DEVELOPMENT OF A GIS-BASED GEOTECHNICAL INFORMATION ENTRY SYSTEM USING THE GEOTECHNICAL INVESTIGATION RESULT FORM AND METADATA STANDARDIZATION

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ABSTRACT: In March 2007, Korea's Ministry of Construction & Transportation (MOCT) established "Guidelines on the Computerization and Use of Geotechnical Investigation Results," which took effect as official instructions. The 2007 Geotechnical Information DB Construction Project is underway as a model project for a stable geotechnical information distribution system based on the MOCT guidelines, accompanied by user education on the geotechnical data distribution system. This study introduces a geotechnical data entry system characterized by the standardization of the geotechnical investigation form, the standardization of metadata for creating the geotechnical data to be distributed, and the creation of borehole space data based on the world geodetic system according to the changes in the national coordinate system, to define a unified DB structure and the items for the geotechnical data entry system and to computerize the field geotechnical investigation results using the MOCT guidelines. In addition, the present operating status of the geotechnical data entry system and entry data processing statistics are introduced through an analysis of the model project, and the problems of the project are analyzed to suggest improvements.

Education on, and the implementation of, the model project for the geotechnical data entry system, which was developed via the standardization of the geotechnical investigation results form and the metadata for institutions showed that most users can use the system easily. There were problems, however, including those related to the complexity of metadata creation, partial errors in moving to the borehole data window, partial recognition errors in the installation program for different computer operating systems, etc. Especially, the individual standard form usage and the specificity of the person who enters the geotechnical information for the Korea National Housing Corporation, among the institutions under MOCT, required partial improvement of the geotechnical data entry system. The problems surfaced from this study will be promptly addressed in the operation and management of the geotechnical data DB center in 2008.

Keywords: Standardization; Geotechnical Investigation Result Form; Metadata; World Geodetic System; Geotechnical data entry system

1. INTRODUCTION

The Geotechnical Data DB Construction Project started as a public labor project of Korea's Ministry of Information and Communication (MIC) in 2000. Korea's Ministry of Construction & Transportation (MOCT) has been promoting the project since 2001. The implementation of the project has been underway as the first usage frame of the National Geographic Data System, based on the construction of the Underground Geographic Data System as the second step of the development of the National Geographic Data System, since 2002 [2] .

As of 2006, the geotechnical data included 60,581 boreholes. The Geotechnical Information DB Construction Project was expected to be completed in 2007. Therefore, MOCT promoted the legislation of the automatic field computerization of geotechnical data instead of the current method that collects the geotechnical investigation results from institutions via visits, for the construction of a permanent geotechnical data DB that would be available even after the project's completion [3].

In March 2007, MOCT established "Guidelines on the Computerization and Use of Geotechnical Investigation Results," which took effect as official instructions (MOCT, 2007). Accordingly, the 2007 Geotechnical Information DB Construction Project is underway as a model project for a stable geotechnical data distribution system based on the MOCT guidelines, accompanied by user education on the geotechnical data distribution system.

The geotechnical data distribution system comprises the following: the geotechnical data entry system for the field entry of geotechnical investigation results, the geotechnical data inspection and registration system for the inspection of registered geotechnical data and the registration to the distribution DB, and the web distribution system for the provision of the constructed geotechnical data to users. For the geotechnical data distribution system, the geotechnical data entry system was developed via form standardization due to the different geotechnical investigation results forms of the institutions under MOCT.

1.1 Research Trends

Because of the many natural disasters in Korea including earthquakes and tidal waves, the management of accurate national geotechnical data is becoming more important. The project concerning geotechnical data started as a public labor project in 1999, and is now managed by MOCT.

Research trends on underground data management, including of the geotechnical data inside and outside Korea, had to be reviewed in this study. First, in keeping with the domestic research trend, MOCT collected geotechnical data from construction projects that were initially under the control of the Construction and Management Administration, and performed the incorporated management of about 10,000 boreholes operated by the Korea Land Corporation in 2002 [8]. According to the “Guidelines on the Computerization and Use of Geotechnical Investigation Results” of MOCT in 2007, the geotechnical investigation results from the construction sites of the Construction and Management Administration and four other state corporations, namely, the Korea Expressway Corporation, Korea Land Corporation, Korea Water Resources Corporation, and Korea National Housing Corporation, were obligatorily entered in the site for continuous geotechnical information DB construction [7]. Besides, local autonomous entities have also promoted the Geotechnical Information DB Construction Project as part of their construction policy and management. Seoul started its Geotechnical Information DB Construction Project at the same time as MOCT, and already has about 18,000 borehole geotechnical data [10]. Daegu also constructed a geotechnical boring DB, which has about 1,000 borehole data for space data integration management and analysis, as part of its 2004 Space Data Integration System, which is not constructed nor used as of now. [1].

Different institutions construct and manage DBs on in-depth geological data, mine data, well data, and geotechnical data. The Korea Institute of Geoscience and Mineral Resources constructs and manages DBs for geological data; the Korea Resources Corporation, for mine data; and the Korea Rural Community & Agriculture Corporation and the Korea Water Resources Corporation, for well data[9]. The results of an analysis of researches in Korea show that geotechnical and geological DBs are constructed and managed in diverse sectors, without sufficient application examples.

The examination of research trends outside Korea showed that many countries had recognized the importance of geotechnical information DBs and proceeded to the application stage as well as to the DB construction stage. First, the US government developed and distributed the GeoLibrary system for public easy access to GIS-based geotechnical research, mapping and analysis, as a nationwide measure to promote the application of geotechnical data in various sectors. Japan also employed geotechnical and geological data from each of its local autonomous entities to prepare a simplified tool for geotechnical diagnosis in residential lands and a 3-D geological model construction geological map, which facilitated the active use of geotechnical data. In Australia, the development of a geotechnical analysis support system, 3-D analysis, and data sharing based on distributed computing technology was actively performed for the advanced application of geotechnical data[9]. The analysis of overseas research trends in the U.S., Japan, and Australia showed that many countries construct geotechnical information DBs accompanied by diversified servers for various applications.

Accordingly, it was found that a continuous DB construction and service model study is required in Korea to promote the active use of geotechnical data in various sectors, including the construction sector.

1.2. Purpose of this Study

This study introduces the geotechnical data entry system developed for the computerization of geotechnical investigation results from constructions sites, according to the MOCT guidelines, and surfaces challenges that must be addressed.

That is, a geotechnical data entry system is introduced that focuses on the standardization of geotechnical investigation forms and distributed metadata by MOCT institutions, and on the application of the world geodetic system, into which data are now being converted nationwide.

By analyzing the problems encountered in the model project, improvements to the geotechnical data entry system are suggested.

2. PRELIMINARY DESIGN OF THE GEOTECHNICAL DATA ENTRY SYSTEM

2.1. Standardization of the Geotechnical Investigation Results and Entry Form

This study standardized the geotechnical investigation form because different geotechnical investigation forms had caused much trouble in sharing and reusing the geotechnical data in the system [6]. First, the geotechnical investigation standards were analyzed to derive basic items such as geological reconnaissance, boring survey and geotechnical property test, and selective items such as physical survey and logging. Based on the derived items, a standard geotechnical investigation form for general information, survey information, field tests, and indoor tests was drafted for the design of the DB schema of the geotechnical data entry system. Table 1 shows the geotechnical investigation standards by institution and structure.

As seen in Table 1, most institutions use the geotechnical property test in their major work items and selectively use it for physical surveys and for logging. The District Construction and Management Administrations and the Korea Expressway Corporation, which is mostly involved in linear construction, have various survey items and higher-level tests.

Table 1. Analysis of geotechnical investigation standards by institution and structure

Classification	Cut-ting	Filling		Bridge	Tunnel	Open Exca-vation Tunnel (Sheet- ing)	Mate- rial Source (Bur- row Pit for Aggre-gate)	Archi-tecture	Remarks
		Ge-ne-ral Soil	Soft Soil						
District Construction and Management Administrati-on	②③	⑥⑦		③	②③		③		Suggest ①②⑦⑧⑫ⓐⓑⓒⓓⓔⓕ in package
Korea Expressway Corporation	②③⑥⑦⑧⑨ⓓⓔ	③⑥⑦⑧⑨	③④⑥⑦⑧⑨ⓐⓑ	③⑧⑨ⓐⓑ	②③⑧⑨ⓓⓔⓕ		③⑦ⓐⓑⓕ		Conduct ① on the whole Conduct ⓐⓑⓒⓓⓔ for the boring specimen
Korea Land Corporation	②③⑦⑧	③⑥⑧⑨	③⑥⑧⑨⑩				ⓕ	③⑦⑧⑪	Conduct ① on the whole Conduct ② selectively Conduct ⓐⓑⓒⓓⓔ for the specimen
Korea National Housing Corporation								①③④⑤⑦ⓐⓑⓒⓓ	Suggest items on the building base on the whole, regardless of filling or cutting
Korea Infrastructure Safety and Technology Corporation					①②③④⑤⑥⑦⑧ⓐⓑⓒⓓⓔ				
Korea Rail Network Authority					①②③④⑤⑦⑧⑨⑪ⓐⓑⓓⓔ				Including the environmental survey
Seoul									Describe ①②③④⑤⑥⑦⑧⑪⑫ⓐⓑⓓⓔ, regardless of the structure type
KT					①③④⑤⑧⑫	①③④⑤⑧⑫			

① Geological reconnaissance ② Physical survey and logging ③ Boring ④ Sampling ⑤ Groundwater level survey ⑥ Hand auger boring ⑦ Borehole survey ⑧ Standard penetration test ⑨ Cone penetration test ⑩ Vane test ⑪ Load test ⑫ Hydraulic test ⑬ Field density test ⑭ Field shear test ⓐ Soil property test ⓑ Soil mechanics test ⓒ Bearing capacity test ⓓ Rock property test ⓔ Rock mechanics test ⓕ Aggregate test ⓖ Materials sources survey

This is thought to be because road construction involves almost all work items such as cutting, filling, bridges, tunnels, etc.

The standard form developed in this study was prepared after considering the characteristics of the various concerned institutions and work items, based on the road construction work form that includes various work items. The boring survey and the geotechnical property test, which are frequently conducted, were set as the references of the standard form. Corrections of the concerned institutions were reflected on the standard form. The results were re-determined in conformity with

2.2 Standardization of the Distributed Metadata

The geotechnical information DB is constructed by computerizing the geotechnical investigation results and offered to users via the distribution system. Therefore, to provide the geotechnical data via the distribution system, the metadata for the distribution of the geotechnical data must be created, and must be standardized and developed according to the Korea Telecommunications Technology Association Standards (TTA.KO-10.0139).

The purpose of the geographical data distribution metadata standards is to provide detailed data, including on the contents, quality, use, etc., of the geo-spatial data in advance, so as to facilitate access to information that will satisfy user demand and simplify the process of transmitting geographical information (Telecommunications Technology Association, 2002).

2.2.1 Structure and Range of the Metadata Standards

The elements of the GIS metadata that FDGC, for instance, suggested are within a broad range. Therefore, most GIS systems apply selected major elements that conform to their purpose and characteristics. To identify data sets, core metadata elements were rearranged in this study. The general metadata standards for distribution provide the ID, range, quality, reference system, distribution, etc. of digital geographical data. Information is represented with Mandatory (M), Conditional (C), and Optional (O) limits for the metadata section, entity, and element. In addition, the minimum metadata set for the service for the entire range of metadata applications and a method of extending the metadata were defined. Mandatory (M) refers to an element that must be described; Conditional (C), to a case wherein at least one element satisfies the obligation, and Optional (O), to a case wherein the data may or may not be described as a subject element.

2.2.2. Geotechnical Information Metadata Items

The metadata for geotechnical data, as defined in this study, are classified into individual set information, identification information, quality information, reference system information, distribution information, range information, and reference data and person-in-charge information, as shown in Table 2. The individual set data comprise the master metadata individual set information, the contact information, and the coordinate information. The identification information table includes the master identification information, spatial information contacts, geographical boundaries, geographical descriptions, ranges, sources, and data structure information. The quality information has information on the subject, quality deductions, conformance results, and quantitative results on the data quality. The reference system information has the coordinate information for the space data of the geotechnical information, and the distributed eXtensible Markup Language (XML)-based document standards for ease of use with computers and the Internet and for application to the geotechnical information entry system.
information has information on the format, transfer location, and acquisition method for data distribution.

Table 2. Items used in writing geotechnical data metadata

No	Classification	Details
1	Individual set information	Information on the individual set that forms the metadata
2	Identification information	Information for data identification
3	Data quality information	Data quality assessment information
4	Reference system information	Information on the data reference system
5	Distribution information	Information on the geotechnical information distribution and acquisition method
6	Range information	Information on the range of the data set
7	Reference data and person-in-charge information	Information on the reference data and the person-in-charge

In this study, a geotechnical information metadata entry wizard was developed, as shown in Figure 1, for efficient entry of the defined metadata and to support the user in filling out the metadata items without error.

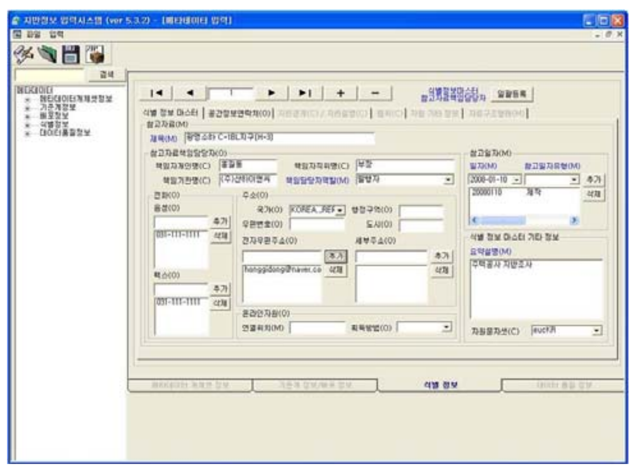

Figure 1. Geotechnical information data management system window

2.2.3. Definition of Space Information Based on the World Geodetic System

In December 2001, the National Geographic Information Institute and MOCT revised Article 5 (Survey Standards) of the Land Survey Act and Article 2-5 (World Geodetic System, etc.) of the Enforcement Regulations for the same Act, to change the survey standards from the local geodetic system to the world geodetic system.

The digital map of the DB portal that manages the geotechnical information has a 1:5,000 TM plane rectangular coordinate system that incorporates the whole land with the central datum that uses the Bessel ellipsoid as a reference. Therefore, the coordinate conversion from the Bessel ellipsoid to the GRS80 ellipsoid must be performed to convert the geotechnical information DB from the current local geodetic system to the world geodetic system. The scale employed for the current geotechnical data digital map is 1:5,000, so that it can be converted merely by using the conversion program provided by the National Geographic Information Institute (GDKTrans) without correcting the distortion. Table 3 shows the converted value from the local geodetic system to the world geodetic system, which was announced by the National Geographic Information Institute(NGII).

Table 3. National coordinate conversion coefficient announced by the NGII

Classification	**Parallel Travel (m)**		
Type	△x	△y	△z
Conversion Coefficient	-145.907	505.034	685.756
Classification	**Rotation (”)**		
Type	Rx	Ry	Rz
Conversion Coefficient	-1.162	2.347	1.592

(wherein the scale change (λ) = 6.342 ppm is applied

The conversion to the world geodetic system produced a deviation of about 365 m to the southeast, which varies somewhat by region.

Initially, the old coordinate system was to be used only until December 31, 2006, but it will be used until December 31, 2009 because a lot of GIS data have not yet been converted to the new coordinate system [5].

The geotechnical data entry system developed in this study is equipped with a module that supports the creation of borehole space information for the entry of the data surveyed using the old coordinate system and the new coordinate system that conforms to the nationally adopted world geodetic system. Figure 2 shows the coordinate system that supports the creation of borehole location data provided by the geotechnical data entry system.

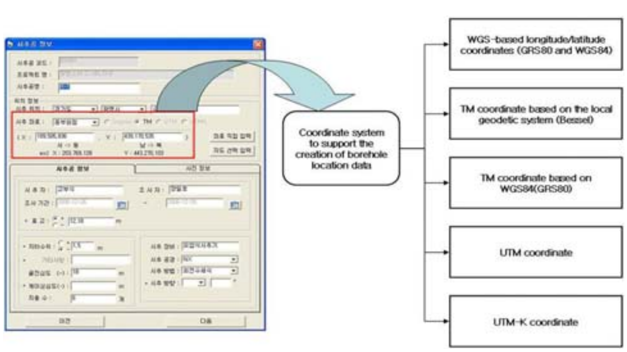

Figure 2. Coordinate system supporting the creation of borehole location data

2.3. UML Design of the Geotechnical Data Entry System

In this study, the Unified Modeling Language (UML) was applied to the design of the geotechnical data entry system, as shown in Figure 3. UML employs usecase, which are sequence or class diagrams that express intermediate products during the software development [4].

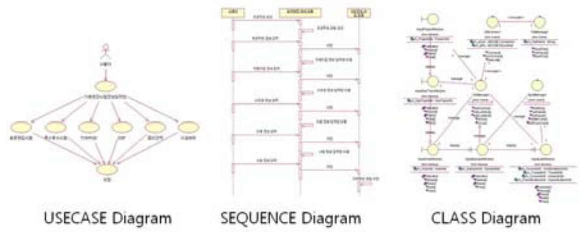

Figure 3. UML design of the geotechnical information entry system

With UML, the request (usecase diagram), operating process (sequence diagram) and objects/detailed functions (class diagram) of the geotechnical data entry system were designed. The geotechnical data entry system consists of the field entry system for entering the geotechnical investigation results and the geotechnical data management system for creating and managing the metadata for distribution. As shown in Figure 4, project information, geographical/geological information, borehole space information, basic physical property information, field test results, indoor test results, etc. are entered in order in the geotechnical data field entry system. The program is downloaded to the user’s computer in the client/server environment, and the entered information is automatically inputted in the geotechnical information DB (using Microsoft Access).

3. SAMPLE GEOTECHNICAL DATA ENTRY SYSTEM

3.1. Application Sector and Subject

The 2007 Geotechnical Information DB Construction Project is underway as a model project for the use of a geotechnical information distribution system through user education, according to MOCT guidelines. The projects were completed in 2007, with five Construction and Management Administrations (Seoul, Busan, Daejeon, Iksan, and Wonju) under MOCT and four state enterprises (Korea Expressway Corporation, Korea Land Corporation, Korea National Housing Corporation, and Korea Water Resources Corporation) as subjects. In addition, the geotechnical investigation results are being computerized using the geotechnical data entry system for roads, complexes, houses, water resources, etc. Figure 5 shows the workflow for the entire distribution system, from the geotechnical data entry to their inspection and distribution, according to MOCT’s institutionalization of the computerization of geotechnical investigation results.

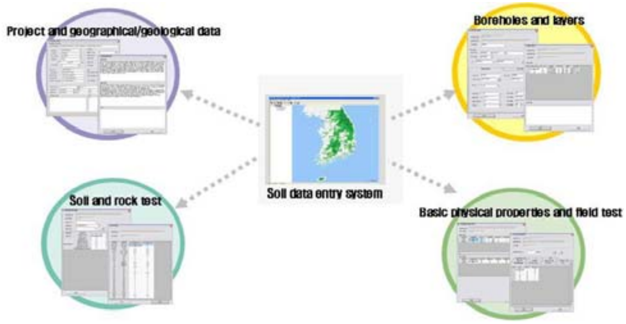

Figure 4. Functions of the geotechnical data field entry system by module

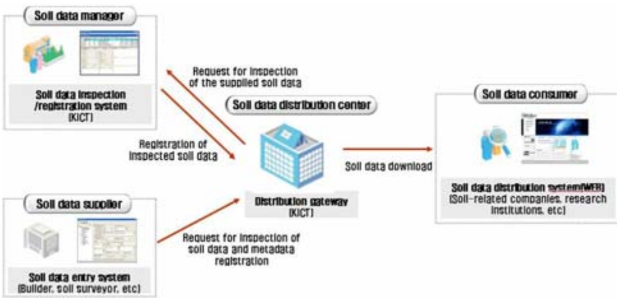

Figure 5. Workflow of the geotechnical information distribution system

When the field entry and registration through the web distribution system are completed, the DB Center of the Korea Institute of Construction Technology inspects the data and uploads them to the Internet. Users can then download and use the geotechnical information through the web distribution system. The distributed data are provided in XML-based text documents to help the users use the geotechnical information.

3.2. Education of Users of the Geotechnical Data Entry System

As for the user training on the geotechnical data entry system, on-site training has been completed for five District Construction and Management Administrations under MOCT and four state enterprises, and on-demand training is being conducted. The subjects of the training are two personnel per construction project (the persons-in-charge from the client company and the contractor). As for the District Construction and Management Administrations, two additional personnel, one each from the Structure Section and the Maintenance Section, of the National Road Maintenance Office are included.

The training was conducted from June 2007 to August 2007, and included GIS basics, an overview of the Geotechnical Information DB Construction Project, the change in the coordinate system, the standardization of the geotechnical investigation form, and introductions to the geotechnical data entry system and the geotechnical information web system. Especially for the smooth progress of the training, four state enterprises were trained separately according to three areas: the central area, the Gyeongsang area, and the Jeolla area. About 95% of the subjects identified from the preliminary discussion attended the training.

With the training completed, the field geotechnical investigation results registered in the geotechnical information DB server are now being inspected. Photograph 1 shows the on-site geotechnical information DB user training in 2007.

Photograph 1. 2007 Geotechnical Information DB user training

During the training, it was found that although the geotechnical investigation results form was already standardized under the Geotechnical Information DB Construction Project, the Korea National Housing Corporation is still using its own form that slightly differs from the standard MOCT form, which complements the geotechnical data entry system. In addition, the person who enters the geotechnical investigation results is currently the constructor, but it seems that this must be changed to the "constructor (or the geotechnical Investigator)" in the Guidelines because the geotechnical Investigator performs the entire work for the Korea National Housing Corporation. These complements and improvements to the Guidelines and the system, which were derived from the training, will be reflected in the "Guidelines on the Computerization and Use of the Geotechnical Investigation Results" in the 2008 project after meetings with experts.

3.3. Trial Application and Analysis of Results

After the on-site training, the construction teams of the institutions under MOCT are continuously uploading the computerized geotechnical investigation results to the geotechnical information DB of the Korea Institute of Construction Technology for inspection and registration. To date, 701 boreholes for 31 construction projects have been entered for inspection. Table 4 shows the geotechnical data inspection process by institution and project.

Following the geotechnical data inspection, the re-inspection ratio was 48%, and 52% of the geotechnical data was entered. The re-inspected items were trivial errors such as the omission of some entry items. Thus, it seems that the geotechnical data entry system could be disseminated and stabilized through continuous user training and publicity.

The Korea National Housing Corporation uploaded the geotechnical investigation results of 21 projects--the most--whereas the Seoul and Daejeon District Construction and Management Administrations and the Korea Expressway Corporation did not upload data for geotechnical investigation results inspection. This is thought to be because most projects are completed at the end of the year, so that much of the geotechnical investigation results data are expected to be uploaded at around October. Figure 6 shows the geotechnical data inspection results graph by institution.

Table 4. Geotechnical data inspection process by institution and project

Institution	August	September	Inspection Status
Seoul	0	0	N/A
Busan	2	2	Complete: 2; Under inspection: 2
Daejeon	0	0	N/A
Iksan	1	0	Complete: 1
Wonju	0	0	N/A
Korea Land Corporation	4	0	Complete: 3; Under inspection: 1
Korea National Housing Corporation	1	20	Complete: 11; Under inspection: 10
Korea Expressway Corporation	0	0	N/A
Korea Water Resources Corporation	0	1	Under inspection: 1
Total	8	23	Complete: 17; Under inspection: 14

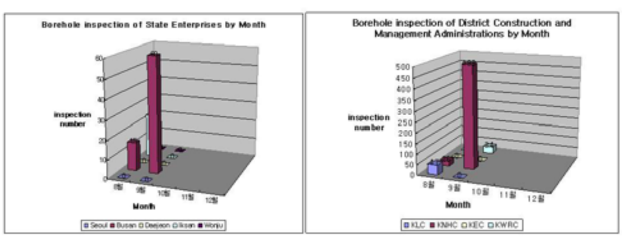

Figure 6. Analysis results graph of Geotechnical data inspection monthly

As shown in Figure 6, the Korea National Housing Corporation constructed geotechnical data on about 520 boreholes after the model project, followed by the Korea Land Corporation, with about 50 boreholes. It is expected that the other institutions will enter geotechnical data continuously by the end of the year, and that more than 5,800 boreholes (MOCT's 2007 target quantity for geotechnical data construction) of the geotechnical data will be constructed in 2007.

Most of the geotechnical data constructed until 2006 involved national roads because the geotechnical data were constructed by the District Construction and Management Administrations of MOCT and focused on the Korea Expressway Corporation and the Korea Land Corporation. The existing geotechnical data, which are focused on national roads, are not so useful, but according to the 2007 MOCT guidelines, the District Construction and Management Administrations and four state enterprises will continuously construct their geotechnical data and the geotechnical data DB for the entire country. In addition, if enough DBs are constructed nationwide, they will be more useful for all construction work items.

Along with conducting the training on and executing the model project on the geotechnical data entry system for the implementation of the MOCT Guidelines, the Geotechnical Information DB Center, which until 2006 managed only the data from the institutions under MOCT, has also been managing data from local autonomous entities since 2007 under the 2007 Geotechnical Information DB Construction Project. The geotechnical data integration is being discussed with Seoul, Busan, Daegu, and Suwon. Especially for the geotechnical data of Suwon, 535 boreholes of boring data for 57 projects according to the first Geotechnical Information DB Construction Project in June 2007 had been completed and are now being offered through MOCT's geotechnical information DB portal and the web distribution system. The second project is underway. MOCT's geotechnical information DB portal (http://www.geoinfo.or.kr) was connected in September, when the geotechnical data system of Seoul (http://soil.seoul.go.kr) was disclosed.

4. CONCLUSIONS

The following conclusions are made from this study on the development of a GIS-based geotechnical information entry system through the standardization of the geotechnical investigation results form and the metadata.

First, the GIS-based standard geotechnical data entry system could be realized by standardizing the geotechnical investigation results form and the metadata for distribution, as determined in the discussion of the District Construction and Management Administrations under MOCT and four state enterprises.

Second, the space data creation module for the application of the world geodetic coordinate system promoted by Korea and for the conversion of the existing borehole locations into the world geodetic coordinate system was developed.

Third, geotechnical information DB user training was conducted for five District Construction and Management Administrations and four state enterprises, and 95% of the previously determined subjects participated in the training, which made it a sufficient preliminary measure. In addition, the entry and inspection of data for 31 projects and 701 boreholes have either been completed or are ongoing. Following the geotechnical data inspection, the re-inspection ratio was 48%, and 52% of the geotechnical data was entered. The re-inspected items were trivial errors such as the omission of some entry items. Therefore, it seems that the geotechnical data entry system could be disseminated and stabilized through continuous user training and publicity.

The institutions under MOCT are currently implementing the Geotechnical Information DB Construction Project, but after the current continuous discussion on the geotechnical information DB integration, MOCT's Integrated Geotechnical Information DB Center and local autonomous entities will continue the implementation.

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