reduced overbreaking excavation, and an enhancing economy.

As a constraint, laser beam is sometimes intercepted by ventilation ducts or obstacles before it reaches the face.

4. FUTURE PROSPECT

On-site tunnel experience proved high level practical marking accuracy, indicating several advantages. The system will progressively find the following potential applications:

* Detect appropriate position and posture to automate the executive machine
* Mark position of concrete lining form
* Control of work execution including field measurement
* Support general survey tasks

This technology will serve to improve the automation of tunnel and other types of construction.