Aketo SUZUKI *1
Koichi NAKANO *1
Eiichi GOTO *2

*1 High-tech Construction Technology Development Section,
Construction Technology Development Department.

*2 Technology Research Center

TAISEI CORPORATION
Shinjuku Center Building
25-1 Nishi Shinjuku 1-chome
Shinjuku-ku, Tokyo
163 Japan
Tel. (03) 348-1111

A THREE—DIMENSIONAL POSITION MARKING SYSTEM APPLIED TO THE INFORMATION—INTEGRATED CONSTRUCTION TECHNOLOGY

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Abstract

This study covers the three-dimensional position marking system (3DPMS) in the information-integrated construction (IIC) of three major fields necessary to improve the productivity of a construction project, i.e. development of an industrialized construction method, promotion of robotization and promotion of IIC.

IIC technology has become an essential part of construction technology as the computer, sensor and communication technology have advanced, and it has seen rapid promotion in recent years.

The 3-DPMS as described here shows the position of the original point that serves as the basis of construction, is important in the development of new domains of technology, such as marine and underground space, etc., and is an effective construction method in the building of structures of a complicated shape. In addition, it will play an important role in the construction method for building structures that have rapidly been fully automated in recent years.

Taisei Corporation has already initiated development of the method using the Global Position System (GPS) including the 3-DPMS for this purpose.

[*1] A. Suzuki et al.: "Present Status of Expert System in Construction Companies". Stanford University CIFE Symposium in March 1990.

1. Introduction

It is interesting that the ancient pyramids in Egypt form a regular tetrahedron facing the four cardinal points of north, south, east, and west. It is said that when the pyramids were designed these directions had been determined by measuring the movement of the sun and the stars. Even in the present day, ocean-going vessels use the latest position measurement techniques including GPS, etc., but yachts, still use a sextant for astronomical observation as an important means of measurement.

The procedure for building a structure can be seen in Fig. 1 "Flow of Procedure," but the system for knowing the three-dimensional position and marking it, relates not only to the survey, but also to all the stages. And it is necessary to know the position that may be invisible to the human eye and positioning for construction must be performed. At present, although the information-integrated construction (IIC) can be seen in Fig. 2, and we have been performing this in the process of construction, the three-dimensional survey and position information are becoming extremely important.

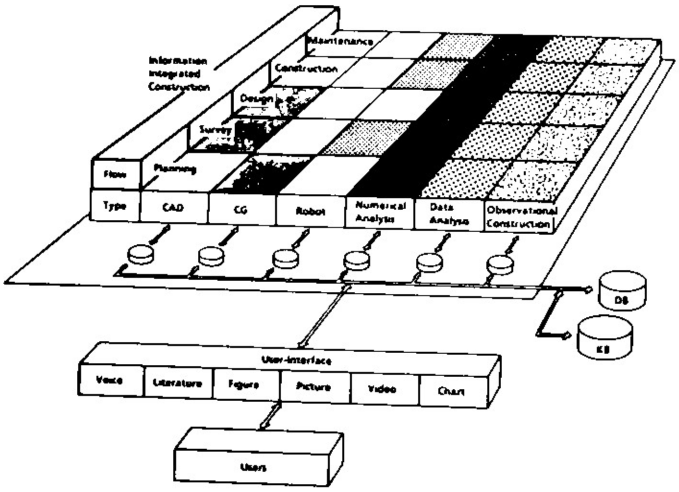


Fig. 1 Position of information-integrated construction technology

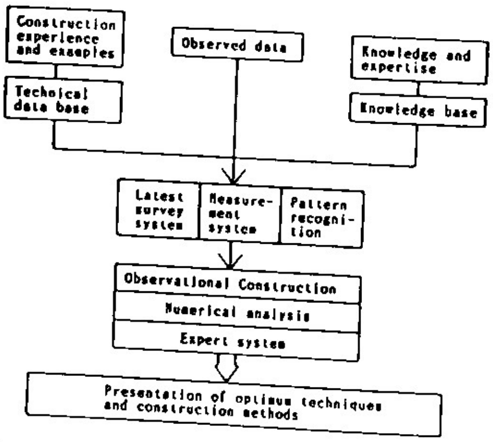


Fig. 2 Information-integrated construction technology

2. To determine position in marine space

The Honshu-Shikoku Bridges completed in 1988 have 11 sets of bridge piers or abutments. These were constructed using a method in which seabed rock was excavated and levelled and a steel caisson was sunk at that position and crushed gravel placed in it, and then mortar was injected. This is a special construction method called the "Laying-Down Caisson Method".

Although the base area where the steel caisson was to be installed ranged from about 1500 m^2 to 500 m^2, and the water depth also varied between 50 m and 10 m, the accuracy of the smooth finish of the base surface was 10 cm. To measure the seabed surface with this high degree of accuracy, a sounding data processor developed using mini-computers was employed first, making use of the self-elevating platform (SEP) to accurately obtain plane position. Nine sets of depth sounders of 400 Hz were installed on both sides of the base of o3.1 m guide pipe, as shown in Fig. 3, with the plane position on SEP as a standard so as to be able to process this vast volume of data accurately in a short period of time. For confirmation of the plane position a Electronic Distance meter and transit were used in combination and the standard length of pipe and depth sounders were used to measure water depth in order to utilize the data processing system.

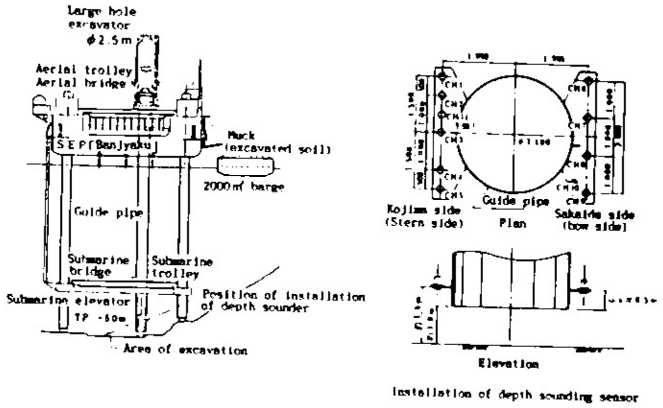


Fig. 3 SEP and position of depth sounding sensors

The caisson now to be laid on the finished rock surface is a huge double wall caisson of 59 x 27 x 37 m to 59 x 75 x 55 m in outer dimensions. To enable installation of such a structure in the designated position, an example of the positioning system adopted is shown. The measurement information necessary for these control operations ranges from position of the caisson, direction, water level in ballast tank and cutting edge of the caisson to the distance to the base of the foundation, etc. Fig. 4 shows the outline of the information processing system for this purpose. The laying of the caisson was implemented by collecting and processing this information. This system has been improved upon and is now being used in the laying of the steel caisson foundations of the Akashi Kaikyo Bridge.

*2. E Goto and A. Suzuki: "An Example of the Underwater Construction of Honshu-Shikoku Kojima-Sakaide Bridge", the Japan Society of Civil Engineers, Sept. 1985.

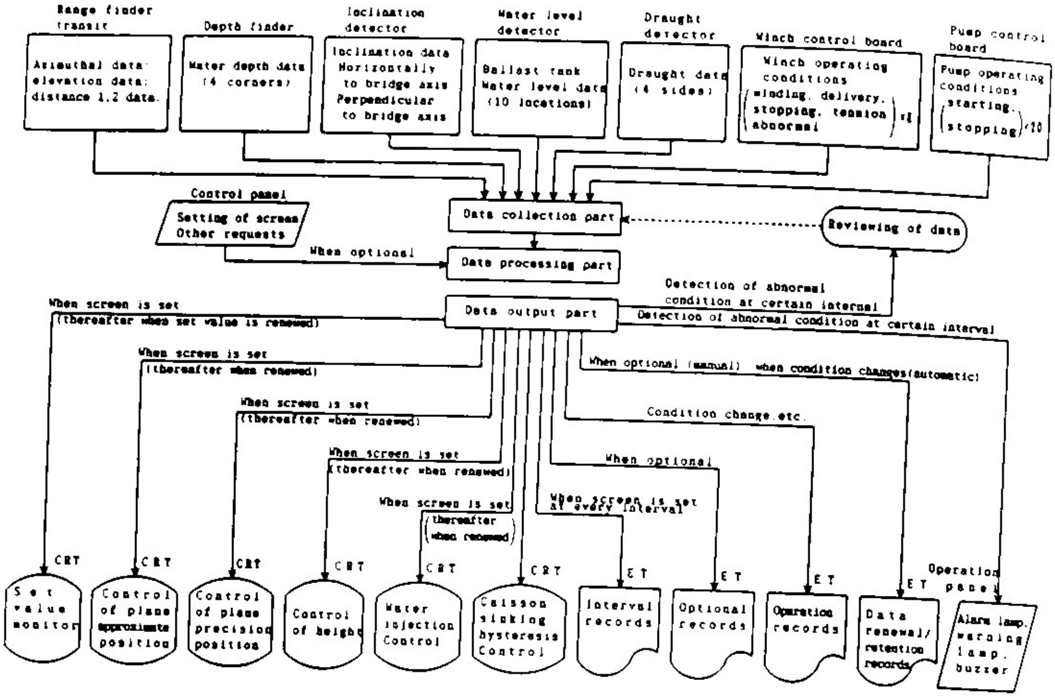


Fig. 4 Outline of positioning system for sinking

3. Measuring a complex configuration

At Disneyland where a new amusement facility has been produced to create a "Splash Mountain" that is covered with rocks of fantastic shapes in Tokyo Disneyland, a model of 1/50 in scale, which was manufactured in the U.S.A., was brought to Japan to prepare a drawing for reproduction. To reproduce and prepare the drawing two methods were adopted: to conduct a photographic survey on the ground and to prepare an analysis drawing and lead it to CAD from a three-dimensional digitizer.

The photographic survey method on ground uses a similar method to the aerial photographic survey method on the model, i.e. take overlapping photographs by moving a precision measurement camera on a rail of the model where numerous datum markers are placed. The overlapped photographs are then held by the analysis drawing maker on the right and left simultaneously and Xp and Yp coordinates of the photographed point at each time period are converted to normal (all photographed points) coordinates. The light ray that passes the common photographed points on two photographs, right and left, and meets at one point, is called the "mutual orientation." With this analysis drawing maker, an analytical reproduction image that is analogous with the model can be obtained. Next, in the photographic triangular survey, the common photographed points (Xp, Yp, Zp) in the group of photographs that are overlapped and continuous in each time period are given an average value by minimizing the square sum of the remaining difference when they are converted to normal coordinates (X, Y, Z) using the photographic model unit triangular survey program. In addition, by giving a different weighting to the normal coordinates, the closest solution can be obtained.

Fig. 5 shows an example of the three-dimensional measurement method using the photographic triangular survey.

For "Splash Mountain" at Tokyo Disneyland, the drawings were reproduced using two methods, the photographic survey method on the ground and the three-dimensional digitizer method and it is now under construction.

4. Realizing position in space

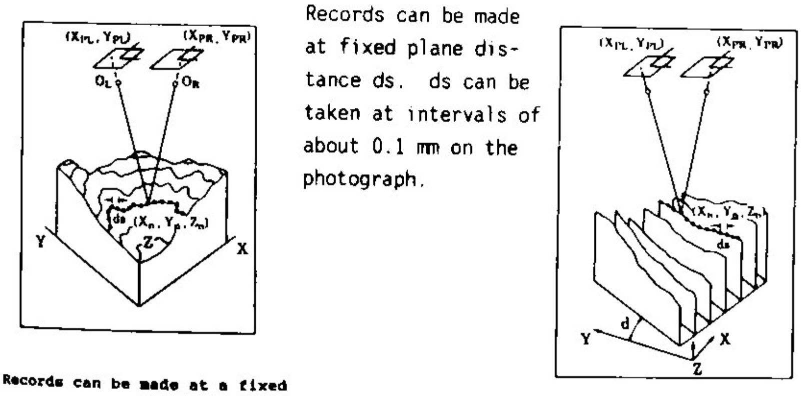
In modern building, a huge dome and a structure of undefined form are often constructed in the space. Research and development concerning the positioning method in spaces such as these is necessary.

As a first step, we have developed a positioning method in underground space. The underground space is where mass transportation and lifeline facilities are constructed 50 m below the ground level in the large cities, requiring the cutting of accurately positioned space underground.

The cutting is begun by excavating vertically or inclinaly from the designated punctual coordinates on the ground. To expedite excavation underground it is necessary to know the correct direction and distance. Formerly the direction and distance of excavation were surveyed individually by men but we have made it possible to compute direction, distance and scope of underground excavation using computerized laser marking system, and to make marking at the same time.

This system consists of a total station and a computerized laser marking system, making it possible to transmit various alignment calculations that are necessary when constructing a physical distribution facility underground to the total station as a program and to give the necessary configuration of an underground structure. Fig. 6 explains this system.

By using two units of this system, it is possible to obtain points in the space of the dome etc., and by means of the method of intersection and resection, the new space framing method can be developed.



Records can be made at fixed plane distance ds. ds can be taken at intervals of about 0.1 mm on the photograph.

Input parameters:
- inclination of sections from datum point
- width of sections
- vertical length of sections
- interval of data taking on sections (plane distance) 0.1 mm is possible on the photograph.

Records can be made at a fixed plane distance ds.

1) Contour line mode

2) Section (profile, cross-section) mode

Measured data format
- Normal system (on ground) coordinate value.

Phorographic coordinates (can be used for photographic overlay evolution)

Fig. 5 Three-dimensional measurement method using analysis drawing maker

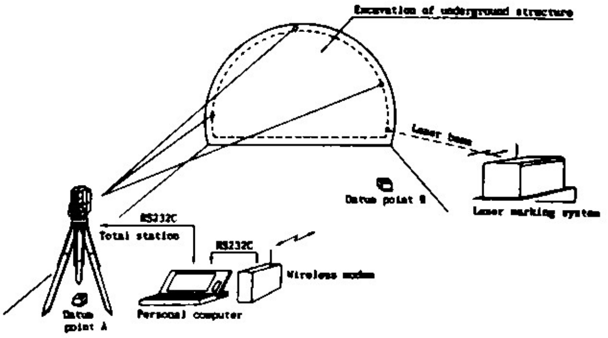


Fig. 6 Details of selection of system

5. To determine a new construction method

The method of constructing buildings is now about to change significantly. The announcement by construction companies of a fully automated construction method is one of the indicators. In the fully automated construction of a building, it becomes necessary to perform a large assembly process to simplify the assembly work at the existing position. Instead of erecting structural steel columns formerly used in the SRC construction one by one, a block assembly mode integrating the column, beam, wall and ceiling is now applied. In a block construction process such as this, it is important that individual members are processed with accuracy and installed in their designated positions without error. It is also important to give an assembly robot an accurate two-dimensional position in this fully automated construction. We are now planning to establish a three-dimensional coordinate recognition assembly method using a combination of GPS computerized laser marking system and the total station.

Also, in construction work already started for the Winter Olympic Games in 1998 for the Hakuba NAGANO Ski Jumping Hill (k = 120 m and 90 m), research into the development of a new construction method employing computerized laser marking system with the total station and a computer in order to give the complex configuration of the ski-jumping hill to the space is already under way.

A proposed plan of application of the marking system to the Hakuba Ski Jumping Hill by slide.

6. Conclusion

Although IIC began with the observational construction in the field of soil mechanics it has received attention as a far-reaching, new technology with the advancement of modern computer sensor and communication technology, and it is reaching a stage where it is changing the positioning of the construction industry whose productivity was previously low, by upgrading the accuracy of fabrication of structures and the ratio of industrialization of products.

The 3-DPMS discussed here is a field that gives positional information and can become the basis of remote measuring in IIC which is a pivotal point in robotization serving as a technology that produces positioning information in fully automated construction. With the connection of the 3-D CAD, we envisage that it will play a major role in changing construction systems of the future.