A STUDY OF THE CONSTRUCTION METHODS FOR THE PRESERVATION OF IMPORTANT UNDERGROUND REMAINS

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ABSTRACT: In this research, the Intelligent Construction that minimizes the damage was suggested. In this case, “stress for the remains” and “direct cutting for the remains” should be avoided to preserve the underground remains. The influence of the stress for the underground remains by the execution machinery was estimated by Boussinesq formula and other geotechnical method. By this result, the limit and kind of the construction machinery were decided. Before the underground remains were excavated, the precise survey for the remains were done and recorded, usually. By these data and “Intelligent construction” which realizes precise execution is available.

Based on this research, the execution was done at the Asuka-Nara Palace Site Historical National Government Park (Nara Palace Site), that is one of Japan's representative historical and cultural legacies and a Special Historic Site as well as being a constituent part of the World Heritage site "Historic Monuments of Ancient Nara."

Although the execution was done above the underground remains, they were preserved successfully.

***Keywords**: Preservation of Underground Remains, Intelligent Construction, 3D-machine Control, Positioning System*

1. INTRODUCTION

The land holds memories of its own long history, and one such example is buried cultural properties.

The construction industry involves development and changes to the land, and yet buried cultural property is something that should be handed down as a record of what our ancestors. Many cultural properties are also the basis of promoting local industry through tourism. It is therefore important to fulfill preservation, development and utilization.

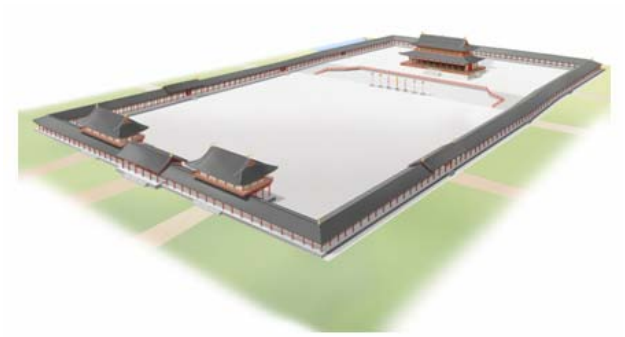

Fig. 1 Artist’s impression of the completed First Imperial Audience Hall Compound

This report describes the intelligent construction work performed at Asuka, an ancient site of cultural and political importance, and the Heijo Palace site, a special historical spot, which celebrated the 1300th anniversary of the relocation of the capital, both of which are extremely important in Japan’s history.

2. INTELLIGENT CONSTRUCTION FOR PROTECTING BURIED CULTURAL PROPERTIES

2.1 Overview

The ancient ruins of the Heijo Palace have been preserved as a special historical site with registered World Heritage status. The site contains important cultural properties, the unearthing of which has repeatedly rewritten the history of Japan.

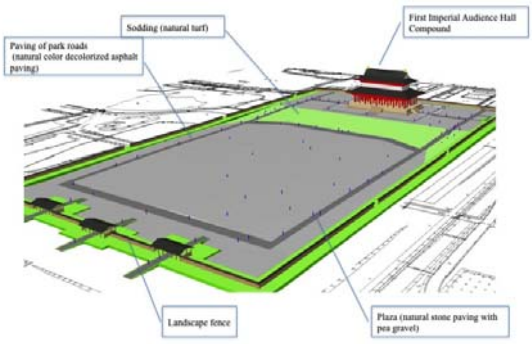

Fig. 2 Illustration of the Project

The work covered in this report is the development of a plaza at the First Imperial Audience Hall Compound (hereinafter FIH area), an area of particular significance, as outlined in the following sections. Specifically, the work comprises sodding and the construction of a plaza together with auxiliary systems such as for drainage, as shown in Fig. 2.

Construction Project:

Heijo Palace Site First Imperial Audience Hall Compound Plaza Development

• Land development

Excavation: 16,830 m^2

Fill for road construction: 12,100 m^3

Lightweight fill: 2,039 m^3

• Planting work

Sodding: 13,950 m^2

• Rainwater drainage system work

U-shaped side ditch: 1,944 m

Stormwater inlet: 53

Conduit work: 470 m

• Pavement work

Natural gravel paving: 27,400 m^2

Natural color paving: 4,020 m^2

2.2 Preparation for construction

The important points about the construction work are as follows:

(1) Identification of cultural remains

Remains of the buried cultural properties must be identified in order to minimize the impact of the construction work.

Excavation of cultural remains at the Heijo Palace site was conducted by the Nara National Research Institute for Cultural Properties, National Institute for Cultural Heritage (hereinafter NNRI). Items identified by their research are shown (in color) in Fig. 3. The red line is the cloister of the First Imperial Audience Hall Compound.

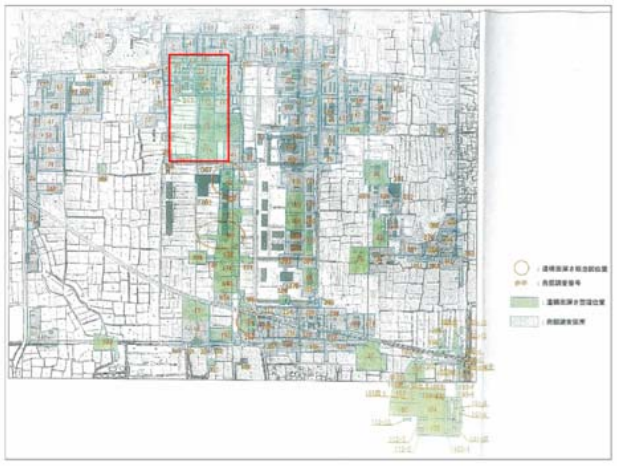

Fig. 3 Condition of identified cultural remains

The data revealed that the remains from the Nara Period are buried at a depth ranging from about 0.2 to 2.4 m from the present ground surface.

Excavation has thus far been conducted at the eastern half of the FIH area, and the western half will remain as is for the future, due to the inability to clearly identify the level of the remains. We sought advice from specialists, estimated that the western area was symmetrical to the eastern area along the central axis and conducted design and construction.

(2) Ground survey

When force is applied from the ground surface, deformation or compressive force reaches the deeper layers

where the cultural property is buried, as shown in Fig. 4.

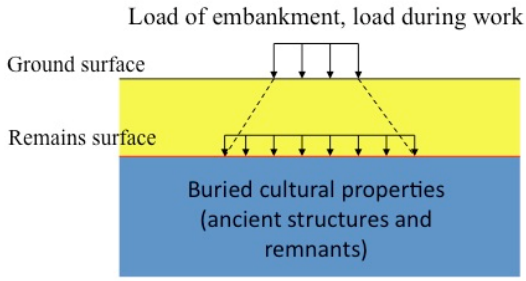

Fig. 4 Schematic illustration of applied load reaching the buried remains

The layer where the cultural remains are buried and the remains themselves may suffer damage depending on the strength of the ground that lies beneath.

Based on a geologic survey conducted in the past, stratigraphic sectional views in the east-west direction and north-south direction of the First Imperial Audience Hall Compound area were prepared (Figs. 5 and 6). As the views indicate:

• A humus layer (Ape layer) exists in the western part of the FIH area, and it is soft ground (overconsolidation of 20 kN/m^2).

• A sandy layer (As layer) exists at the center of the FIH area in the north-south direction, which indicates

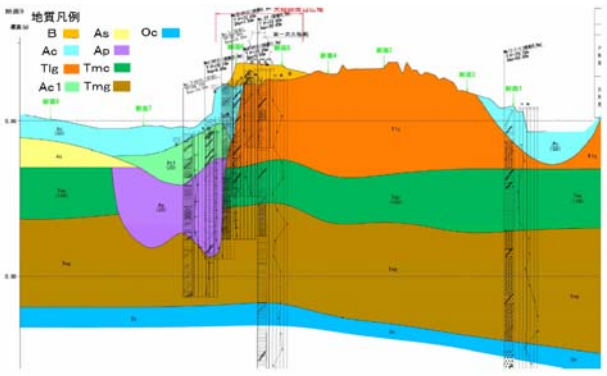

Fig. 5 East-west stratigraphic section

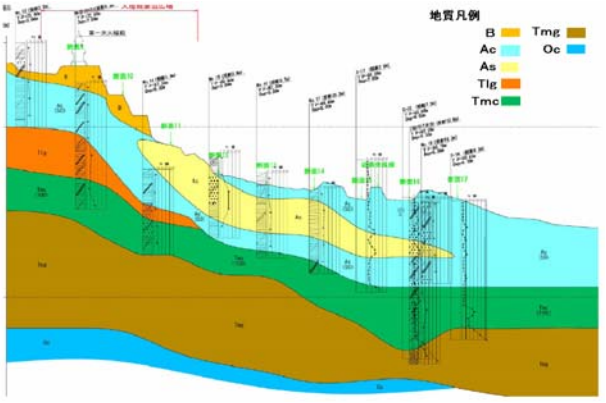

Fig. 6 North-south stratigraphic section

that liquefaction might occur in the event of a major earthquake. As a result, it was found that the Project would need to consider the impact of compaction and its resultant subsidence due to the humus soil layer.

2.3 Purpose of intelligent construction

An essential condition of the work to construct the plaza was to minimize the impact on the buried cultural property. The previous survey and review identified the following items to be taken into consideration:

(1) The plaza should be constructed at a sufficient distance from the remains.

(2) The buried remains should not be harmed by the excavation work (for side ditches and inlets) for the plaza.

(3) Excessive load should not be imposed for soil compaction at the plaza and excessive compaction should not be conducted there.

The engineering method and relevant construction machinery had to be selected to fulfill these goals, and intelligent construction was eventually adopted.

2.4 Selection of construction machinery and construction method

A covering layer of 50 cm from the remains to the ground surface (minimum thickness under the current conditions) was to be maintained to protect the remains. Appropriate trucks and construction machines were then selected based

on the assumed load on the remains. Key points were as follows.

• Since the weight of the transport machinery is a major loading factor on the ground, 4-ton dump trucks were used as the main transport vehicles. However, up to 10-ton dump trucks were allowed only for those locations where structural protection was provided such as by a temporary embankment.

• Vibration rollers were not used for soil compaction since they might affect the deeper soil layers. Road rollers of 12-ton class and tire rollers of 20-ton class were the largest compaction rollers used for the work.

In addition, the technique of intelligent construction was applied to reduce the damage risk.

Engineering methods compatible with intelligent

Table 1 Machines and equipment used for intelligent construction and their purpose of use

Type of work	Construction machinery and system	Purpose of use
Land preparation work Excavation work	Bulldozer, 3D-MC and mmGPS	①
Land preparation work Filled-up ground	Bulldozer and motor grader, 3D-MG and mmGPS, Tire roller, GPS compaction management system	①,③
Stormwater drainage work Construction earthwork	Backhoe, 3D-MG and mmGPS	②
Park road plaza development work Asphalt paving work (roadbed work)	Bulldozer, motor grader, 3D-MC, mmGPS, tire roller, GPS compaction management system	①,③

*"Purpose of use" indicates the itemized part of 2.3.

construction and the relevant machines are shown in Table 1. In addition, lightweight embankment (EPS method) was used to reduce the load on areas of soft ground (Ap layer).

2.5 Execution of intelligent construction and its effects

(1) Overall configuration

The overall configuration of intelligent construction used at the Heijo Palace Site First Imperial Audience Hall Compound Plaza Development Project is shown in Photo 1. Since mmGPS was used, a rotating laser was also installed.

Photo1 Overall configuration of intelligent construction

(2) 3D machine control system

A 3D machine control system using mmGPS was

Photo2 Land development using 3D-MC bulldozer

Photo3 3D-MC controller screen

used for operating the bulldozer and grader to maintain the quality of workmanship.

The resultant advantages are as follows:

1) Efficient execution was achieved although the scale of

land preparation was small.

2) Since there is no need to drive finishing stakes into the ground, there is also no need to file an application with the Cultural Affairs Agency for a change of state, thus greatly reducing the amount of clerical work.

3) The appropriate drainage gradient in the plaza area was provided efficiently and very accurately.

There are, however, several disadvantages:

1) The rotating laser had to be relocated when it was out of the mmGPS application range.

2) The controllers set to the GPS base station and construction machines had to be detached and stored every day to prevent theft, which took considerable time and labor.

3) The equipment for intelligent construction was expensive, almost the same or even more expensive than the construction machinery, and it was necessary to clarify the purpose of use and its effects.

(3) 3D machine guidance system

The 3D machine guidance system was introduced for the Project to enable constant monitoring of the

Photo 7 Excavation using 3D-MG backhoe

relationship between the backhoe and the depth of the remains in order to protect them, as it is necessary to dig deeper than the ordinary excavation level when constructing a drainage ditch.

The surface of the remains at the excavation point was converted to electronic data (coordinate data) based on the execution drawings of the drainage ditch so that the operator could check the condition in real time. Photo 8 shows the controller screen. The depth direction shown on the screen indicates the distance between the front end of the bucket and the surface of the remains.

Due to the system restrictions on the work, the design excavation depth of the drainage ditch could not be shown.

Photo 8 3D-MG controller screen

(4) GPS roller compaction management system

The GPS roller compaction management system was introduced to prevent the effect of excessive compaction on the buried remains and to improve the efficiency of land preparation work.

When the construction machines were selected, vibration rollers that could affect the ground at greater depths were excluded. Note that the construction machines were selected for optimum execution management considering the importance of the buried cultural properties.

Since this system allows operators to see the rolling conditions, as shown in Photo 10, on a real-time basis, shortage or excess of rolling times was prevented.

(5) Summary

The Heijo Palace Site First Imperial Audience Hall Compound Plaza Development was successfully completed without any damage to the buried cultural properties. The use of intelligent construction was effective for protecting

the buried cultural remains.

Photo 9 Execution using tire roller

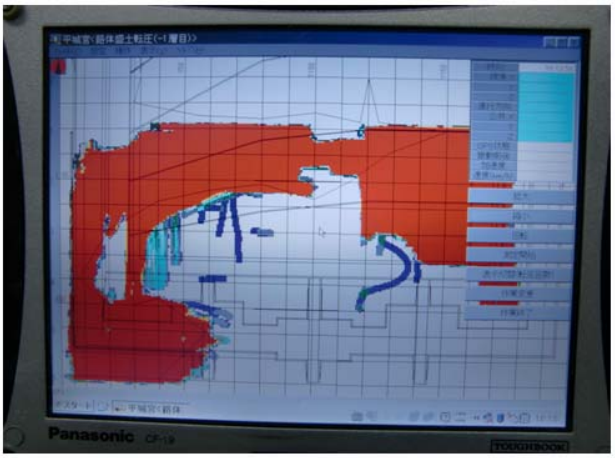

Photo 10 Screen showing roller compaction management system

When it is necessary to both to protect and utilize buried cultural properties, this case shows that quality control method using intelligent construction may be applied to various uses.

For this application to the Project, since intelligent construction provided an accurate status of the work, positive effects were produced including reduction of reworking. Although it is a desk calculation, the estimated effect was a saving of 11 days for the road embankment and paving work.

On the other hand, the use of intelligent construction resulted in 20% higher construction costs compared to ordinary work without intelligent construction due to the special requirements including the limitation on machinery size.

However, considering the social responsibility for protecting cultural properties and the risk involved, the increase in cost is considered acceptable.

The application of intelligent construction at sites that contain buried cultural properties is expected to play a new role in technical proposals for comprehensive evaluation type bid contracts in the future.

4. SUMMARY

Intelligent construction, as a modern construction technique, was successfully used to safely execute projects requiring the protection of buried cultural properties.

In the history of Japanese government, there has always been the question of how to develop social infrastructure for people’s lives while preserving buried cultural properties. We hope that advanced construction technologies such as intelligent construction discussed in this paper, will help protect buried cultural properties nationwide while building social infrastructure.

Acknowledgements

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