Current Status of Unmanned Construction Technology Developed using a Test Field System

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Abstract –

Unmanned construction work is civil engineering work carried out by remotely operating construction machinery located in a caution zone (a zone whose entry is prohibited or restricted), thus enabling the operator to perform remote work from inside the safe area without any need to enter the caution zone.

This technology came into being as a result of a proposed public offering of technology from each civilian company, which utilized the test field* of January 1994, and also technology verification at the site. From then onward to the present time, new technology was acquired continuously, then it evolved, and spread throughout Japan.

This paper describes the birth of unmanned construction, the development of related technology, and the trend of current technology.

***A system for constructing a life-size building intended for increasing the degree of completeness through technology verification in the field.**

Keywords –

Unmannde Contruction; Remote control; Operation guidance; Wireless communication; Safety monitoring

1 Description of unmanned construction

This unmanned construction technology consists of construction machinery that is operated remotely, and supporting equipment for operating remote operation of this machinery (Figure 1).

Also, it is necessary to arrange the shape of the the civil engineering structure and equipment constructed in the caution zone, and also the quality confirmation method.

A description of each item is set out below.

1.1 History of unmanned construction

Work using remote-operated construction machinery commenced in 1969. In this case, land reclamation was carried out on the Joganji-gawa River in Toyama Prefecture using an amphibious bulldozer (Figure 2). Subsequently, the use of remote operation was extended to land type back hoes, bulldozers and dump trucks.

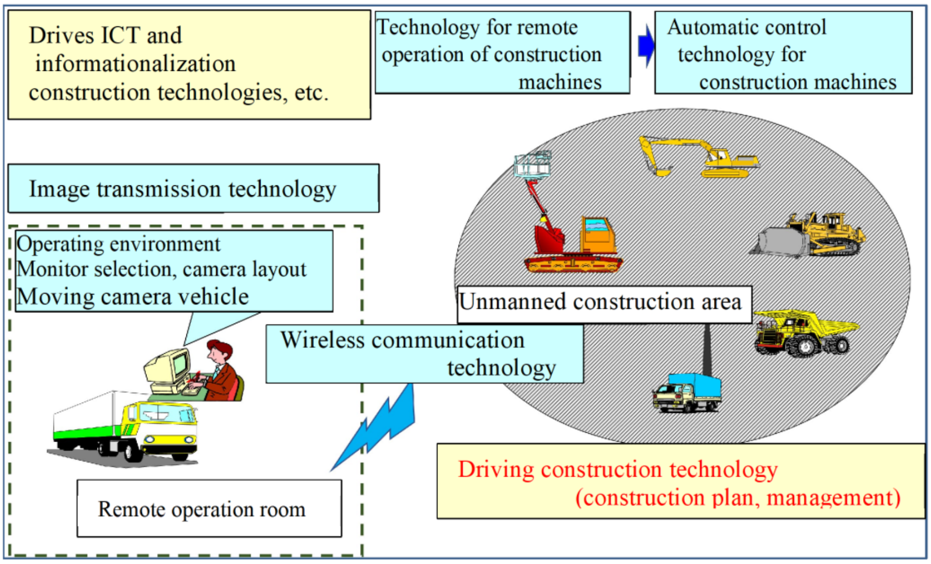

Figure 1. Unmanned Construction Technology

Figure 2. AMPHIBIOUS BULLDOZER

1.2 The birth of unmanned construction

A test field system tests new technology at the jobsite, in order to confirm its integrity.

In the case of the test field at Mt. Unzen-Fugendake, because mudslides occurred due to the increase in volcanic activity, and sand and soil accumulated in sand ponds, it is necessary to urgently remove boulders and also sand and soil. Because it is difficult to carry out construction using manned machinery, topics are assigned such as the acquisition of technology for continuous excavation and removal of soil by unmanned construction (Table1).

Table 1. Technical subject of a test field ［1］

	Contents of a technology	Technological standard
①	Excavatingand carriage accompanied by the smash at the condition and moreover, of a rock that isn't uniform	A pellet smash as much as 2 in diameter - 3 m is possible
②	A temperature in a spot is prepared to the humidity conditions.	It has been possible to operate even the condition as much as 100 °C of a temperature, 100 % of the humidity temporarily as a peripheral condition
③	The remote control can do a building machine.	Equal to or more than 100 m of remote control is possible.

In response to this emergency technology, public offering of technology that could be used together with procurable technology were selected, and then grouped together. The base machines consisted of large, remote operation type construction machines (bulldozers, backhoes, dump trucks) grouped together. As the operation support equipment, an ITV camera was used for securing adequate visibility over an operation distance of 100 m. Also, because the operation signals transmitted to and from the construction machines, and the image information obtained from the camera is transmitted wirelessly, wireless relay facilities for preventing instantaneous shutdown of wireless transmission, mobile camera vehicles which compensate for the dead angle of the camera image, remote operation rooms, and other ancillary facilities that are peculiar to unmanned construction were installed (Figure 3).

Figure 3. Relay vehicle＆camera car

At the commencement of construction, work is extremely difficult to carry out, even in the case of excavation work which is considered to be easy work.

Examples include radio interference, power source problems, a breakdown due to impact during construction, and problems concerning contact between construction machines at the in the dead angle of the camera. Upon completion of the test construction it was determined that excavation work could be carried out.

2 Improved technology used at Mt. Unzen-Fugendake

At Mt.Unzen-Fugendake, there is a danger of the lava dome collapsing, even at present. For this reason, a sand arrestation facility was fabricated using unmanned operation, from August 1994 corresponding to the completion of a test construction under the field system, to the present day. Concerning unmanned construction which has been employed in the Unzen region over the past 50 years, it was considered necessary to make technology improvements in communication by using a variety of sand arrestation structures and also the positional relationship between the safety zone and the work location. Also, on the other hand, equipment and other items for performing quality control was installed on trial. These items basically consist of existing useful technology that has been converted into remote technology.

For this reason, “unmanned construction” has been used from August 1994, corresponding to the completion of test construction, to the present day. This technology has been improved according to changes in the situation of the work, such as the object of construction or the operation position. Also, whenever new technology was employed, it was corrected and verified at the jobsite and its effectiveness confirmed.

2.1 Application to a variety of sand arrestation structures

Excavation technology that was confirmed by test construction was developed to the final structure.

2.1.1 Construction of a weir using the RCC method

The RCC (Roller Compacted Concrete) method which enables construction work to be performed by improving earthmoving machines was adopted. To enable this method to be used, vibration rollers, water spraying vehicles, cleaning cars, and sand and soil formwork shaping machines were developed. (Figure 4)

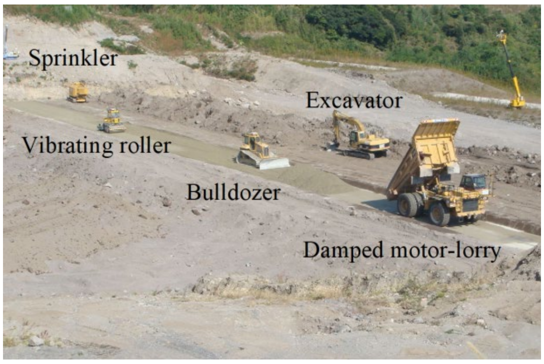

Figure 4. Building of RCC

2.1.2 Building of a steel slit dam

In the construction of a steel open type dam, transportation and installation were carried out, taking into consideration the shape of the steel slit. The dam was fixed by using high-fluidity concrete. Also, conveying of the concrete, conveying of the concrete to be laid, laying of the concrete, and surface-finishing were carried out. (Figure 5).

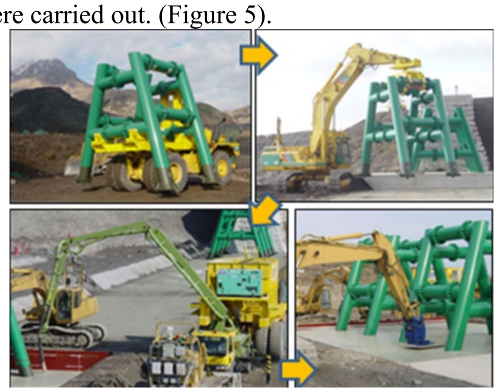

Figure 5. Building of a steel slit dam

2.2 Operating method

The operating methods are classified as shown in Table 2.

Table 2. operating method

	Watching operation	Monitor operation		
Form of construction work	It operates directly.	Monitor operation	Utilization of a becoming ICT	Utilization of TCP/IP
Overview	Watching operation	It operates while seeing the monitor of a camera.		
		-		Utilization of TCP/IP
Overview of the construction system of becoming of the unmannedness	Independent work of a remote type operation machine	Direct method A remote type construction machinery communicates with an operation place directly. Relay method An operation place and remote type operation machine are done through a relay-aircraft.	Utilization of a becoming ICT GNSS measure uses a technology and guidance equipment.	Utilization of TCP/IP It adopts a wireless LAN to the operation and transmission of the picture information.

2.3 Quality control

In Japan, the control outline was formulated in 2012. Presently, "Compaction control using TS-GNSS" has come into general use. When compaction was carried out in the Unzen zone using unmanned operation, it was used from 1995 as RCC method concrete laying control and also compaction control using a GPS in 1999 (Figure 6, Figure 7).

When an unmanned operation was performed at Mt. Unzen-Fugendake, concrete laying control using a GPS occurred in 1995. In 1999 compaction control took place using an GPS.

In this way, when unmanned operation was performed at Mt. Unzen-Fugendake,new technology was introduced proactively, enabling the performance to be confirmed. As a result, the spread of new technology advanced (Figure 8, Figure 9).

Subsequently as well, efforts were made to promote remote operation of surveying equipment, flat plate loading tests, and core boring machines.

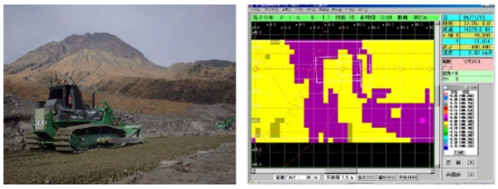

Figure 6. Management of an leveiing

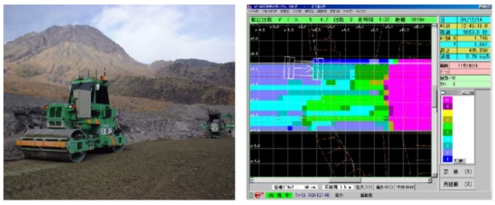

Figure 7. Management of an compaction

Figure 8. Remote control type measure equipment

Figure 9. Measuring machine of a remote control type bearing power of groun

3 Information transmission base of a new technology

Building of becoming of the unmannedness was established by a thing such as it develops Unzen Fugendake as a base in various parts of Japan and that technology feeds back into Unzen Fugendake again with a technology.

Also, we used it at an early stage such as compaction control using GPS to verify its performance.

3.1 Whole country spread of building of becoming of the Unmanned Construction Technology

Building of becoming of the unmannedness of an Unzen area makes it the causing place of a nucleus technology, and that technology is developed in the volcanic disaster / landslide disaster of various parts of Japan (figure 10).Also, also, that disaster occurrence form is done to the improvement adjusted to the characteristic of each place to be different respectively.

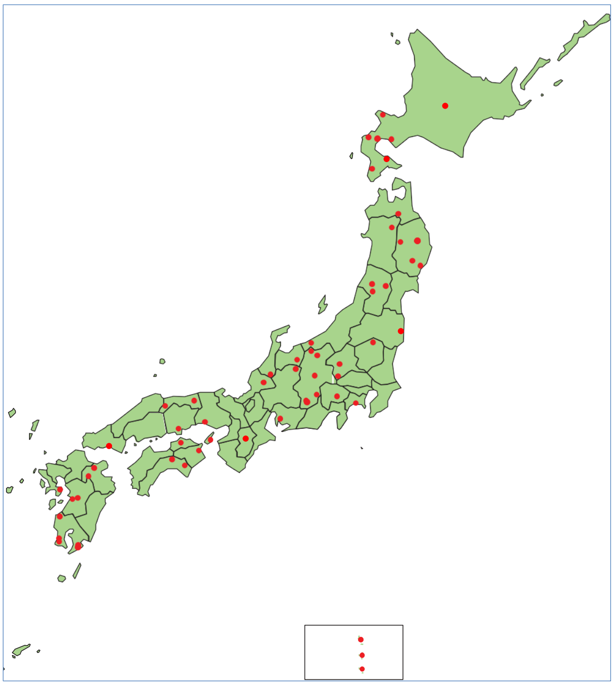

Figure 10. Building of becoming of the unmannedness implemented in Japan

4 Recent situation concerning unmanned operation at Mt. Unzen-Fugendake

Preparation of a sand arrestation on a dry river bed at Mt. Unzen-Fugendake is advancing, and the object of unmanned construction also changes. Very recently, this work consists of reinforcement work for existing sand arrestation facilities. Compared with the previous operations, it can be seen that this work is carried out on a narrow working area. When carrying out unmanned construction in the applicable zone, technology will be updated.

A description of the latest technology is set out below.

4.1 Construction technology

The most up-to-date technology is used. at Mt. Unzen-Fugendake.

4.1.1 Machine control bulldozer

An operation guidance system is provided as standard. Regarding control of the blade of the bulldozer that determines the quality of the concrete compaction, a automatic control system is used.

4.1.2 Compaction using a Excavator

When performing compaction work in confined spaces, a excavator bucket with compaction equipment was used in order to regulate the compaction time (Figure 11) .

Figure 11. Bucket total firming equipment

4.1.3 Surveying by using TS tracking and electronic reference points

In order to increase the accuracy of UAV surveying, it is necessary to use the altitude points (verification points and evaluation points) inside the measurement points. In order to reduce the number of measurement points inside the prohibited zones, the number of elevation points was reduced by measuring the position of the camera mounting on the UAV, by means of an automatic tracking total station. Regarding the evaluation points, a device that measures the self-coordinates by static conveying, of a remotely operated type construction machine was installed on a remote-operated construction machine. (Figure 12).

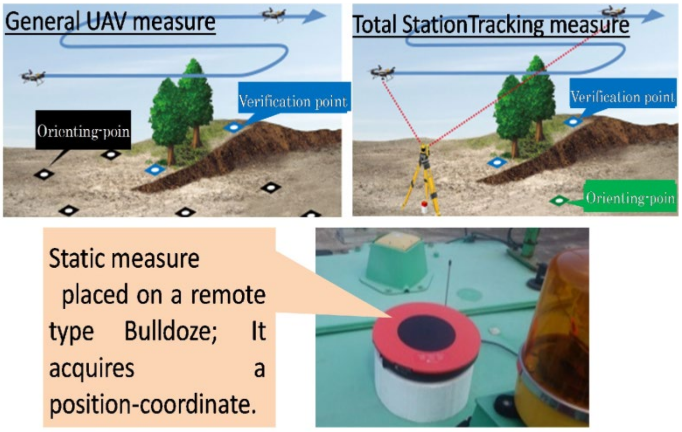

Figure 12. Electronic tacheometer tracking and UAV measure by an electronic reference mark

4.2 Safe watch

When carrying out unmanned construction at Mt. Unzen-Fugendake, it is important to carry out safety monitoring as well. The greatest danger is that of the lava dome collapsing. Consequently, visual monitoring and image monitoring were carried out.

4.2.1 Securing visibility by image clarification processing

Much fog and mist envelope the Mt. Unzen-Fugendake zone, posing an impediment to monitoring. For this reason, image processing was performed to determine whether foggy or misty areas are thin or dense, and also whether the distance is near or far, in order to improve the visibility of misty areas (Figure 13).

Figure 13. Securance of the visibility by processing of becoming of the image clearness

4.2.2 Obtaining an early grasp of an earthquake

There is a danger of the lava dome collapsing due to an earthquake. For this reason, an integrated type quake detection system has been installed in the operation room to permit earthquake monitoring (Figure 14).

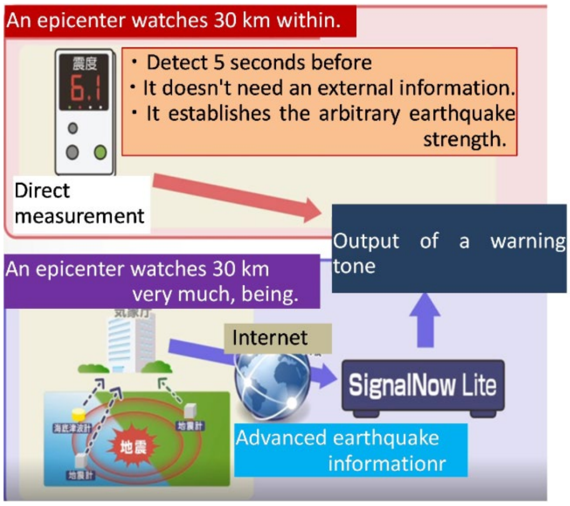

Figure 14. Earthquake watch

5 Conclusion

Even after the eruption of Mt. Unzen-Fugendake, Japan has been fraught with many disasters such as the eruption of Mt. Usu, the Mid-Niigata Prefecture Earthquake, the Iwate-Miyagi Inland Earthquake, and the Great East Japan Earthquake. As a result of the adoption of unmanned constructions, the regions concerned quickly recovered from the disasters.

In this way, unmanned construction enabled quick action to be taken for all disaster regions in Japan. This is because even after the end of the test field system, unmanned operation was performed continuously at Mt. Unzen-Fugendake, and also because efforts were made to realize performance improvement. Also, in recent years, informationalization construction as well is used in advance at Mt. Unzen-Fugendake enabling the performance to be confirmed. It also performs an important role with respect to new technology in the construction zone at Mt. Unzen-Fugendake.

However, at Mt. Unzen-Fugendake, there still exists the danger of an avalanche due to the collapse of the lava dome, and also apprehension concerning the possibility of the disappearance of the unmanned construction jobsite when the scheduled sand arrestation facility is completed.

Japan, from its national land consisting of location, terrain, geology, and also its natural conditions, is considered to be a fragile land from the viewpoint of natural disasters including earthquakes, typhoons, and localized torrential rain. It is also considered that the securing of a providing ground for unmanned construction, which is effective technology for recovery from a disaster, is important for to the future development of civil engineering.

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