# (40) Construction of Automatically-built 3D Geological Column System of Existing Boring Data

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In recent years, MLIT has encouraged conversion from paper-based to digital data and the digital data share to improve the efficiency of construction process and cost reduction (CALS/EC). Subsequent to the introduction of CALS/EC, MLIT also initiated CIM (Construction Information Modeling/Management) to advocate the use of digital data for efficient construction and further cost reduction. Presently, soil data distributed on the internet is called “boring data,” which is shown in pdf for geological drawing and information.

Boring data is an essential type of data in construction projects. According to CALS/EC, the data is freely distributed over the internet. As boring data is garnered in two dimensions only, its use is significantly limited. Based on such facts, the authors have constructed a system which can directly convert the distributed data into three-dimensional data. Through case study, the authors explicate the usability of 3D boring pole.

***Key Words :*** *boring data, existing data, 3D data, CIM, convert-to-3D system*

## 1. INTRODUCTION

When thinking about building any structures, it is mandatory to sufficiently examine status, quality, strength, etc. of the soil. The structures include all types of structures which are constructed above the ground, e.g. bridge, buildings, dam, embankment, road, etc. The data of soil information is called “boring data.” Boring data is stored in the form of digital data in compliance with the insistence of Ministry of Land, Infrastructure, Transport and Tourism (MLIT).

Since 2008, MLIT has fostered the sharing of digital data instead of paper-based data. With the goal to improve the efficiency of construction process, such data-sharing is called “CALS/EC.” This digital data is then called “electronic delivery.” Following CALS/EC, MLIT has introduced Construction Information Modeling/Management (CIM) in order to make full use of ICT for an efficient construction process. Based on these introductions, paper-based boring data is transformed into digital data, then is used in construction projects[1)].

Digital formats—both pdf and xml—are distributed online in National Land Geo-information site. There are vast varieties of programs that can convert xml data into 2D CAD drawing. There is yet a system that can convert xml into 3D-CAD data.

Therefore, in this research study, the authors constructed a system that can convert geological xml data directly into 3D-CAD data. With the constructed system, the authors applied the system in a case study to find the data usability in construction projects.

## 2. BORING DATA

Boring data represents diverse information contained inside the soil: layer, depth, histogram, color, N value, etc. These values are acquired from examinations of the ground for soil properties and strength, so called "soil tests," such as Swedish weight sounding and standard penetration test. These values are important in construction projects.

**(1) Current Status of Boring Data**

The formats of the boring data, which are currently distributed on the internet, are in pdf for geological column drawing and XML for geological information.

**a) Geological Columnar Drawing**

Geological column drawing is made of the results elicited from soil tests. The drawing shows the design of state and foundation of soil layers. This drawing consists of important information of the soil which is surveyed for many constructions. The location of the boring data is shown on 1/25000 or 1/50000 map.

**b) XML Data**

XML data for geological information is defined by the company that did the soil test. Such data is then made into an electronic delivery format for management usage. XML data of geological information comprises many tags including latitude, longitude, depth, colors, classification of soil quality, etc.

**(2) Challenges**

Boring data is usually stored inside the internet without much use. The stored data is sometimes outdated because there is no specific need to update it. Two-dimensional data cannot satisfy the need of the owner since its use is limited. To be precise, it is difficult to determine the location of multiple 2D drawings on the map in one place. Even though the two dimensional data, such as boring panel, can be used inside a 3D viewer, it still lacks clear visualization because the panel blocks the view. This makes it difficult to determine the project status. As the boring data is truly essential in construction projects, there is a need for 3D data of boring data.

**(3) Merit in 3D Data Use**

3D data is in a digital format; consequently, it is easy to share the data among related parties. Other than the sharing of 3D data, 3D data has its own merits. 3D data is widely used in construction planning due to the fact that it is uncomplicated to see what cannot be seen in reality. It is also extremely simple to edit the data, and to show clear understanding of the current state of the target surface. In addition, 3D data can hold many attributes which are very useful for a variety of purposes including construction planning and maintenance of civil structures.

With these merits, 3D geological columns are

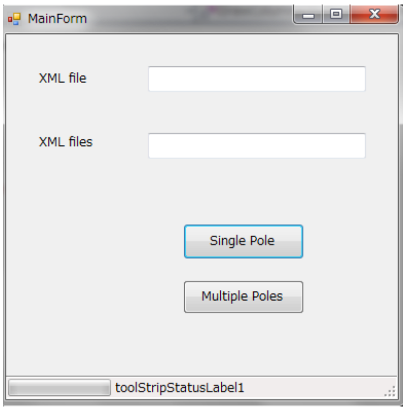


**Fig.1** Soil+

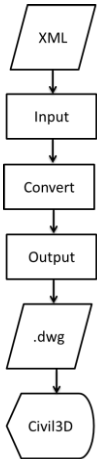


**Fig.2** Flow chart of Soil+

proved to be practical for construction projects as well. The authors hence have created a program, entitled the Automatically-built 3D Geological Columnar System, or abbreviated to Soil+, to handle difficult challenges.

## 3. AUTOMATICALLY-BUILT 3D GEOLOGICAL COLUMN SYSTEM

The authors constructed a system which can convert xml into 3D data. The system—Automatically-built 3D Geological Column System (Soil+)—is shown as a stand-alone system, illustrated in figure 1. The purpose of Soil+ is to read geological XML data, calculate, and generate 3D data.

**(1) System Overview**

The flow chart of the process is shown in figure 2. The process of Soil+ starts from inputting XML data into the system. The system will read the tags inside XML and then convert those tags into both string and number information. For instance, the numerical information, e.g. latitude and longitude, will be calculated and inputted for coordinate information.

The string information such as code of soil classification is used to identify the colors of layers of boring poles. The output is the boring pole in the shape of a cylinder which contains attributes, e.g. location and colors. Finally, the data is automatically displayed on Civil3D.

### (2) System Analysis

Soil+ is able to calculate and convert information provided inside xml data.

**a) Location information**

Longitude and latitude need to be converted into plane rectangular coordinate for exact location inside 3D viewer. The formula is shown, as follows[2)]:

$$X = \{(S - S_0) + \frac{1}{2!} N \cdot \cos^2 Lat \cdot t \cdot (\Delta Lon)^2$$
$$+ \frac{1}{4!} N \cdot \cos^4 Lat \cdot t \cdot (5 - t^2 + 9N^2 + 4N^2) \cdot (\Delta Lon)^4$$
$$- \frac{1}{6!} N \cdot \cos^6 Lat \cdot t \cdot (-61 + 58t^2 - t^4 - 240N^2 + 330t^2 N^2)$$
$$\cdot (\Delta Lon)^6$$
$$- \frac{1}{8!} N \cdot \cos^8 Lat \cdot t \cdot (-1385 + 3111t^2 - 543t^4 - t^6)$$
$$\cdot (\Delta Lon)^6 \} \cdot m_0 \qquad (1a)$$

$$Y = \{N \cdot \cos Lat \cdot (\Delta Lon)$$
$$- \frac{1}{3!} N \cdot \cos^3 Lat \cdot (-1 + t^2 - N^2) \cdot (\Delta Lon)^3$$
$$- \frac{1}{5!} N \cdot \cos^5 Lat \cdot (-5 + 18t^2 - t^4 - 14N^2 + 58t^2 N^2) \cdot (\Delta Lon)^5$$
$$- \frac{1}{7!!} N \cdot \cos^7 Lat \cdot (-61 + 479t^2 - 179t^4 + t^6) \cdot (\Delta Lon)^7 \} \cdot m_0 \qquad (1b)$$

Where, X and Y are x, y coordinates in plane rectangular coordinate, Lat is latitude, Lon is longitude, S is meridian arc length from the equator to latitude, $S_0$ is meridian arc length from the equator to the origin of latitude, t is tangent of latitude, N is prime vertical circle, and $m_0$ is the scale factor in the origin of the coordinate system (0.9999)

**b) Depth**

The highest z coordinate of the boring pole is decided according to the aperture mouth altitude provided inside xml data. Then, each depth of the pole is calculated in the formula, as follows:

$$p_1 = h - \frac{d_i}{2} \qquad (2a)$$
$$p_2 = d_i \qquad (2b)$$
i = 0
$$p_1 = h - (p_2 + \frac{d_i}{2}) \qquad (2c)$$
$$p_2 = p_2 + d_i \qquad (2d)$$

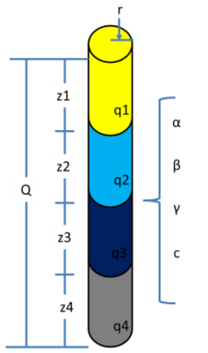


**Fig.3** Boring pole concept

i = 1,2,3,…,n

Where, $p_1$ is the upper height position of the pole, $p_2$ is the lower height position of the pole, d is depth of the pole, and h is aperture mouth altitude.

**c) Color**

The colors of the boring pole are decided in accord with the soil classification code inside xml data. The code is in an RGB format. The color data—apart from the soil classification code—does not have specific rule because colors in geology engineering and geology information are sometimes different[3)]. In this study, the colors are applied by using the color table of Database of Underground Structure and Borehole Log in the Kanto Plain as reference[4)].

### (3) System Output

The boring pole is generated as the output of the system. It has location information in x, y, z coordinate with the radius of 0.5 metre. In addition, the boring pole has the depth information and is colored according the soil classification table. The formula for constructing the boring pole from xml data is shown below.

$$[A_i] = [\alpha, \beta, \gamma, c, \ldots]^t \quad i = 0 \qquad (3a)$$
$$[Q] = [q_1, q_2, q_3, q_4, \ldots]^t \qquad (3b)$$
$$[q_i] = [z_i, r]^t \quad i = 0 \qquad (3c)$$

Where, A is the attributes; α, β, γ, c are tags inside xml data; Q is the whole boring pole; q is members inside the pole; z is the height of each member; and r is the radius of the pole. The concept of the pole according to formula 3 is shown in figure 3.

To prove its usability, the system is then applied to the Kumamoto area.

## 4. CASE STUDY

### (1) Application Site

Kumamoto area was used as a case study of the system. The xml data can be downloaded from the website and is used for many civil engineering projects, e.g. disaster prevention and road construction.

### (2) Attributes of Boring Poles

Boring poles containing location information are displayed on the map which is generated using a 3D viewer. Figure 4 illustrates the location (blue points) of many boring poles on a map.

The depth from the ground is decided by aperture mouth altitude which can be shown inside 3D viewer as the first z coordinate. Also, each depth of the members can be measured.

The colors of the boring pole tell the soil classification. In figure 5, the orange color represents the member in gravel class. The pink color represents the member in volcano rock class, and the yellow color represents the member in desert class.

### (3) Discussion

The authors found many merits of the boring pole. First, boring pole data is in dwg format, which makes it easy to combine the model with other already-built models. This can be seen in figure 6 where there is a combination among the boring pole data, 2.5D models, and 2D drawing.

Second, boring pole can be seen inside 3D viewer (Figure 7). This makes it easy to look inside the geological surface, resulting in identification of soil layers, where the soil changes layers and becomes softer.

Third, Soil+ can read multiple geological xml data in one time. The result can be seen in figure 8.The time that it took to finish the whole process is only one minute.

Finally, the combined data can be used in many phases of construction life cycle. It can be used as a database in maintenance phase. In design and construction inspection phase, such data can identify dangerous places since the pole can show the state of soil.

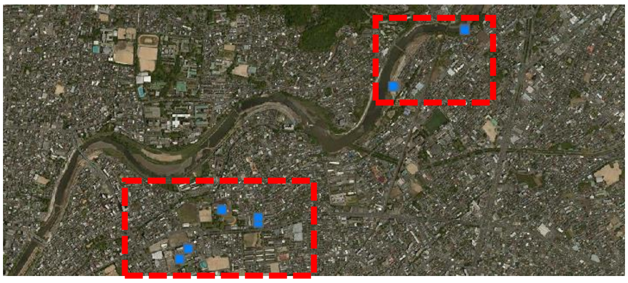

**Fig.4** Boring pole location on the map

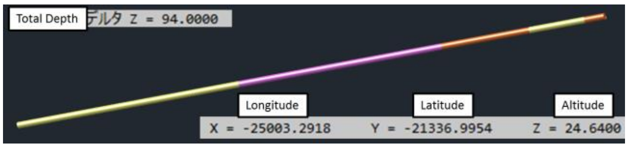


**Fig.5** Location information inside the pole

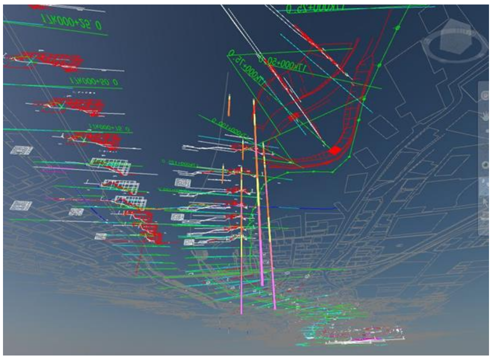

**Fig.6** Combined model

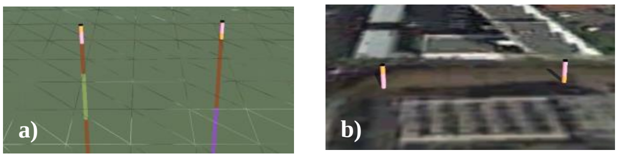


**Fig.7** Boring poles in surface

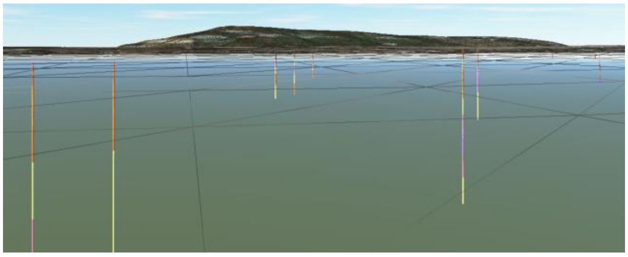

**Fig.8** Multiple boring poles

## 5. CONCLUSION

In this study, the authors constructed the system, Soil+, in order to further improve the use of 3D models in construction projects. First, the authors identified the challenges in using 2D data. Second, the authors constructed a system to address those challenges. Finally, the authors illustrated the use of boring pole data through a case study of Kumamoto.

The authors have found that there are many possibilities in using the system from the case study. However, the constructed system can still be further improved by reducing time for analyzing and projecting the data. Moreover, additional information, such as soil pattern, should be added to the system.

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