Development of Multi-media Management System for Tunnel Construction and its Practice

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ABSTRACT

It is common that the tunnel construction site in the hard rock ground is remotely located from office on the site, making it difficult to manage the construction works real-time wise with high accuracy. Moreover, the current demands for the increases in length, size and depth of the tunnels and more difficult construction conditions require more sophisticated management on the field. The automatic management system successfully used in shield tunnelling needs the electric cables to convey the data. However, the use of the blasting could damage the electric cables and as a result, such system has been conventionally considered to be difficult to be introduced in the hard rock tunnelling. The authors have newly developed the multi-media construction management system without use of the electric cable but wireless radio for the purpose of the hard rock tunnel and confirmed its validities in the actual tunnel project.

1. INTRODUCTION

Due to the increase of the demand of the underground development in Japan, length, size and depth of the underground structures become larger and their construction conditions are more difficult. Corresponding to such changes in the circumstances in construction industry, more sophisticated construction management methods on the field have been required for the successful completion of the works.

Currently, because of the aging of the skilled workers and decrease of the young engineers with the interests in the field works on the sites, labor shortage has become a serious problem surrounding the Japanese construction industry, leading to the decrease of the site engineers. Accordingly, limitted number of the site engineers may not always stay on the site and observe the construction works. Those tendencies could prevent the sufficient construction management on the site although it is becoming more important.

Moreover, for the tunnelling in the hard rock, the excavation work is surrounded by a lot of uncertainties such as the presence of the discontinuities, and skills and experiences of the workers still play an important role in the work in spite of the introduction of the several machines. As a result, subjective information may be involved in each working step through skilled workers and sufficient exhange of the information may be difficult resulting in the erroneous understanding. It has been desired that works in the tunnel are monitored real-time wise including the measured data and their integrated informations are centralized and objectively evaluated.

In shield tunnelling method, management systems have been highly advanced based upon the introductions of the several automations and successfully operated. Automatic total management system, for example could handle the several actual data through installed electric cables along the tunnel wall real-time wise and its validity is widely confirmed. It is common that several cables are used for various kinds of information required for the remote construction managements in the central controlling unit. Since shield machine advances pulling several cables behind, the cables for the information may be automatically extended with others and may not bother the everyday works.

On the contrary, for the case of the hard rock tunnel, installation of the electric cable between the excavation face and office located outside is not practical and efficient since it could be damaged by blasting and frequent extention would be manually needed. Therefore, the automatic management system like that for shield tunnel has not been conventionally introduced into the hard rock tunnelling although it is highly desired by the site engineers and workers.

The authors have newly developed the multi-media construction management system without use of the electric cable but wireless radio for the purpose of the hard rock tunnel [1]. The system may transmit the information consisting of video, voice and sound, and several numerical data between the working spot and central controlling unit real-time wise by the identical media. This paper discusses about the outline of the system and its validities through actual application.

2. OBJECTIVES OF SYSTEM

Prior to the start of the development of the system, following objectives are established:

(1) The system does not transmit the information by electric cable but wireless radio;
(2) By identical media, several kinds of information are transmitted consisting of video, voice and sound, and numerical data real-time wise;
(3) The operation of the system is not be practically affected by the several factors such as the noise from the electric equipments and machines;
(4) The system ransmits the information more than 1 km distance inside the tunnel;
(5) The system is lightly weighted and easy to be handled; and
(6) The system is successfully operated under the severe circumstance of tunnel construction.

Corresponding those objectives, the authors have examined the several radio transmitting devices and performed the various experiments on actual tunnel project sites under the severe condition. Finally, microwave radio

transmitter with 50 GHz frequency has been selected as the principal transmitting device for the system.

3. OUTLINE OF SYSTEM

The idealized configuration of the system is shown in Fig. 1. The components of the system are a pair of radio transmitters as shown in Photo 1, TV camera with its controller, microphone to collect sound and voice, various measuring instruments, personal computer, printer and software. The specification of the radio transmitter for the system is described in Table 1. The radio transmitter retains 1 channel for the video for one direction, that is transmitting or receiving only and 2 channels for the voice, sound and numerical data for both directions which are transmitting and receiving. As a result, several information consisting of video, voice and soundn and numerical data could be transmitted and received between a pair of transmitters. Although according to the specification, the data is supposed to be transmitted up to 10 km, developed system is designed so that the data may be transmitted within 2km through 3 km inside the tunnel for the safety. When the distance between a pair of radio transmitters is large and data may not be accurately transmitted, additional pair could be installed as a relay pair.

In the actual long tunnel whose excavation face is remotely separated from the office, the real-time recognition of the current works is mostly desired for the safety and smooth working scheduling. In the developed system, TV camera with its base is placed at the higher point at the working spot so that whole work could be observed. Since the contents of the work may be more precisely understood by auditory information in addition to the visual one, microphone is also placed near camera. The TV camera and microphone are designed and chosen to be small and light for installation at any positions as needed. For the numerical information, several measurement devices such as axial stress and displacement gauges in shotcrete are installed locally and corresponding data are automatically recorded. Other examples of the numerical information which the system could handle are information on blast pattern design, names and positions of workers and vehcles, codition of tunnel atmosphere such as dust density and fan speed of ventilation system. Those information may be easily added into the system, if necessary. On the other hand, informations from central controlling unit are electric signal to control the movement of the TV camera and acknowledging data for the remotely controlled equipments, for example. The alarm and voice for the emergency may be easily transmitted from the unit.

In the personal computer located in the central controlling unit, those information are centralized and managed automatically. The information of video and several observed data are brought to the output to be printed in the official format as daily work report. Also, using centralized information, the evaluation of the cycle time of the work and automatic work scheduling may be possible by the help of the artificial intelligence such as expert system.

4. APPLICATION TO ACTUAL TUNNEL PROJECT

The developed system has been introduced into the tunnel project for the bullet train in Toyama Prefecture in Japan and successfully operated. The length of the tunnel is 4km and the entrance of the tunnel is 200m separated from the offfice. For the rapid and efficient construction, several machines and automatic systems are introduced and their accurate managements and

controls have become very important even for the case that excavation face as the working spot is largely advanced. The developed system has been regarded as the most suitable management device for the project and imployed. The data transmitting between working spot and tunnel entrance could be performed by wireless radio transmitting and conventional electric cables are used between tunnel entrance and office as central controlling unit. The data which are currently treated in this system are summarized in Table 2. Numerical data in the system are CO density, dust density, temperature and humidity at the working spot automatically recorded in the fuzzy-aided automatic ventilation system [2], and corresponding controlled fan speeds. As described above, it is the big advantage that additional information is easily added into this system upon necessity.

Since one of the purposes in introducing this system is the real-time and accurate observation of the point where most of the works are performed, the excavation face has been determined as the point for observation using the system. One of the radio transmitters is located on the crown portion of the entrance towards the excavation face. The other is installed on the stage for the ventilation located about 100m through 200m behind the excavation face. The point closer to the excavation face may give the more precise observation to the system, but more risky to be damaged by blasting. The position of the stage including the radio transmitter is changed with the advance of the tunnel. Whenever the radio transmitter is moved, it is strongly recommended that its direction is adjusted with more accurate data transmitting and receiving. According to the specification, the radio transmitter should be positioned accurately face to face for the accurate data transmission. However, presence of the several equipments inside the tunnel opening and curvature of the tunnel have made the face-to-face positioning difficult and require the adjustment in positioning directions. Based upon various experiments, it has been observed that the microwave from the radio transmitter seems to reflect on the excavated wall through tunnel and it could be transmitted zigzag like the case that the light is transmitted inside the optical fiber cable. Generally, curvatures for the regular road and railroad tunnels may not bother the application of the system although the degree of the reflection may depend upon the surface condition of the wall. Through the experimental uses, it is observed that the smooth surface like the secondary lining may give the best result in radio transmitting.

The computer at the central controlling unit and its monitor are shown in Photos 2 and 3, respectively. Data about video picture from the monitor could be transfered to the daily work report upon demand to be printed and its quality is sufficient to be submitted as the official report.

The following advantages are observed through the introduction of the system:

(1) The time for regularly checking the work at the working spot is saved and more efficient working advance is expected;
(2) Through the real-time work observation, more precise working schedule may be determined;
(3) For the case of emergency, quick response is possible corresponding to real-time and accurate information; and
(4) Base upon several information centralized in the office, more precise decision becomes possible by the engineers in the office.

5. CONCLUSION

The paper discusses about the outline of the muti-media construction

management system and its validities through the actual use. Treatment of the several information consisting of the video, voice and sound, and numerical data in multi-media is a world-wide tendency and its demand will be surely increased. The authors will apply the system into the other constructions such as dams and land development works, and contribute to the promotions of the productivity and labor saving in construction industry. The information collected in this system will be utilized more effectively and play a very important role in fully automated construction in the near future. Introduction of the new technologies such as multi-media to solve the several problems embeded in construction industry is essential for the continuous improvement of the civl engineering.

REFERENCES

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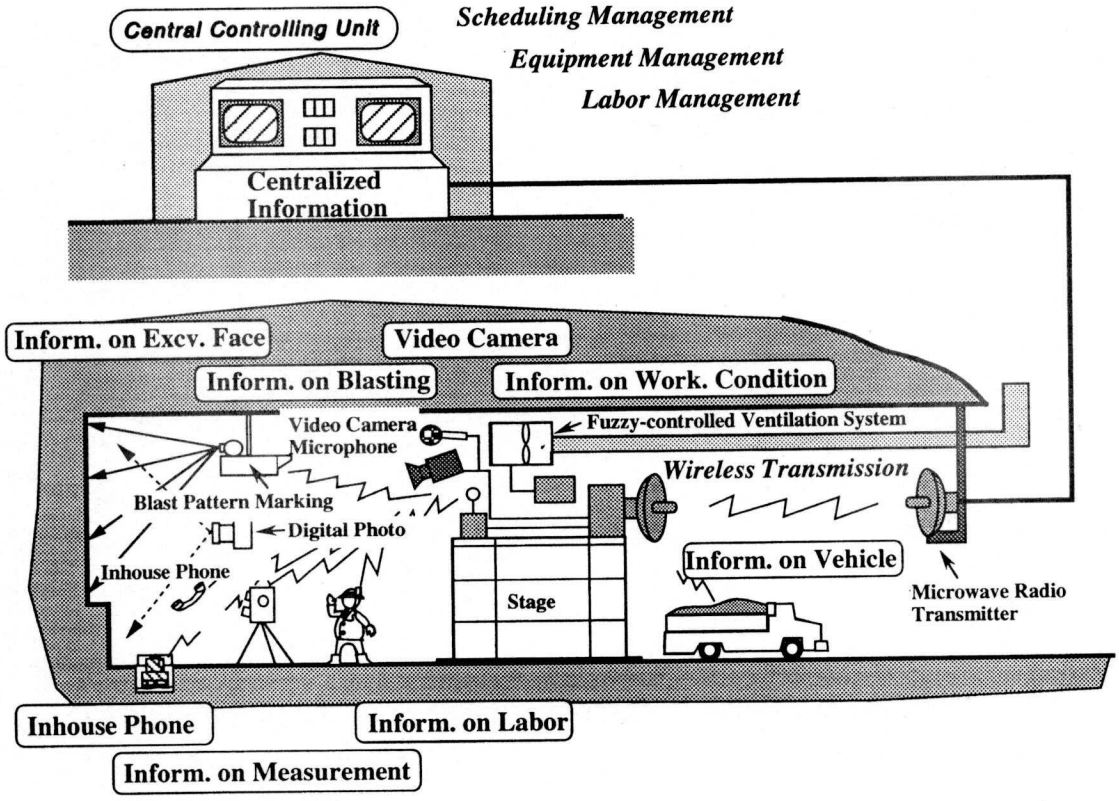

Figure 1 Idealized System Configuration

Table 1 Specification of Microwave Radio Transmitter

Radio Freq.	49.2 ~50.2 GHz	
Transmission Capacity	TV+2 sound(both way)	
Modulation	FM(FSK)	
TX Output Power	+12 dBm typical	
RX NF	15 dB typical	
Radio Freq. Stability	200 ppm	
RX Threshold Level	- 70 dBm	
Antenna	Conical Horn	Cassegrain
Diameter	25 mm	300 mm
Gain	20 dB	40dB
Beam Width	17 degree	1.5 degree
Power Supply	DC - 48V	
Power Consumption	Appr. 15W	
Dimensions	Appr. 176x118x260 mm(antemma excl.)	
Weight	Appr. 6.5 kg (antenna excl.)	

Table 2 Summary of Data Treated in the System

Inform.	Contents	Transm. Direction
Video	Works at Excv. Face	Tunnel ---> Cent. Cont. Unit
Sound	Sound at Excv. Face	Tunnel ---> Cent. Cont. Unit
Numbers	CO and Dust dens. Temp, Humid.,Controlled Fan Speed	Tunnel ---> Cent. Cont. Unit
Remote Control	TV Camera Control	Cent. Cont. Unit---> Tunnel
On/Off Signal	Emergency Alarm	Cent. Cont. Unit---> Tunnel

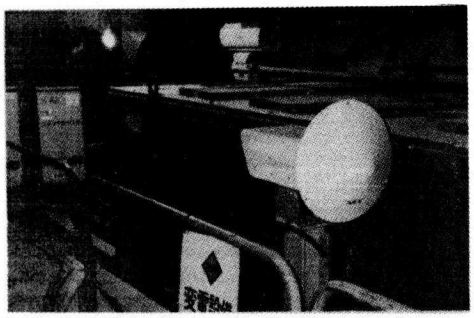

Photo 1 Microwave Radio Transmitter

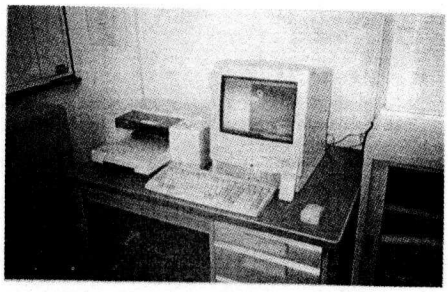

Photo 2 Computer at Central Controlling Unit

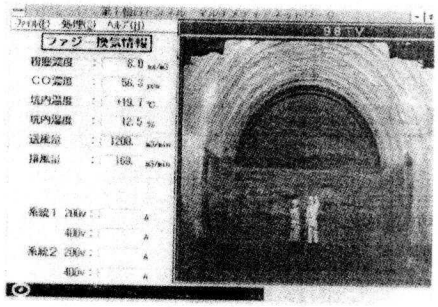

Photo 3 Monitor on Computer