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The Development of Geotechnical Database of Bangkok Subsoil Using GRASS-GIS

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ABSTRACT: The unique soil identification is often regarded as one of the most important information for the design and construction phases in civil engineering works. Data availability and accessibility can reduce time and the expense of the projects, especially during feasibility stage. In the last fifteen years, the numbers of construction projects in Bangkok have been increased rapidly and continuously. Consequently, the number of soil boring reports has been accumulated largely. Data interpretation and management, then, cannot be regarded as simple tasks. The utilization of the information technology including geotechnical database system and GRASS-GIS can be served the geotechnical engineer as the very effective tools. Not only for non-data area prediction but also used to interpret the complex data area with reliability and accuracy.

1. INTRODUCTION

The growth of information technology applications including GIS and database system, in many fields has become more popular today. These technologies provide very effective tools for data management and interpretation even for complicated data. In geotechnical engineering, soil formation, physical properties and engineering properties are very important data. With the good soil information, engineers can make proper decision and effectively design. However, nature of soil is vary and more complicate in some area depending upon its formation process or some disturbing condition. Thus well subsoil survey planning during feasibility and detail design stage of the project is necessary for balancing of cost and acquiring the significant data. Although significant data are obtained, data management and interpretation are also very important processes and not easy tasks to achieve the subsoil information.

The increase of social and commercial investments for the last fifteen years in Thailand, especially in Bangkok, causes the construction projects to rapidly increase. The soil boring reports have been also increasing, until now may be more than 20,000 boreholes exists covering almost all of the Bangkok area. The propose this study is to elaborate the usage of information technology to manage and interpret the soil data and establish geotechnical database system to provide information support to others geotechnical work and precaution such as very soft clay zone or thin sand layer and sand lens zone. Furthermore this system can be used as a decision support system for geotechnical engineers.

2. GEOLOGICAL AND GEOTECHNICAL BACKGROUND

Bangkok is situated on the Lower Chao Phraya River basin in the central plain basin of Thailand. The basin is formed under a complex sequence of alluvial, fluvial, tidal flat and deltaic environment up to 2,000 meter thick during late Quaternary (up to 1.8 million years ago). The changing sea level in the Holocene epoch (10,000 years ago) is the most important factors shaping the landform of the plain. The deceleration of river flow interacted with the sea water resulted in rapid sedimentary accumulation of marine and fluvial deposits (Sinsakul, 1997). This young sediment is called "Bangkok Clay" (Mukthabhant *et.al.*, 1966). For the engineering purposes, less than thirty meters depth is concerned. The general feature of this subsoil consists of four soil layers (Figure 1). The first layer is crust or topsoil layer that is high shear strength and low water content as it has been always subjecting to cycling of wet and dry process. The next layer is compressible clay including very soft, soft and medium gray clay, which is low shear strength and high compressibility. This layer attains a thickness more than 10 meters, lied on stiff clay or very stiff clay layer. Finally hard clay or first sand layer is founded at a depth about 20-25 meters.

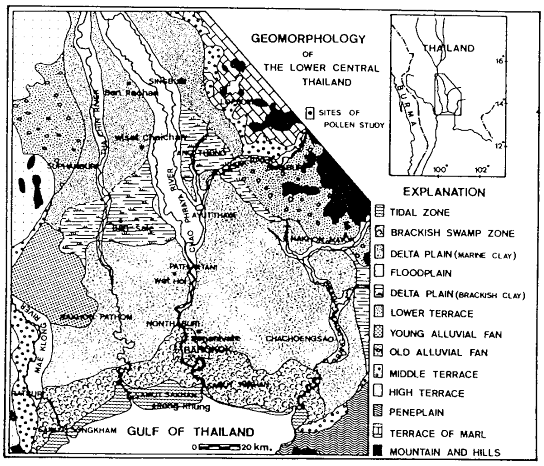


Figure 1. Geomorphology of Lower Central Plain (Somboon, 1988)

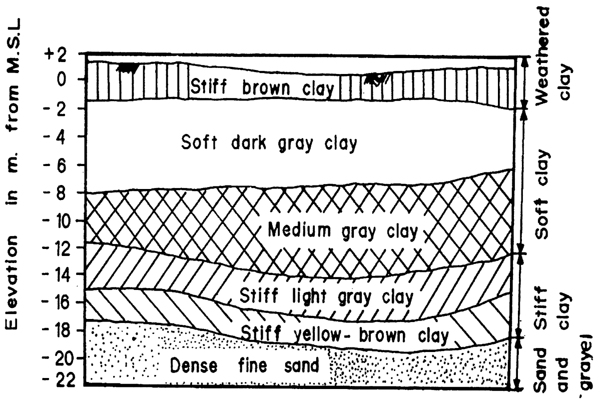


Figure 2. Typical profile of Bangkok subsoil (Mukthabhant *et.al.*, 1966)

3. METHODOLOGY

The Geotechnical information system can be divided into two major parts. The first one is development of geotechnical database system for storing and managing of soil parameters. The other is modeling and visualization using GIS software. For no restriction of software license and easy to distributions with no cost, the general public domain software are most preferred. The Red Hat Linux is used for the main operating system since has already been proven for its high stability and security. The object relational database management system (RDBMS), PostgreSQL is used as the database server software for managing and manipulating the soil data. The GRASS 5.0 GIS and remote sensing software is also a best choice in graphical modeling, 3D analysis ability and PostgreSQL connection support.

3.1 Geotechnical database system

The database system is an essential part, like a backbone system, of this study. The careful overall system design must be taken to provide an effective service and easy to maintained. The Client/Server system architecture was selected which provide high capacity for very large data loading, high security, high reliability and high stability of the system. Furthermore, it must provide the network connection including LAN, Intranet and Internet for data sharing and can be remotely maintained. To achieve these requirements, the database server with PostgreSQL software was set up on Linux system and connecting to Kasetsart University network (NONTRI-NET) for the Internet connection.

3.2 Data model design

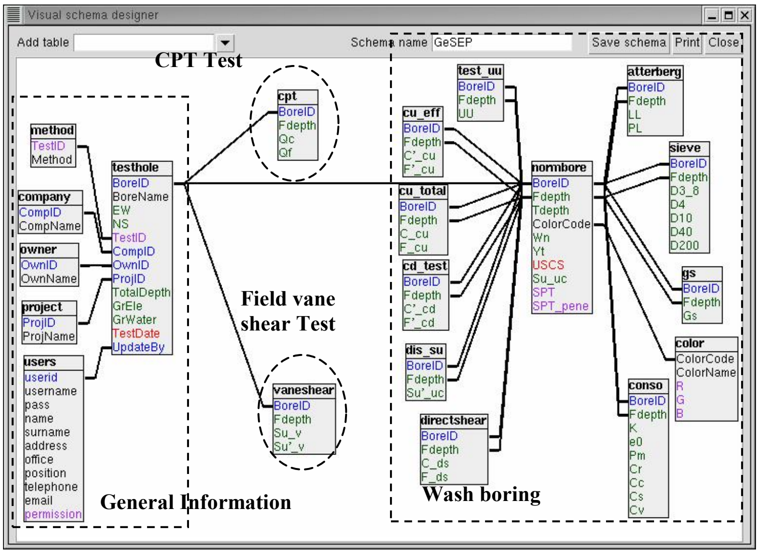
The method of soil testing can be classified into in-situ test and laboratory test. The in-situ test methods are mainly used for determination of soil strength such as field vane shear test, cone penetration test and standard penetration test (SPT). The SPT is very popular and most practice in Thailand. For the laboratory test, soil samples are collected by a series of thin wall tubes along borehole depth by wash boring soil sampler method. The soil samples are heedfully tested for their physical and engineering properties, up to 30 parameters acquired in the laboratory. However, some parameters are rarely tested since these parameters are required for special design cases only. Therefore, the optimization and normalization of data model design is needed for NULL value storage spaces reduction, maintain data integrity and increasing the database performance.

The GeSEP (Geotechnical Subsoil Explorer Project) data model is shown in Figure 3. The main concept for this design is all geotechnical parameters must be stored and expandable for adding new testing methods in the future. Hence, along the design, four main groups of relations are defined:

a) General bore holes information Relation group: This Relation contains borehole identification number, location, project name, testing company and others data.
b) Wash boring information Relation group: All laboratory-tested parameters including SPT test are stored according to their depth. The normal testing parameters stored in “normbore” Relation, the others seldom tested parameter are stored in their testing name Relations and linked all Relations together using BoreID and Fdepth attribute.

c) Field vane shear Relation: This is a simple structure relation, linked to general information Relation group by using BoreID attribute.
d) Cone penetration Relation: Same as field vane shear Relation.

The "users" Relation is a special relation, used for controlling access and permission to GeSEP over Internet connection.



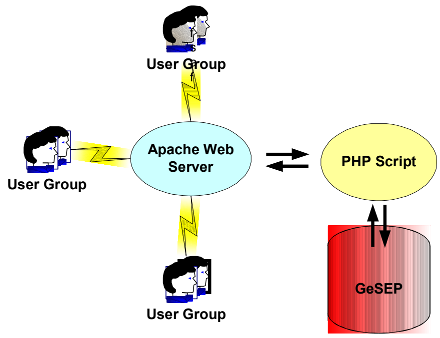


Figure 3. GeSEP data model

Figure 4. GeSEP web application

3.3 Database and web applications

For connection GeSEP into Internet, Apache web server and PHP Script language are compiled and installed to the server machine. The PHP is an intermediate layer between apache server and database system, the user requests from web page are sent from apache to PHP then PHP will make a connection to GeSEP and response the results to users (Figure 4). The PHP user-tracking script is toggled every time when users log in to the system and the user permission level is broadcasted to the system variable until users log out. Thus, only allowable pages can be opened according to level of the users.

Unfortunately in Thailand, the slow speed and high Internet connection cost are common problems that may reduce the efficiency of the system especially data input system, which more time consumption is needed. These problems can be led to irritation of the users and block the growth of GeSEP system in the future. To shorten the connection time, fasten the system and reduce the opportunity of loss data over connection, a new method is proposed.

3.4 Geotechnical Data Interchange Format (GDIF)

The data transferring problem is coming up with applied computer technology to geotechnical field. In 1991, the Association of Geotechnical specialists of UK held a seminar on the interchange of geotechnical data by electronic means. The result of the seminar led to form a "Geotechnical Data Interchange Format (GDIF)" that was aimed to aid the transfer of the factual data and allow its readiness into other systems for the manipulation, presentation and analysis of the data, however it does not cover the descriptive introductory elements of a report (Giles, 1994).

In this study, some modification of the original GDIF is made to suit the data structure and extend to covers all geotechnical testing in Thailand. The principal concepts are:

a) Using 2 text file groups as shown in figure 5 for whole data transmission: general information file and a tested data files group e.g. wash boring file, field vane shear file etc.
b) Using "Tab" key as a column separator for each parameter.
c) Using temporary BoreID as a reference key in each file.

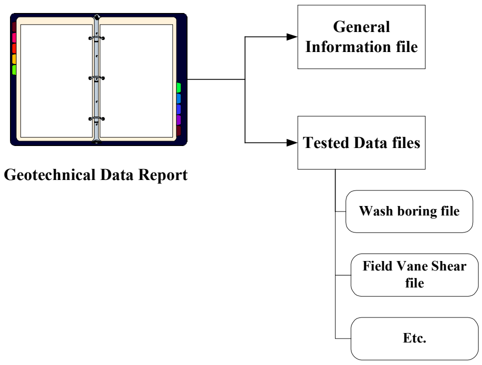


Figure 5. Modified GDIF files structure.

BoreID	Fdepth	Tdepth	ColorCode	Wn	LL	PL	Yt	Gs	D3/8	D4
1	-2.5	-2.95	33.75	54.75	24.42	1.94				
1	-5.5	-6	68.39			1.65				
1	-7	-7.5	55.53	51.64	23.7					
1	-8.5	-9	66.54			1.68				
1	-11.5	-12	81.98			1.53				
1	-13	-13.5	67.16	71.91	30.72	1.62				
1	-14.5	-15	67.31			1.67				
1	-17.5	-18	60.13			1.69				
1	-19	-19.5	59.61	76.7	31.65	1.68				
1	-20.5	-20.95	18.63	32.25	15.82	2.17				
1	-22	-22.45	16.75					100	100	100
1	-23.5	-23.95								
1	-25	-25.45	26.77			2				
1	-26.5	-26.95	22.71	54.24	23.65	2.03				
1	-28	-28.45	23.35			2.06				
1	-29.5	-29.95								
2	-1.5	-2	34.31	52.84	23.78	1.8				
2	-3	-3.5	32.54			1.83				
2	-6	-6.5	39.19	31.75	15.18	1.8				
2	-7.5	-8	39.53	34.08	15.9	1.7				
2	-10.5	-11	75.77			1.53				
2	-12	-12.5	43.9			1.7				
2	-15	-15.5	44.71			1.85				
2	-16.5	-17	23.08	62.85	28.2	2.07				
2	-18	-18.45	19.69	70.02	30.66	1.83				
2	-19.5	-19.95	30.66			1.78				
2	-21	-21.45	21.59	36.23	17.68					
2	-22.5	-22.95	20.04							
2	-24	-24.45	20.47							
2	-25.5	-25.95	20.39	53.07	24					
2	-27	-27.45	16.66			2.02				
2	-28.5	-28.95	21.63							
2	-30	-30.45	23.79	71.91	31.67					
2	-31.5	-31.95	15.4							
2	-33	-33.45	18.12							

Figure 6. Data pattern in each file (wash boring).

3.5 GRASS GIS

GRASS is a public domain raster based GIS, vector GIS, image processing system, and graphic production system that is originally designed and developed by researchers at the U.S. Army Construction Engineering Research Laboratory (USA/CERL). It is now supported and enhanced by the GRASS Development Team headquartered at University of Hannover and Baylor University. Since the first release of GRASS software in 1985, the number of users has rapidly grown. Because GRASS is distributed with source code and GNU General Public License, users are able to customize and enhance GRASS to meet their own requirements. The application of GRASS is implemented in many fields such as environmental, agricultural, hydrological and geological. In October 1999, the GRASS 5.0 beta version was released. Many scripts and modules were added including 3D modules that are most suitable for this study.

3.6 GRASS Modules

The GRASS 5.0 is integrated with many supporting modules for various tasks, which can be classified up to eight groups including raster analysis, vector analysis, point data analysis, image processing, DTM analysis, screen displaying, map creation and others extra modules (Neteler, 1998). The command in each module has the similar pattern that the first letter of the GRASS module followed by a dot. The next word defines the subtopic as in Table 1. The associated GRASS's commands for this study are shown in Table 2.

d.*	display commands for graphical screen output
g.*	general file management commands
i.*	image processing commands
r.*	raster processing commands
v.*	vector processing commands
s.*	site processing commands (point data)
m.*	miscellaneous commands
p.*/ps.*	map creation commands
…	unix scripts

Table 1. GRASS commands pattern.

Commands	Description
g.region	use for defining interested 2D boundary.
g3.region	use for defining interested 3D boundary.
r3.mapcalc	three dimensional map calculation module.
r3.mkdspf	make isosurface model from interpolated data.
r3.out.v5d	export interpolated map to Vis5d format.
r3.showdspf	display isosurface model.
r3.out.ascii	export Grid3D map data to text file.
s.to.rast3	covert site format to Grid3D raster format.
s.vol.idw	Invert Distance Weighted interpolation module.
s.vol.rst	Spline with tension interpolation module.
v.in.shape	convert ESRI shape file to GRASS vector format.

Table 2. GRASS commands are in the study.

4. GENERATION OF SOIL MODEL

After a number of soil boring data were imported to the GeSEP system, a small target area of Kam Ling Flood Prevention Project, which is located in Southwestern of Bangkok, was selected as a testing site for the subsoil model interpretation. The nine soil investigation bore holes were taken in grid pattern covering the area approximately 100 x 100 square meters as shown in Figure 7. Each of them is 35 meters depth in average. The soil data from testing were interpreted by geotechnical engineer and re-generated into subsoil strength consistency profile (Figure 8), which is a good representation of the soil strength distribution in the area and a major point for this study.

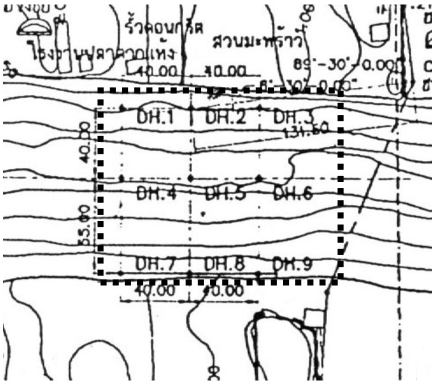


Figure 7. The target area in Kam Ling Project

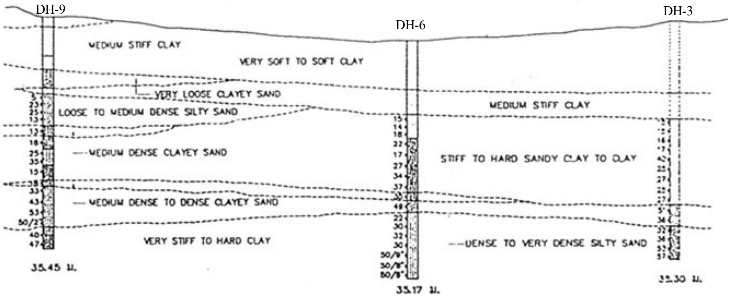


Figure 8. The soil consistency profile in section DH 9-6-3

To classify the soil consistency, the criteria were set up according to the shear strength from SPT and type of soil (Table 3). The category number was added for soil consistency identification that is very useful during map calculation process.

Category No.	SPT (blows/ft)	Description
100	0 - 4	Very soft to soft clay
200	4 - 8	Medium clay
300	8 -30	Stiff to very stiff clay
400	> 30	Hard clay

(a)

Category No.	SPT (blows/ft)	Description
500	0 - 4	Very loose to loose sand
600	4 - 10	Medium sand
700	10 -50	Dense sand
800	> 50	Very dense sand

(b)

Table 3. The criteria of soil consistency classification. (a) clay (b) sand

In order to generate a 3D soil consistency map, the soil type and SPT were interpolated by GRASS's Spline with tension interpolation module over pre-defined 3D region in the user mapset. The map calculation module was used for soil consistency classification. The result of the calculation was visualized by both build-in GRASS visualization module and exported to Vis5D+ visualization software.

5. RESULT

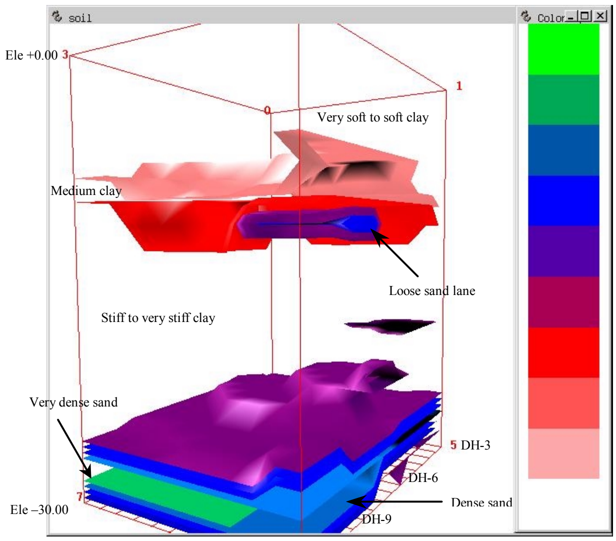


Figure 9. 3D soil consistency by r3.showdspf command

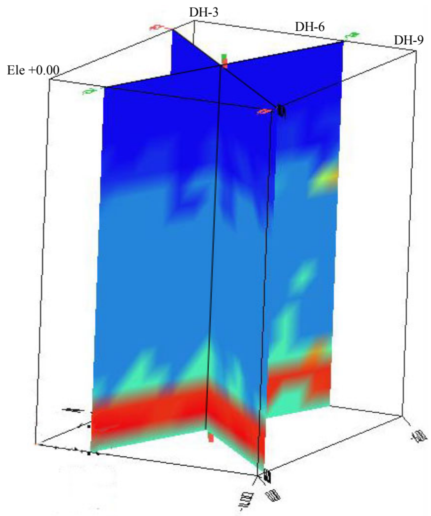


Figure 10. Soil consistency profile by Vis5D+

The iso-surfaces of each soil layer are shown in Figure 9. These surfaces present the upper most of each soil category. The GRASS visualization module allows users to toggle the surface one by one or multi-surfaces at the same time. The surface concept of visualization allows users to visualize everything inside the model. However, it may be regarded as a complicate view for some users. Thus, the Vis5D+ is another option for users to visualize the model. The Vis5D+ provides some extended facilities over the GRASS's module including conventional contour making, shading contour, iso-surface, profiles making, transparency layer, model probing for a value, volumetric shading and time step support. The program can therefore serve most of the user requirements. In Figure 10, the 3D model of the result is illustrated in the difference view by using the Vis5D+.

In order to access the model accuracy, the original three of soil profiles manually interpreted and tested data from soil investigation report are compared with the generated model. The comparison result is satisfactory. The models can indicate the stratigraphic of subsoil very similar to the original ones. The overall model cell values are exported as a text file for checking the possibility of soil distribution in the area. The result is also satisfactory. Nevertheless, during the model verification process, some error of the original profile is detected when it is compared to the model and the raw soil data. This initial result indicated that the concept of using GRASS 3D model is suitable for interpreting a soil model.

For further research, the map server module will be integrated to the GeSEP system that can increase the searching capability of the system. The larger area and a great number of boreholes will be utilized for generating overall stratigraphic of subsoil in Bangkok. Besides, the concept of soil identification and visualization will be applied to others geotechnical works such as borrow area calculation, tunnel layout planning or the others similar.

6. CONCLUSIONS

The geotechnical data of Bangkok subsoil can be safely stored and managed in the PostgreSQL server. The integration of web-base data management system can extend the utilization of GeSEP to the registered users without time and place limitations. GRASS-GIS provides several effective tools for soil data interpretation and manipulation, which were considered as the problematic process for forerunner geotechnical engineers. Unlike the 2D method which applies only the data in specific section, the value of all existing data points are used for model calculation. Data interpolation during 3D generating can then provide more reliable and accurate model than the conventional approaches. In addition, GRASS visualization module and Vis5D+ can be used as a powerful visualization tool for the soil models as well.

7. ACKNOWLEDGEMENT

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8. REFERENCE

Department of irrigation, 2000, Soil investigation report of Kamling project at Klong Mahachai - Klong Sanamchai. Bangkok, Thailand.

Giles, D., 1994, A geographical information system for geotechnical and ground investigation data and analysis. Fifth Europe conference and Exhibition Geographic Information System, Vol. I, pp.776-778.

Muktabhant, C., Teeravong, P., and Tengamnuay, V., 1967, Engineering Properties of Bangkok Subsoil. Proceeding Southeast Asian Regional Conference on Soil Engineering, Bangkok, 37 p.

Neteler, M., 1998, Introduction to GRASS GIS software. Hannover, Germany. Available at http://www.geog.uni-hannover.de.

Soomboon, P., 1988, Paleontological study of the recent marine sediments in the lower central plain, Thailand. Journal of Southeast Asian Earth Sciences, Vol.2. pp.201-210.

Sinsakul, S., 1997, Late Quaternary Geology of The Lower Central Plain, Thailand. International Symposium on Quaternary Environmental Change in The Asia and Western Pacific Region. University of Tokyo, Tokyo, Japan.