NEW TUNNELING INFORMATION SYSTEM AND ITS APPLICATION TO ROAD TUNNEL CONSTRUCTION SITES IN KOREA

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Abstract: Ground and rock mass considered in tunnelling have characteristics such as uncertainty, heterogeneity and structural complexity because they have been formed undergoing various geological events for a long period. So, it is difficult for engineers to predict behaviors of rock mass in tunneling. In the paper the authors describe the development of an integrated expert system prototype for site investigation, design and construction in tunnelling and introduce the case applying this system to the tunnel construction site under construction. Geostructure Research Group in Korea Institute of Construction Technology (KICT) has developed the system during the past 4 years. The system mainly consists of several modules which is related to the design, construction and management of tunnelling. The test site, Neung-dong tunnel is located in Ulsan, Korea. The geology map shows it may confront big fault zone whose width is over kilometres. With the networking system of ITIS, various information of face mapping, monitoring and other construction task can be transmitted into the database and GIS Server at real time. And necessary analyses can be carried out with the modules equipped in the system.

Keywords: tunnel, database, GIS, real time, artificial neural network, virtual reality.

1. INTRODUCTION

In general, experiences play the most important role in construction of geotechnical engineering structures such as a tunnel. The reason for this is due to the difficulty of gathering sufficient information on the geology and evaluating the true mechanical behavior of the ground at the design stage. And geological information is generally difficult to quantify because of imprecise and incomplete data observation. With insufficient information on the geology and the mechanical behavior of the ground the tunnel design is carried out.

The concept of 3-D visualization system certainly gives a new aspect in the field of geotechnical engineering. The analysis and interpretation with attention to geotechnical or geological data using 3-D visualization techniques are valid to understand geotechnical site characteristics. Furthermore, the adequate analysis prevents construction delay and additional cost and leads to minimize geological and geotechnical uncertainties.

As 3-D visualization system has become popular in recent years, the authors have started to investigate how to systemize the experiences and decision making procedures of experts in tunnel design and construction by using the 3-D visualization technique, artificial intelligence (AI) and database (D/B) system since 1999. A national research laboratory (NRL) was established for developing the Intelligent Tunneling Information System (ITIS) in September 1999. As a result of 4 years studies, the prototype system consisting of several modules was developed. The modules are (1) visualization module for ground data and structure, (2) analysis module for stability of tunnel, (3) field data acquisition system (4) selection module for tunnel reinforcement, (5) prediction module for face failure, (6) tunnel monitoring system and (7) Virtual Reality (VR) for visualization of tunnel construction. In the paper, the authors introduce the overview of ITIS such as the features and the functionality for analysis and interpretation. Also, the application of some modules on the tunnel site under construction in Korea is introduced.

2. ITIS System Outline

Geotechnical site investigation, tunnel design and construction data are generally existed in forms of manually completed documents, project reports, regional geotechnical maps and geotechnical relational database, etc. And the analysis of these data that located against some form of map or plan is generally two dimensions. ITIS is an integrated D/B management, analysis and visualization system for geotechnical projects especially in tunneling. It provides the environment that makes much easier to create 3-D subsurface model and analysis results and creates presentation-quality.

In developing ITIS the important considerations are easy-operating environment and PC-Windows-based for civil engineers who have antiquated computing capabilities. Using the graphical user interface, the user can operate the system with the mouse and the keyboard. The system consists of input, output, and analysis/interpretation modules. There are a lot of

input data available such as basic geological information acquired from borehole, field investigation and geophysical exploration, in situ test, laboratory test, pre-investigated reports and tunnel initialization information, including start and endpoints. These data are managed and analyzed in a lump to make a 3-D model and several types of analysis with adapting mathematical and scientific algorithms.
Within the system it is possible to zoom, move, rotate, cut, select a gradient and custom coloring, and copy/paste directly to other Windows compatible software. The user can take cross sections in all directions and create subsurface profiles in the cross sections. All of cross sections created are easily compared with each other.
Using the report functionality, the user can get most of the requested information. The extensive pre-prepared report formats are available. Furthermore, the query options can be used to generate lists of data that exist within the database. These can be exported as a pre-prepared files.

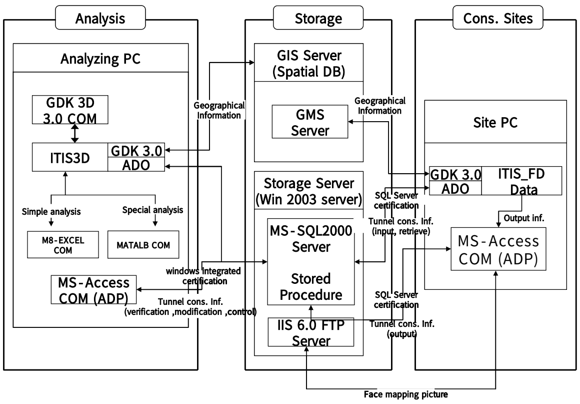

Figure 1. ITIS system outline


Figure 2. ITIS graphical user interface with 3-D windows

3. Modules of ITIS

Visualization module for ground data and structure
The module allows engineers and scientists to input, edit and manage data, and create 3-D models easily. Once logged on to the system, the user meets the Graphical User Interface (GUI). The GUI comprises two units. One enables the user to use all the functions such as file management, digital map editing, data input and analysis, drawing, setting of options, and help. The other is used for creating 2-D and 3-D models with selecting projects. It is possible to zoom, measure scaled distances, drag, select layers, and copy/paste directly to other compatible programs. This module treats most of the data observed and measured in site investigation.
- Three-dimensional geomorphologic data (x, y coordinates and elevation)
- Borehole location and depths of samples and stratigraphic samples taken in borings
- Physical property and other attribute data measured at outcrops
- In Situ and laboratory test results
- Tunnel initialization information, including start and endpoints
The user manages systematically all the data that the user wants to include in the project by using Object-oriented database system (OODB).

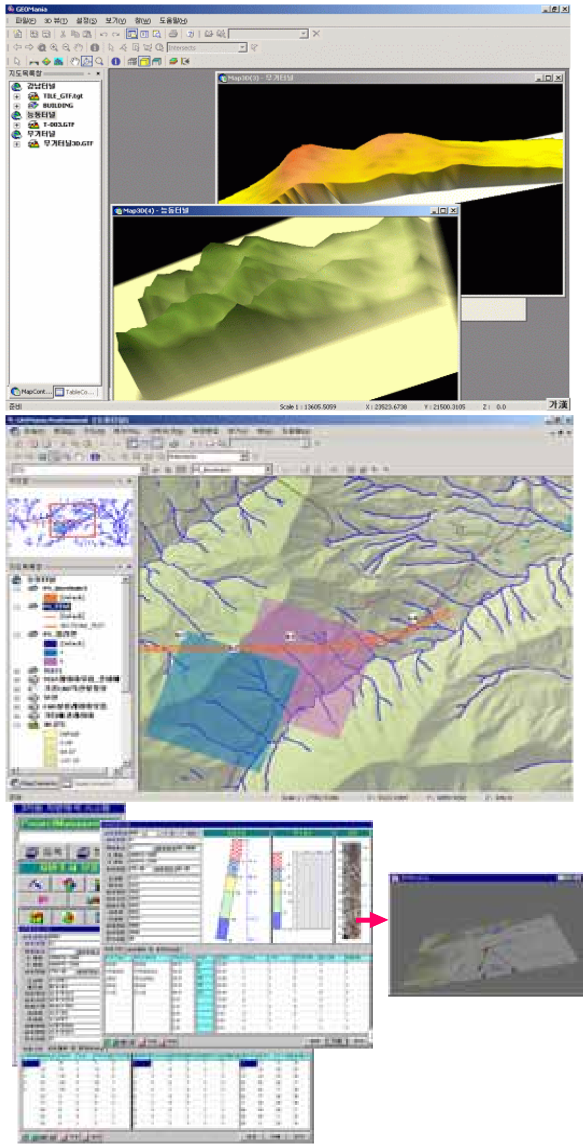

Figure 3. 3D model of Neung-dong tunnel in Korea

3.1 Tunnel Face Information

One of the important parameters influencing the stability of tunnel construction is the information of tunnel face acquired from the excavation steps. The ITIS system can accumulate the database on information of tunnel face mapping during tunnel construction and visualize it 3-dimensionally for the purpose of predicting the state of ground and the geological structure ahead of excavation. Users can access the accumulated database easily and compare the information with the current state of tunnel face. Tunnel face mapping database is mainly composed of two different GUI according to the geological state of tunnel. In the case of soil ground, the fields in the database are filled with ground condition and reinforcement rather than discontinuities and classification of ground. But in the case of rock mass, various items related with rock mass characteristics are very important factors. Figure. 2 shows the sample data of tunnel face mapping database in Neung-dong tunnel.

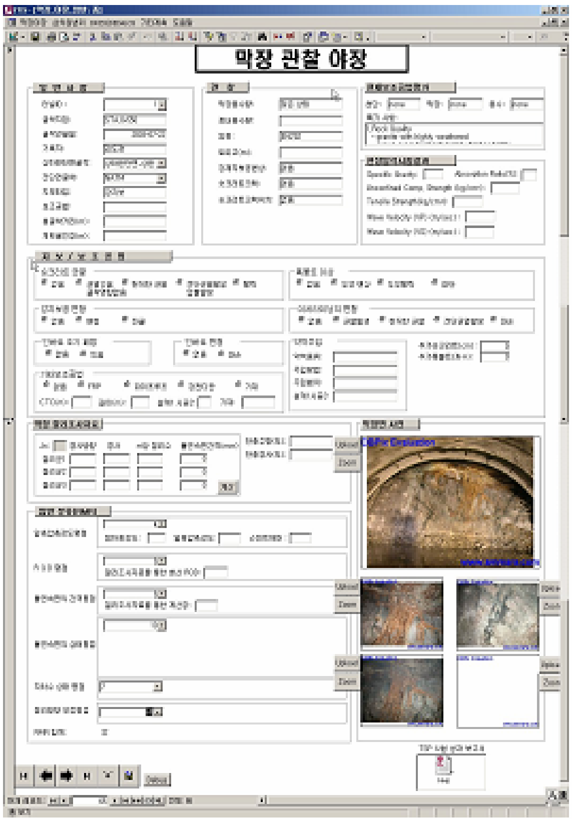

Figure. 4 tunnel face maaping example of Neung-dong tunnel in Korea

3.2 Management of Monitoring

During tunnel excavation a systematic monitoring is important for the determination of support type and quantity, as well as for controlling the tunnel stability. Geodetic methods of absolute displacement monitoring allow determining the spatial displacement vector of each measured point. During the tunnel construction, daily general monitoring and special monitoring are carried out at the station of tunnel face. And after the construction is finished, monitoring for maintain and management of tunnel is planned to be performed. Special monitoring items are axial force of rock bolt, shotcrete stress, ground displacement and 3-dimensional displacement. Each item has its own database table and all items are connected with one another throught the key field, face station. Figure 5 shows windows of database system for monitoring.

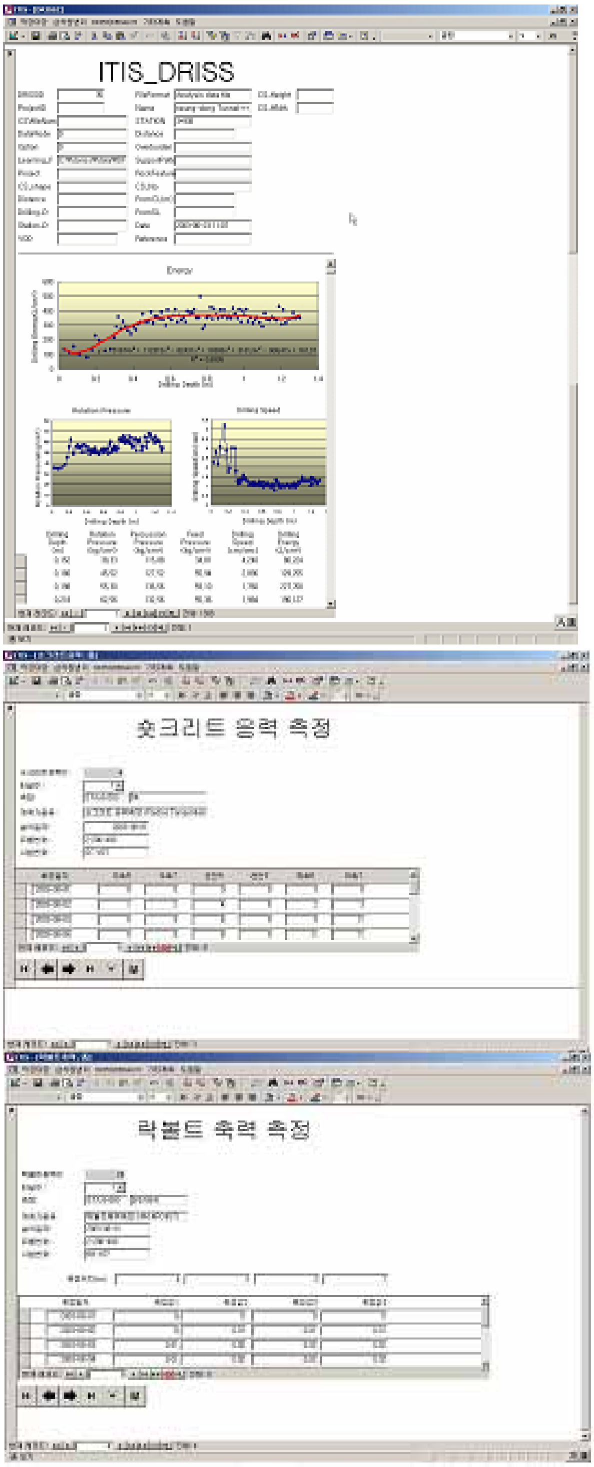

Figure 5. Database system for monitoring

3.3 VR for visualization of tunnel construction

Technology is providing engineers and geologist with new and interactive ways to model the design and construction of tunnel. The virtual environment, in which the visualization of the design and construction progress is effected, shows to be ideal for simulating geological features, the predicted results for ground surface settlement and face failure. The system prototype has been tested on the tunnel construction site. Figure 6 shows examples of the prototype system's outputs. The recent VR techniques are extended to connecting with GIS D/B. It will be more powerful tool that gives rise to many civil engineering fields including tunnel engineering to adopt this technique as computer hardware industry grows rapidly.

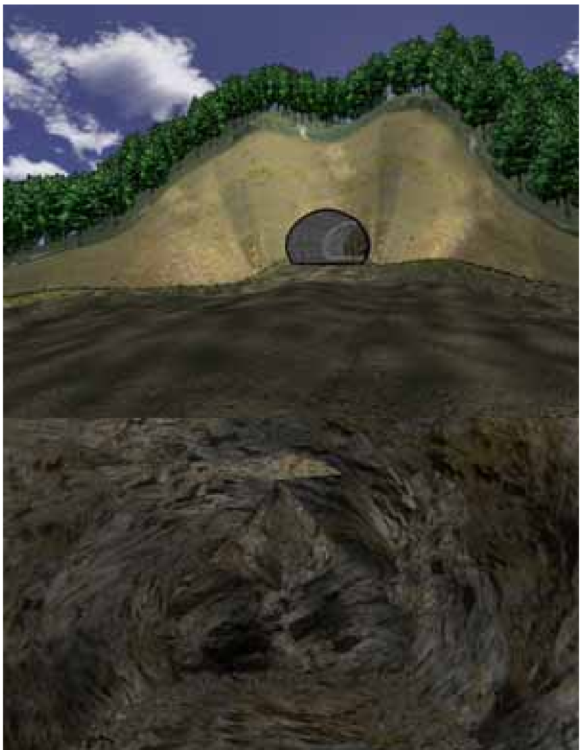

Figure 6. VR screen shots of the portal in tunnel and wedge failure.

4. CONCLUSIONS

The authors have developed Intelligent Tunneling Infor-mation System (called ITIS) that is an integrated expert system including visualization, evaluation and prediction technology of tunnel survey, design, construction and reinforcement system based on D/B, Artificial Intelligence, 3-D visualization and Virtual Reality technologies. And the system is applied to the tunnel site under construction, which will be benefit for engineers who do not have sufficient knowledge or experience in tunnel construction.

The system will be extended continuously with several additional modules as a National Research Laboratory (NRL) Project in Korea.

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