DIGITAL FIELD SYSTEMS FOR SMART SITE INVESTIGATION

QuocPhi Nguyen[1], KimLong Nguyen[1], Phuong Nguyen[1], TruongThanh Phi[2]

[1] Department of Environmental Sciences, Hanoi University of Mining and Geology, Hanoi, Vietnam
[2] Department of Geotechnical and Environmental Engineering, Paichai University, Daejeon, Korea
Email: nguyenquocphi@gmail.com

ABSTRACT

Successful stabilization of roadway slopes in mountainous area requires an in-depth understanding of geological conditions as landslides and slope stabilities are the main factor causing damage and imposing safety hazard to the traveling public. Unforeseen geological conditions of a slope or a construction site can cause additional costs of excavation several times the original estimates. Most of the time and money spent during the different phases of investigations involve the collection and interpretation of structural data. A detailed investigation program and a qualified geological interpretation and geotechnical modeling are necessary. Even though, there are misconceptions between site geologists and engineers in interpreting investigated data no matter how much time and money are spent if they did not study the ground together. Fast developing adjacent fields, such as computer and optical sciences, allow us to develop new survey methodologies and interpretation techniques. To reduce the costs of site investigation, this paper proposes a smart site investigation framework using digital survey techniques that would:

- Improve the communication between site geologists and engineers by creating a benchmark for data collection that can justify by reference to the reality in the ground.

- Develop a more reliable method to quantify the properties of the ground and represent results in appropriate forms.

The primary objective of proposed framework is to design and implement information technology-based systems for geologic mapping and geohazard management where relevant information will be processed and communicated effectively. The field systems involve of:

- A handheld system to collect site information and rock mass quality.

- A close-range photogrammetry system to perform fracture mapping on rock surfaces.

- A fracture projection system to construct 3D rock mass models and analyse potential unstable areas.

These systems speed up the process of data collection that could improve the quality of interpretations by presenting field data in their nature contexts for both uses of geologists and engineers. It could result in the optimization of slope stabilization strategy and of more cost-effective for support design.

***Keywords**: site investigation, geological field data collection, IT-based systems.*

1. INTRODUCTION

Collecting accurate field data plays a key role in the success of any engineering project. Field data collection involves the earlier interpretations and further judgment of more detailed natures, such as rock/soil characteristics, fracture characteristics, failure activities and the possible causes can only be described from detailed field surveys.

Traditionally, field survey is carried out as observations using topographic maps or aerial photos. Observations are made at an outcrop and recorded on the map. Descriptions are recorded on field notebooks or spread sheets.

Technological advances have expanded the manual data acquisition to automated digital process in recent years. The main driving force behind this revolution is the advance of computer technology. The effectiveness of the digital data collection is in the efficiency and precision of data acquisition. Enormous amount of time have been saved from digital data and map processing, as well as the publication map working process. One other benefit from the digital process is the ability to convert the field data into Geographic Information System (GIS) format which will provide a spatial context and the ability of using data instantaneously.

The site geologist, who is in charge of examining rock mass characteristics, will collect data at outcrops or subsurface boreholes. The rock type, material weathering grade, joint data, other significant geological features which may affect the stability of the rock mass (e.g. bedding, fabric, clay infillings, weak zones, faults etc), and seepage locations and flow rates should be noted. Attention is also paid to ensuring focus on persistent fractures and major weak zones. Depending on the project type, material and mass descriptions of rock exposures may need to be of sufficient detail for further characterisation using rock mass classifications and discontinuity shear strength models.

Although some of these data may be useful for the field observer, the primary value of collecting these data is for use by engineers, who may use these field data for creating rock engineering models or designing rock reinforcements. However, there always are misconceptions between site geologists and engineers in interpreting investigated data if they do not have similar view on data descriptions of the site (Knill, 2002; de Freitas, 2004). The need of improving the communication between site geologists and engineers is clear and it can be done by creating a framework for data collection that can justify by reference to the reality in the ground.

2. PROCESS USED FOR SMART SITE INVESTIGATION

Engineering geotechnical practice (slope, tunnel, construction…) heavily bases on good geological field data. The field data collection is the process of site characterization, it includes the identification of the geological materials and structures present, their extent and disposition. The reconnaissance can also include:

- Inspection of outcrops for lithological variations, major joint sets and structural features (faults, highly fracture zones).
- Observations on the outcrop for unstable blocks and relevant fractures.
- Checking of groundwater seepage and surface drainage condition.

Most of the time spent during the different phases of geological investigations involves the collection and interpretation of structural data. The mapping of the structures on the excavated faces is a tedious process, especially when traditional techniques, compass and tape, are used. Collected data could result in the optimization of field sampling strategy and of more cost-effective for excavation support design.

Commonly, geologists and engineers do not communicate effectively while studying the ground because their education is quite different. While civil engineers are commonly educated and trained in mathematical and mechanical based sciences as statics, geotechnics, structural engineering etc., the education of geologists is mainly based on natural science, and maybe added with some engineering courses. Therefore, they both have different priorities and capabilities, which may affect to the time and cost of project. The costs of site investigation could be reduced by forming a smart site investigation framework using digital field systems that would:

- Improve the communication between site geologists and engineers by creating a benchmark for data collection that can justify by reference to reality in the ground.
- Develop a more reliable method to quantify the properties of the ground and represent results in appropriate forms.

This task can be done by creating inventory systems for field data collection and management. These systems are now available by advances in information technology. These advances, such as mobile computers, wireless communications, 3D laser scanning, digital close range photogrammetry, sensors, have provided new ways for collecting and managing field data. However, due to geological conditions, there should be a systematic process in formulating the necessary and relevant data field to be incorporated in an inventory database.

3. DIGITAL FIELD SYSTEMS

The necessary of detailed mapping leads to the need of digital field data systems to collect more data at precise locations. The field systems involve of:

- A handheld system to collect site information and rock mass quality.
- A close-range photogrammetry system to perform fracture mapping on rock surfaces.
- A fracture projection system to construct 3D rock mass models and analyse potential unstable blocks.

3.1 Handheld system for field data collection

The development of handheld computers with long battery life and significant mass storage has afforded the opportunity to revolutionize field data collection (fig. 1). Simple user interface of self-explanatory data input forms are developed to record geological data based on visual/manual observations (Hwang, 2005; Nguyen, 2008). The data lists are user-defined and can be modified to include necessary data during the study.

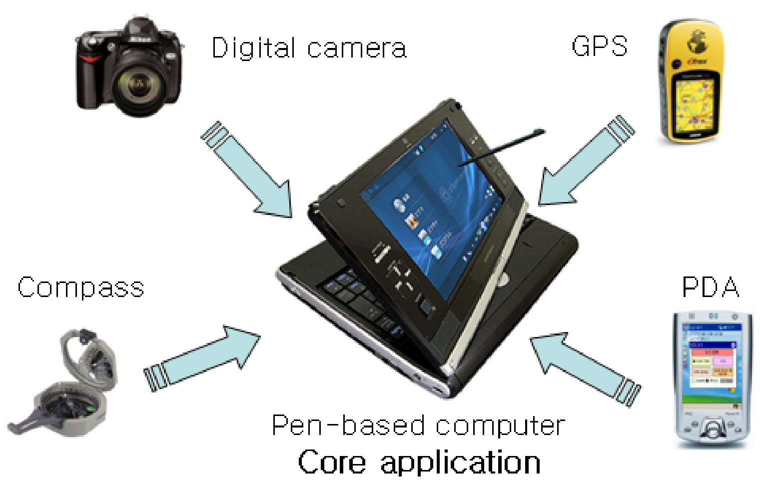

Figure 1. Components of a real-time pen-based data collection system (Nguyen, 2008)

3.2 Photogrammetry system for fracture orientation measurement

Photogrammetry method is used to measure fracture orientations on excavation surfaces. The method can be used to analyse large portions of rock masses, including inaccessible areas. It shows the ability of collecting large data sets to give realistic picture of the fracture pattern inside rockmass at low cost and in limited time. Beside that, the benefits of photographing newly exposed faces are for a historical visual database and possible back analysis for tracing major structures and eventual identification of rock failures.

The system uses two overlapping photographs for measuring 3D coordinates. The determination of spatial location of objects within images is based on triangulation in three dimensions. A set of stereo photographs is required taken and for maximum use of the photos, based on several experiments, an overlap area of at least 70% is recommended. The method determines a position in 3D space of an object using the relationship between the relative positions in two images where they are referred as a 'stereo pair' (fig. 2).

a) *b)*

Figure 2. Stereo-pair pictures taken on slope (*a*) and inside tunnel (*b*).

These positions are used to calculate point coordinates and construct fracture plane in 3D space (Manh, 2004).

3.3 Fracture 3D projection system

Once the orientation and location of fractures are collected, they can be projected on real 3D space to analyse the stability of excavated surfaces. A fracture project system is developed to:

- Database collected fracture data and excavation information.
- Display excavation shape and fracture data in 3D space.
- Generate rock blocks by intersecting fractures and excavation faces to analyse them.

Analysed sequence can be expressed in the following diagram:

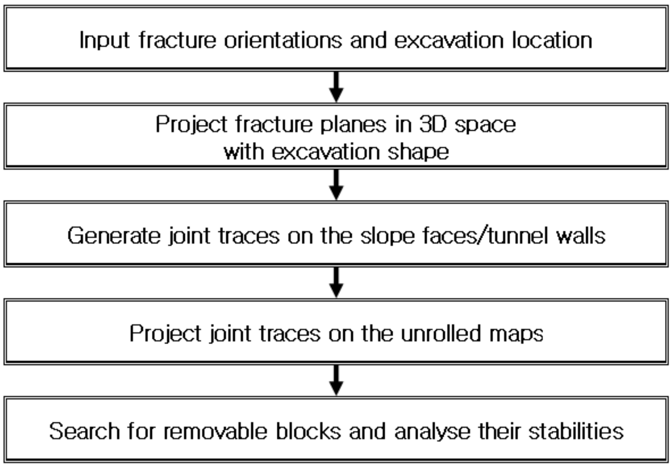

Figure 3. General framework of the system (Nguyen, 2009).

Project database

The power of a field system lies in its capability of handling data ready for analysis. Implementation of an effective integrated database is vital to the project. Designed databases are developed to store detailed information of a project at different excavation stages. Excavated surfaces can be stored as photos and their locations can be plotted on project's base map.

Face mapping for structural data collection.

Face mapping involves the collection of fracture types, their orientations and locations, lithology and rock mass conditions. Figure 4 shows an example of data input on a tunnel face.

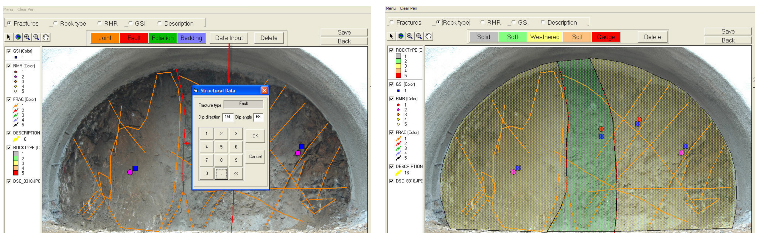

Figure 4. Fracture data input and geological data interpretation.

3D presentation of data and stability analysis

Fracture data are then projected to show structural conditions surrounding excavation area. The intersection of fractures and excavation surfaces results in rock block forming at specific location and geological conditions can be foreseen for unexcavated areas. Rock blocks around excavation are identified by projecting joint traces on unroll map of excavation faces and examined for potential unstable blocks. Real shape of unstable blocks and their properties can be projected back to 3D space to have an interactive view (fig. 5).

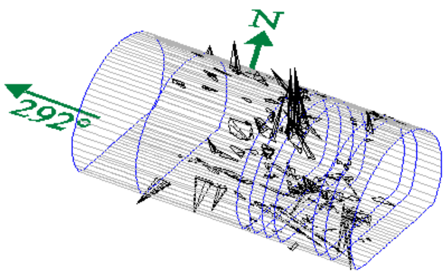

Figure 5. Removable blocks of a tunnel.

4. DISCUSSIONS AND CONCLUSION

Effort of having accurate field data and good communication between site geologists and engineers has lead to the development of field data systems. Face mapping of excavations is used to derive the in-situ fracturing of surrounding rockmass. The projection of fracture network in true 3D space helps site geologists and engineers to visualize structural conditions on excavated walls and at working faces.

The systems contain a rich database readily for analysing. Once the basic setups are learned, these steps can be done more efficiently. The learning curve for adapting to field systems is adequately steep if a geologist does not take enough time to practice the use of software. In the case of a dedicated staff member might become proficient in the more subtle features of the program, this problem would be less apparent. That is, routine data entry and data manipulation in the software is easily learned in a few days, particularly by younger workers who had no difficulty adapting to the system.

These systems have been evaluated for their accuracies and applicability at several investigation sites (Nguyen, 2008; Nguyen, 2009; Hwang, 2010). Although current systems do not replace conventional geological fieldwork, they speed up the process of field data collection that could improve the quality of interpretations by removing burden of manually data input in the field.

5. REFERENCES

de Freitas, M.H., 2004. The Necessity of Combining Geologists and Engineers for Fieldwork in the Practice of Geotechnics. In Hack, R., Azzam, R., and Charlier, R. (editors), Engineering *Geology for Infrastructure Planning in Europe*. Lecture Notes in Earth Sciences 104, 54-58.

Ho (2000) Quantitative Risk Assesment: application, myths and future direction. In: *Proceedings EngGeo 2000*, Sydney, Australia.

Hwang, S.G., Nguyen, Q.P., 2005. Fieldmate - A geologic field data system. *Proceedings of 2005 Geological Conference*, Geology Society of Korea.

Hwang, S. G. and Ji, I. T., 2010. New Surveying Techniques for Rock Slope Engineering and Their Application Examples. Slope. *International Conference on Slope 2010*. Chiangmai, Thailand.

Knill, J (2003) Core values: The first Hans-Cloos lecture. *Bulletin of Engineering Geology and the Environment* 62, 1-34.

Manh, N. V. and Hwang, S. G., 2004, Image processing for the strike and dip measurement for the excavated rock surface. *Annual Meeting of the Korean Society of Economic and Environmental Geology*, 87-91.

Nguyen, Q. P., Phi, T. T., and Nguyen, D. T., 2008. Digital field data system for geological mapping and geohazard management. *International Conference on GeoInformatics for Spatial-Infrastructure Development in Earth & Allied Sciences (GIS-IDEAS)*, Hanoi, 49-54.

Nguyen, Q. P., 2009. Analysing rock stability using block theory and 3D surveying tools, *unpublished PhD thesis*, Paichai University, Korea.

Van Staveren, M. T., van Seters, A. J., 2004. Smart Site Investigations Save Money!. In Hack, R., Azzam, R., and Charlier, R. (editors), *Engineering Geology for Infrastructure Planning in Europe. Lecture Notes in Earth Sciences* 104, 792-800.