Jurnal
Teknologi

Full Paper

CIVIL INFRASTRUCTURE AND BUILDING DESIGN: THE DEVELOPMENT OF GIS DATABASE AND PRODUCT AS DESIGN AID

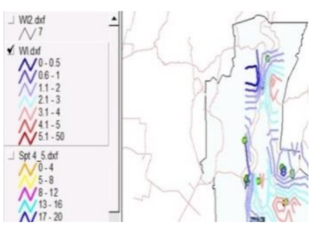
Article history
Received
14 August 2015
Received in revised form
10 December 2015
Accepted
3 March 2016

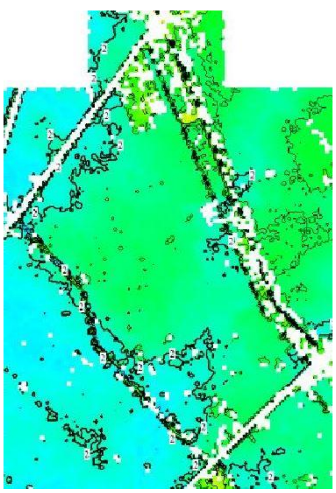
Devagaran Samugavelu[a], Abdul Naser Abdul Ghani[b*]

[a]Public Works Department (PWD), Malaysia
[b]School of Housing Building and Planning, Universiti Sains Malaysia, 11800, Penang, Malaysia

*Corresponding author
anaser@usm.my

Graphical abstract





Abstract

Civil infrastructure as well as building foundation design depends primarily on the availability and accuracy of soil investigation data. The data from site and laboratory are vital for a safe and economical design for any kind of infrastructure or buildings. This paper describes the use of GIS in processing and presenting factual data of site investigation reports in formats that are meaningful to users especially geotechnical designer. The initial effort is carried out for Perak Tengah District in the State of Perak, Malaysia. In this study the site investigation reports are archived in an appropriate manner so it can be quickly retrieved by user at any time. In the second part, the data are stored in GIS system that can be processed and presented into maps describing some basic important data for designer at various depths. Thus, the data are available at any time and the systems will be a meaningful tool for geotechnical designers.

Keywords: Geographic Information System, GIS, Geotechnical Database, Civil Infrastructure

Abstrak

Rekabentuk infrastruktur kejuruteraan awam dan bangunan bergantung kepada kesediaan dan ketepatan maklumat dan data kajian tanah. Data yang diperolehi dari tapak dan ujian dimakmal adalah penting bagi memastikan rekabentuk yang ekonomik dan selamat untuk sebarang bangunan atau infrastruktur. Kertas kerja ini menerangkan pengginaan GIS dalam pemerosesan penghasilan data kajiann tapak dalam bentuk yang berguna kepada pengguna terutama perekabentuk geoteknik. Usaha ini dijalankan berdasarkan data data yang diperolehi dari Daerah Perak Tengah di negeri Perak, Malaysia. Di dalam kajian ini maklumat yang diperolehi dari laporan laporan kajian tapak telah disusun dalam teknik yang mudah dicapai oleh pengguna pada bila bila masa dengan cepat. Bahagain kedua kajian ini mengemukakan hasil yang boleh didapati dari data yang disimpan dalam bentuk GIS yang boleh dikeluarkan dalam bentuk yang lebih bermakna kepeda perekabentuk. Sistem seperti ini boleh menjadi alat yang berguna kepada perekabentuk.

Kata kunci: Sistem Maklumat Geografi, GIS, Pengkalan data Geoteknikal, Infrastruktur Kejuruteraan Awam

1.0 INTRODUCTION

In geotechnical design, soil formation, engineering properties and water level are the basic important data. With the good soil information an engineer can produce the most economical but safe design and indirectly have minimum impact to the nature [1]. Nature of soil varies and more complicated is some area depending on the geographical formation process or some disturbing conditions. Therefore, access to preliminary data are crucial during feasibility studies to ensure project cost effectiveness and the requirement for acquiring additional data.

The fast moving world technology has been part and partial of assisting tool. Not forgetting the development of information technology application including Geographic Information System (GIS) that has the capability to store, manage and referencing database that have been stored to its geographical locations. By using GIS as soil investigation information database, it would ease the designer to retrieve data in minutes and have an idea of soil condition and type of foundation to be used. With the good soil information, engineers can make proper decision and design effectively. This paper describes the development of an electronic archive that contains the basic needed soil information of an area linked with its location on a map. It is expected that map produced will be a useful tool for planners and engineers in their efforts to achieve better land-use planning and to quickly decide on optimum foundation options.

2.0 LITERATURE REVIEW

2.1 Geology of Malaysia and the Study Area

There are three main geological formations in Malaysia - granite residual, sedimentary residual soils and quaternary deposits soils. In Malaysia, except the coastal areas where soft clay dominates, the rest of the area are covered by granite residual and sedimentary residual soils [2]. More than three-quarters of West Malaysia is covered by residual soil. The residual soils in Malaysia are a composite of sand, silt and clay with various domination which influenced by the geological formation [3].

Limestone is a sedimentary rock consisting mainly of the mineral calcite (calcium carbonate, $CaCO3$). Common impurities in limestone include chert, silica, clay, organic matter and iron oxides. Engineering geologic problems have been encountered in Klang Valley, Kinta Valley and their immediate vicinities, including subsidence and sinkholes, landslides and rock falls, foundation problems in limestone bedrock, and problems with ex-mining grounds (slime, tailings, mining ponds) [4]. In northern and western of Perak Tengah District, Perak which is the location of nearby Kinta Valley, where the geologic settings are similar, with limestone bedrock, granitic hills, and mine waste deposits that are comparable.

Perak Tengah District covers few main towns such as Parit, Seri Iskandar (Bota) and Kampung Gajah. The second longest river of Peninsular Malaysia, Sungai Perak passes these towns. Base on geological mapping there is no ground above 900 m from sea level in Perak Tengah District and is covered by granite residual, sedimentary residual soils and quaternary deposits soils.

2.2 Subsurface Investigation

Site investigation has been defined as investigation of the physical characteristics of the site and includes documentary studies, site surveys and ground investigation. The last item refers to the actual surface or subsurface/soil investigation, including on site and laboratory tests [5]. Practically site investigation is including study of the site history and environment, interpretation and analyses of all available data, and making recommendations on the favorable/unfavorable locations, economic and safe design, and prediction of potential risks. In any site investigation work, the questions which should be resolved in determining the investigation plan are what, why, where and how. Another question which one should always ask oneself is whether the investigation is sufficient or too much. With this question a geotechnical engineer can have better guideline to determine what to do. Knowing the site history and availability of the data would be a part of preliminary stage of geotechnical design.

The main component of site investigation is subsurface investigation. Sufficient information of site geologic and geotechnical soil conditions is the most important aspects of a design. The need for adequate geologic input into civil engineering projects is common knowledge to all. However, quite surprisingly, in many construction projects in Malaysia geologic input is either totally lacking or highly inadequate [4]. During planning of the subsurface investigation, the engineer shall always remember that majority of the unforeseen costs associated with construction on soft clay are geotechnical in nature. Additional costs are often attributed to inadequate planning of subsurface investigation and improper interpretation of the factual information and results of the field and laboratory tests [6]. Geological/Geotechnical Investigations should be conducted for new projects and reviewed for existing structures to determine the following:

a) The geologic conditions related to selection of the site.
b) The characteristics of the foundation soils and rocks.
c) Any other geologic conditions that may influence design, construction, and long term operation.
d) Seismicity of the area.
e) The sources of construction material.

The methods of subsurface investigations used are dependent on the data required to fully understand the foundation or treatment for both constructed and proposed projects. These investigative methods actually depend on the types and size of the structures involved, and on the extent and quality of the information needed. The geotechnical engineer plays the main role to decide type of information to be collected. It is important at site during soil investigation, geotechnical engineers should supervise, recording the drilling process, soil and rock sampling, classification, progress control and making judgments [7]. Once back to office engineers must designate laboratory tests and integrate the field data and the laboratory test results. This work practice will make sure the quality of soil investigation guaranteed and parameters needed for design can be fully obtained. The selection of types of field tests and sampling methods should be based on the information gathered from the desk study and site reconnaissance. Method of soil testing can be carried out as in-situ test and laboratory test. The in-situ test gives results immediately. It is mainly for determination of soil strength, test such as light dynamic penetrometer (JKR or Mackintosh Probes), standard penetration test (SPT), cone penetration test (CPT) and vane shear test are commonly used in Malaysia. Standard Penetration Test (SPT) is the most commonly used in-situ test in Malaysia [6]. In this study the data collection will be concentrated on SPT results for in-situ test. Where else for the laboratory test soil sample are collected during boring either in the form disturbed or undisturbed sample as required by designers.

2.2.1 Standard Penetration Test

The Standard Penetration Test (SPT) is an in-situ dynamic penetration test represents strength of the soil as engineering properties. SPT N value gives an indication of the soil stiffness and can be empirically related to many engineering properties. In Malaysia as standard, N value depth of penetration is 30 cm compare to certain country they use 60 cm. The great merit of the SPT test, and the main reason for its widespread use is that it is simple and inexpensive [8]. As per BS1377, the hammer weight is 65kg, with drop height of 760mm. Sampler is driven a total of 450mm into soils and the number of blows for the last 300mm of penetration is the SPT'N' value. SPT is generally carried out at 1.5m depth interval or larger interval depending on the undisturbed soil sampling schedule. At greater depth, the interval can be increased.

When SPT is carried out there is no chance to obtain undisturbed sample but disturbed sample can be collected for laboratory test. The disturbed soil samples can be collected from the split spoon sampler The soil parameters which can be obtained are only as guide in ground conditions where it may not possible to obtain borehole samples for adequate quality like gravels, sands, silts, clay containing sand or gravel and fractured rock.

2.2.2 Laboratory Test

The types of laboratory test commonly used in Malaysia to determine engineering and physical properties are summarized in Table 1. The total stress strength parameter like undrained (UD) shear strength, is required for short term undrained stability analysis of embankment on cohesive soils and for foundation design (e.g. footing, pile, retaining wall) in cohesive soils. The effective strength parameters like c' and φ' are for long term stability analysis of foundation, embankment and slopes, particularly cut slopes. Consolidation parameters will able engineers to estimate settlement of the subsoil when there is a change of stress in the subsoil. At times chemical tests on the subsoil or water to detect any chemicals that are detrimental to concrete and other materials used and buried inside the ground.

Table 1 Laboratory Test [6]

SOIL CLASSIFICATION TEST	TEST FOR MECHANICAL PROPERTIES
1. Particles Size Distribution : - Sieve Analysis (for content of sand and gravels) and Hydrometer Tests (for content of silt and clay)	1. One Dimensional Consolidation Test (Oedometer Test) :- to obtain compressibility and consolidation parameters for settlement analysis.
2. Atterberg Limits :- Liquid Limit, Plastic Limit & Plasticity Index (to be used in Plasticity Chart for soil classification)	2. Shear Strength Test : (a) For Total Stress :- Laboratory Vane, Unconfined Compression Test (UCT), Unconsolidated Undrained Triaxial Test (UU), Shear Box Test. (b) For Effective Stess :- Isotropic Consolidated Undrained Triaxial Test (CIU), Isotropic Consolidated Drained Triaxial Test (CID). (Note : Side Drains shall not be used on samples to accelerate consolidation to prevent errors) (Gue (1984) and Tscheboutarioff (1951))
3. Moisture Content	
4. Unit Weight	
5. Specific Gravity	
CHEMICAL TEST	
1. pH Test	
2. Chloride Content Test	
3. Sulphate Content Test	
4. Organic Content Test	3. Compaction Test

2.3 Geotechnical Design

Geotechnical design for proposed sites can be generally divided into three separate phases to minimize costs and for developing the necessary data at each stage of the approval, design, and construction of a project:

- Preliminary Investigations (Adequate information to justify site selection and preliminary cost estimates).
- Initial Design Investigations (Information necessary to obtain regulatory approvals, refine cost estimates, and develop engineering and environmental data).
- Final Design Investigations (Information necessary for developing plans and specifications, obtaining bids, and constructing the project).

2.4 Geographic Information Systems (GIS)

Geographic Information Systems (GIS), a coin termed in the 1960s, had evolved by the late 1980s into a widely adopted software application. The scientific community had been involved from the start in solving the technical problems of building a GIS, including the design of data structures and algorithms for executing simple operations such as topological overlay. Yet the concept that there might be a science of geographic information took longer to take root, and in some quarters the debate continues today [9]. Geographic Information System allows you to map, model, query, and analyze large quantities of data within a single database according to their location in the computer system. Traditionally the main activities in which GIS was involved in geosciences projects were in the data management, visualization, spatial analysis, and decision support system [10].

GIS uses the commonality between the multiple layers to search their relationships. This can be done with its ability to combine different map layers and observe them simultaneously to discover their relationship. This would be the main concept of GIS to carry out spatial analysis. Exploring spatial association between available data layers is eventually used for extrapolation of suitable areas for a special target. When it comes to geoscience GIS can be applied for six main activities [10];

i) Data Organization, which involving data modelling, data compilation and database construction.
ii) Data Visualization, where it produce data views and map, and graphically evaluating spatial patterns.
iii) Spatial Data Search, can be used for query and retrieve information.
iv) Combining (integration) of diverse data types.
v) Data Analysis
vi) Prediction, particularly to support decision making based on multiple factors of spatial information.

The large volume of data concerning the bore holes properties needs to be stored, managed and visualized and this is best done by a Geographic Information System (GIS) in an integrated geographic framework [11]. Vector and Raster (Grid) are the two types of data used in a GIS. Vector uses geometric objects, points, lines and polygons to represent real features on the earth's surface such as light poles, roads and buildings.

Vector is ideal for discrete themes with definite boundaries. Grid is composed of a continuous grid cells that represents a portion of the earth's surface. Ideal for continuous themes where there is lots of change. Raster and vector maps can also be combined visually. For example, a vector street map could be overlaid on a raster aerial photograph. The vector map would provide discrete information about individual street segments, the raster image, a backdrop of the surrounding environment.

The attributes of different types of geospatial data such as land ownership, roads and bridges, buildings, lakes and rivers, counties, or congressional districts can each constitute a layer or theme in GIS. GIS has the ability to link and integrate information from several different data layers or themes over the same geographic coordinates, which is very difficult to do with any other means. For example, GIS could combine a major road from one data layer as the boundary dividing land zoned for commercial development with the location of wetlands from another data layer. Precipitation data, from a third data layer, could be combined with a fourth data layer that shows streams and rivers. GIS could then be used to calculate where and how much runoff might flow from the commercial development into the wetlands. Thus the power of GIS analysis can be used to create a new way to interpret information that would otherwise be very difficult to visualize and analyse.

2.4.1 ArcView GIS

These days, numbers of software systems offer GIS decision-making capabilities. The range and number available sometimes make it difficult to discern the differences among systems and the strengths and limitations of each. The important point to remember is that there are as many different types of GIS software systems as there are decision-making processes. Particular GIS software systems are often specialized to fit certain types of decision making. That is, they are customized to meet needs specific to demographic forecasting, transportation planning, environmental resource analysis, urban planning, and so on.

The Intergraph Corporation's MGE/MGA system or ArcGIS (produced by the Environmental Systems Research Institute (ESRI)) have become well-known because they can be used in a wide number of applications. These general purpose systems also offer features that can be customized to meet various individual needs. The ArcView software started as a graphical program for spatial data and maps developed ESRI's to use for other software products. ArcView is an excellent tool for solving spatial problems and presenting information graphically (in charts, tables, maps and images) to decision makers. Later more functionality was added in ArcView 1.0 and ArcView 2.x versions and it became a true GIS program capable of complex analysis and data management. ArcView 3.x included even more full-featured GIS functionality, including a geoprocessing wizard and full support of extensions for raster and 3d processing. It was eventually renamed "ArcView GIS" by ESRI. The last release of ArcView GIS was version 10.3.

Many GIS professionals and users still use ArcView 3 even though it has been discontinued and replaced by a new product line. Some users with access to ArcGIS 9.x or 10.x may still install and use ArcView 3.x (http://www.gislounge.com/why-arcview-3x-is-still-in-use/). ArcView 3.x offers various advantages over ArcGIS including faster start up, faster functions such as dissolve, spatial joins and summary functions executed on the tabular data. Figure 6 shows the typical ArcView interface.

2.4.2 Application of GIS

Geographic Information System GIS has been widely used recently in the field of geotechnical engineering. Preparation of geotechnical maps and plans volumes of information related to geotechnical data, the use of software such as the Geographical Information Systems (GIS) has become an inevitable tool [12]. GIS has also been used in many geotechnical applications all over the world [13]. For example, in Brazil, GIS were used for geotechnical and environmental risk management of Brazilian oil pipeline in 2010. In addition, in Greece, GIS has been used to produce a thematic map for the geotechnical, geological, seismological, and geomorphological data of Athens. In Turkey, GIS used to produce zonation maps and to estimate if a further precaution is required for a safer area. In New Jersey USA, it was reported that the development of web based GIS was very useful to manage and disseminate soil information as developed from soil investigation data [14]. GIS can also be used to effectively visualize and analyse the results of the experimental studies and site investigation to prevent occurrences of possible problems and take appropriate design precautions before construction of any new project in an area [15], [16].

3.0 METHODOLOGY

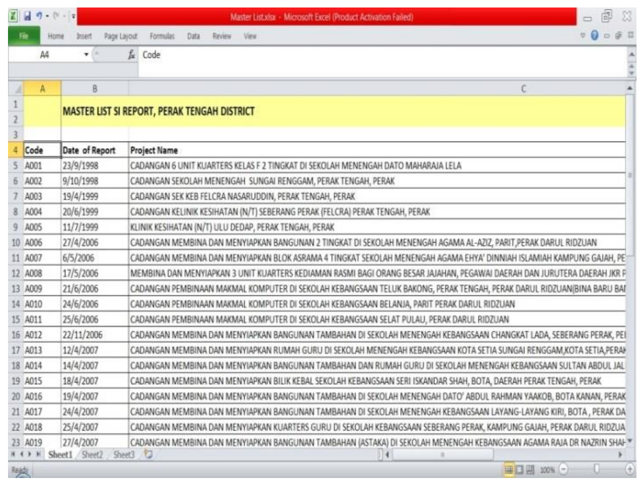
The preliminary stage of this study is to collect all the available data in JKR Perak Tengah district. The development of this studies is fully based on from data availability. At the first stage all the existing soil investigation report are scanned to pdf file as and backup and part archiving the reports in to soft copy. A unique code will be given to each report or job for ease tracking, tracing and creating a master list for available data. At the second stage, most basic data that would be used for geotechnical engineer are keyed in Microsoft Excel for this initial mapping development purpose. Compiling this information is the time consuming part of developing a GIS. In future, the data created can be expanded and new data can be keyed in. Then the data are integrated or entering a new data in to GIS software. Integration is a process where data were keyed in Microsoft Excel being transferred to ArcView where else the second method involves entering new data into GIS. Other available data that were being merged is the district map, JKR road map are also included in mapping, google satellite image as well as contour/isohyetal map that has been generated from QuickGrid (software). At final stage the basic information are created in layers that can be used for design planning, design and initial cost estimation for foundation.

4.0 RESULTS AND DISCUSSION

The holistic approach due to lack of storage capacity have showed a positive sign when the bundles of soil investigation reports have been archived and stored in soft copies. This have led to creating an aided tool for geotechnical engineers during desk study and designing stage.

4.1 Soil Investigation Reports Data System

Total of 28 numbers of soil investigation reports with 72 numbers of borehole have been collected in JKR Daerah Perak Tengah for building projects. The designer can view the Soil Investigation as it is in the original format. All the reports are given a numbering code arranged ascending year of the report. Base on that the data can be easily retrieved in minutes by referring the master list of report as been shown in Figure 1. These reports can be accessed by everyone for references. New reports can be easily added with a basic knowledge. Yet, this data system would not be enough to help a designer to have an overview at project location and the surroundings. This would be even more difficult if designer not use to the place.


Master List.xlsx - Microsoft Excel (Product Activation Failed)

MASTER LIST SI REPORT, PERAK TENGAH DISTRICT

Code	Date of Report	Project Name
A001	23/9/1998	CADANGAN 6 UNIT KUARTERS KELAS F 2 TINGKAT DI SEKOLAH MENENGAH DATO MAHARAJA LELA
A002	9/10/1998	CADANGAN SEKOLAH MENENGAH SUNGAI RENGGAM, PERAK TENGAH, PERAK
A003	19/4/1999	CADANGAN SEK KEB FELCRA NASARUDDIN, PERAK TENGAH, PERAK
A004	20/6/1999	CADANGAN KELINIK KESIHATAN (N/T) SEBERANG PERAK (FELCRA) PERAK TENGAH, PERAK
A005	11/7/1999	KLINIK KESIHATAN (N/T) ULU DEDAP, PERAK TENGAH, PERAK
A006	27/4/2006	CADANGAN MEMBINA DAN MENYIAPKAN BANGUNAN 2 TINGKAT DI SEKOLAH MENENGAH AGAMA AL-AZIZ, PARIT,PERAK DARUL RIDZUAN
A007	6/5/2006	CADANGAN MEMBINA DAN MENYIAPKAN BLOK ASRAMA 4 TINGKAT SEKOLAH MENENGAH AGAMA EHYA' DINNIAH ISLAMIAH KAMPUNG GAJAH, PE
A008	17/5/2006	MEMBINA DAN MENYIAPKAN 3 UNIT KUARTERS KEDIAMAN RASMI BAGI ORANG BESAR JAJAHAN, PEGAWAI DAERAH DAN JURUTERA DAERAH JKR P
A009	21/6/2006	CADANGAN PEMBINAAN MAKMAL KOMPUTER DI SEKOLAH KEBANGSAAN TELUK BAKONG, PERAK TENGAH, PERAK DARUL RIDZUAN(BINA BARU BA
A010	24/6/2006	CADANGAN PEMBINAAN MAKMAL KOMPUTER DI SEKOLAH KEBANGSAAN BELANJA, PARIT PERAK DARUL RIDZUAN
A011	25/6/2006	CADANGAN PEMBINAAN MAKMAL KOMPUTER DI SEKOLAH KEBANGSAAN SELAT PULAU, PERAK DARUL RIDZUAN
A012	22/11/2006	CADANGAN MEMBINA DAN MENYIAPKAN BANGUNAN TAMBAHAN DI SEKOLAH MENENGAH KEBANGSAAN CHANGKAT LADA, SEBERANG PERAK, PE
A013	12/4/2007	CADANGAN MEMBINA DAN MENYIAPKAN RUMAH GURU DI SEKOLAH MENENGAH KEBANGSAAN KOTA SETIA SUNGAI RENGGAM,KOTA SETIA,PERA
A014	14/4/2007	CADANGAN MEMBINA DAN MENYIAPKAN BANGUNAN TAMBAHAN DAN RUMAH GURU DI SEKOLAH MENENGAH KEBANGSAAN SULTAN ABDUL JAL
A015	18/4/2007	CADANGAN MEMBINA DAN MENYIAPKAN BILIK KEBAL SEKOLAH KEBANGSAAN SERI ISKANDAR SHAH, BOTA, DAERAH PERAK TENGAH, PERAK
A016	19/4/2007	CADANGAN MEMBINA DAN MENYIAPKAN BANGUNAN TAMBAHAN DI SEKOLAH MENENGAH DATO' ABDUL RAHMAN YAAKOB, BOTA KANAN, PERAK
A017	24/4/2007	CADANGAN MEMBINA DAN MENYIAPKAN BANGUNAN TAMBAHAN DI SEKOLAH MENENGAH KEBANGSAAN LAYANG-LAYANG KIRI, BOTA , PERAK DA
A018	25/4/2007	CADANGAN MEMBINA DAN MENYIAPKAN KUARTERS GURU DI SEKOLAH KEBANGSAAN SEBERANG PERAK, KAMPUNG GAJAH, PERAK DARUL RIDZUA
A019	27/4/2007	CADANGAN MEMBINA DAN MENYIAPKAN BANGUNAN TAMBAHAN (ASTAKA) DI SEKOLAH MENENGAH KEBANGSAAN AGAMA RAJA DR NAZRIN SHA

Figure 1 Master list of Soil Investigation reports

4.2 Soil Investigation Data Base in GIS

As an initial studies or development, the data have been limited to only borehole reports, SPT results, water level data and soil type. The additional data can be incorporated to existing easily but there must knowledge on the usage of related software. The information that has been used from the SI report is as shown in Figure 2.

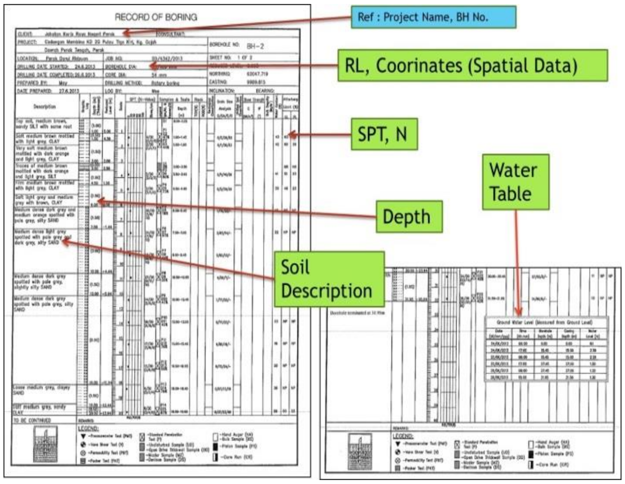


Figure 2 Important data extracted from SI reports

There were total of 28 numbers of SI reports with 72 numbers boreholes. Only 29 boreholes (40%) had coordinates and the reduce level indicated in the report. This data is very important since it will indicate the location and level of original ground level. With help of google maps and sketch map in report the coordinates can be indicated. Even though the accuracy of coordinates is uncertain, for a mapping purpose this would be fair enough to indicate the location. Where else reduce level (RL) the data cannot be retrieved since there is a high possibility the area been filled or cut. So the designer have to make an assumption base on site visit, history of the projects or some simple test like Mackintosh Probe and correlate the SPT values. With this condition the data for reduce level leaved blank, in any case the data could be retrieved in future it is an simple step to add the data.

Water level is also important information; it is the deciding factor for deformation of soil, expected settlement, excavation for earth works, actual insitu strength for soil and many more. Out of 72, 62 boreholes the water level was recorded which about 86%. This data also is helpful for plantation sector and irrigation department.

SPT value and soil description is the gist of a soil investigation report. Using this data a designer can decide to use shallow or deep foundation. Base on the data been collected only in few locations the shallow foundation can be applied and depending on the loading. In the study area the formation is alluvial soils which correlate with geographical mapping. Base on the data collected the formation of rock only traced at 1 location which is at 24m deep. About 38% of the boreholes were terminated less than 30m where SPT 50 obtained more than 3 times continuously. As an initial studies this data are very useful to create a soil investigation mapping as an aid for designers.

4.3 Development of Design Aid

The output from soil investigation reports, mapping shows most of the boreholes are located along the federal and state main road. It clearly shows the developments main factor would be the infrastructure (mainly road). The access would be the deciding factor for development of a land. This is clearly shows in Figure 3. Just with a basic data input the mapping can give some idea and better overall view to the user. This mapping can be used by local township planning for record and future development planning.

With GIS and combination of other software Google Map and QuickGrid mapping would be better and meaningful to the designer. At this stage the user should be able to know the basic usage of GIS software to retrieve and filter the data required. This is because in geotechnical field the designers have various schools of thoughts. There some basic filtered information have been created for the use of designers.

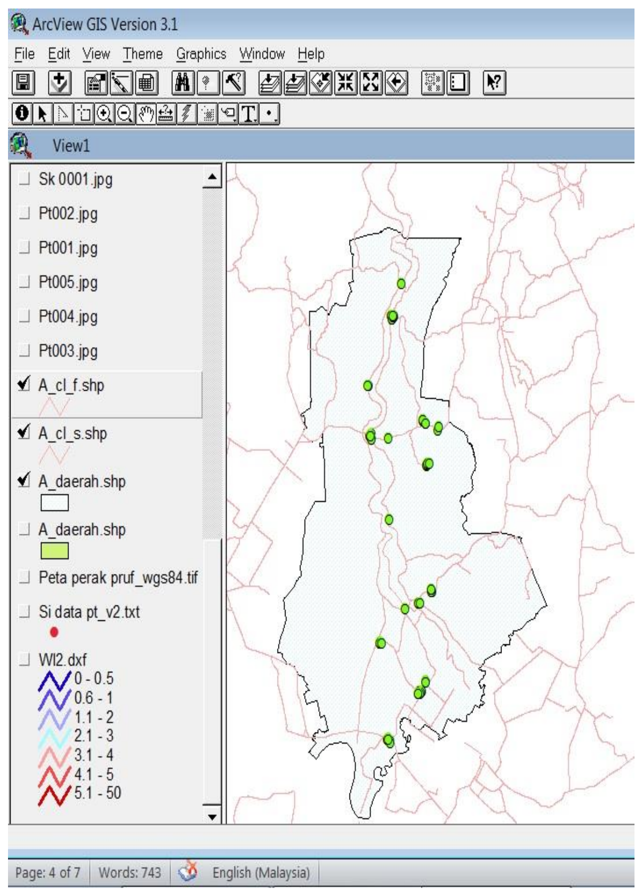


Figure 3 The development take place along the federal or state road

Figure 4 and Figure 5 shows the view from Google Map, location of SI and information of SI in ArcView GIS where this information can be retrieve easily from a map. The designer will have better fell of the site condition and the surroundings. At the same time the nearby SI information, if any available can be viewed. The detail SI information can be viewed at the same screen this will be and value added information for designer to optimize the design and estimate the changes that might take place if the formation of soil differs. Where else at the same time if nearby SI information shows the soil formations are similar it would give more confidence and convincing output at the site.

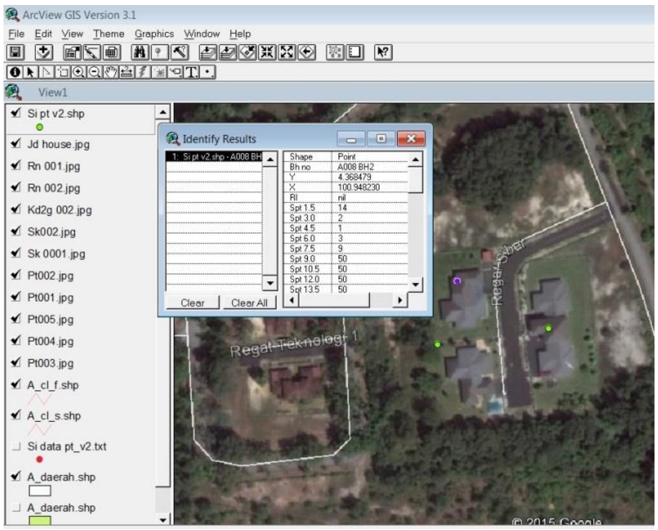


Figure 4 Combination of software Google Map and ArcView GIS

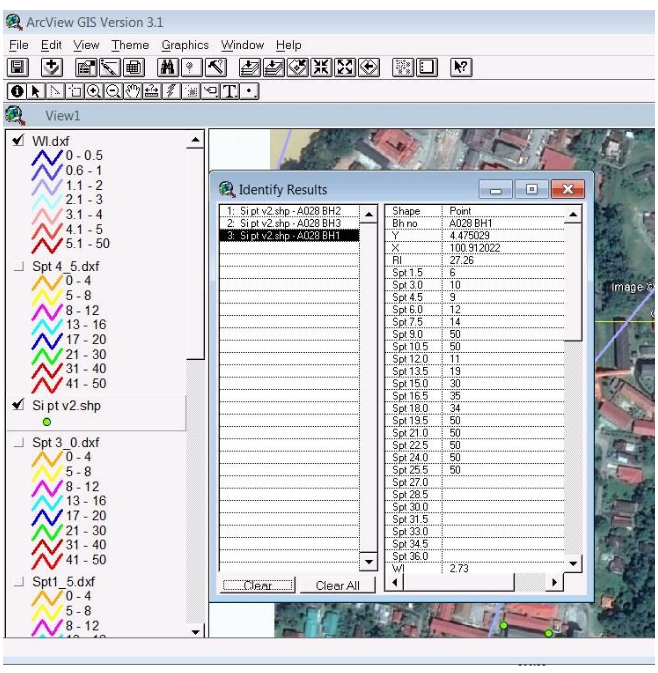


Figure 5 Nearby SI data can be selected and viewed at the same time in same screen

Another output that been created is the ground level, this mapping would be used to know the original ground level. It can be used for indicating low land and with data from irrigation department can be used to know flood level if it is a flood prone area. It is important data for study area since Kinta River and Perak River crossing this area and it is flooding area in the southern region of study area. This data also can be used for road alignment planning.

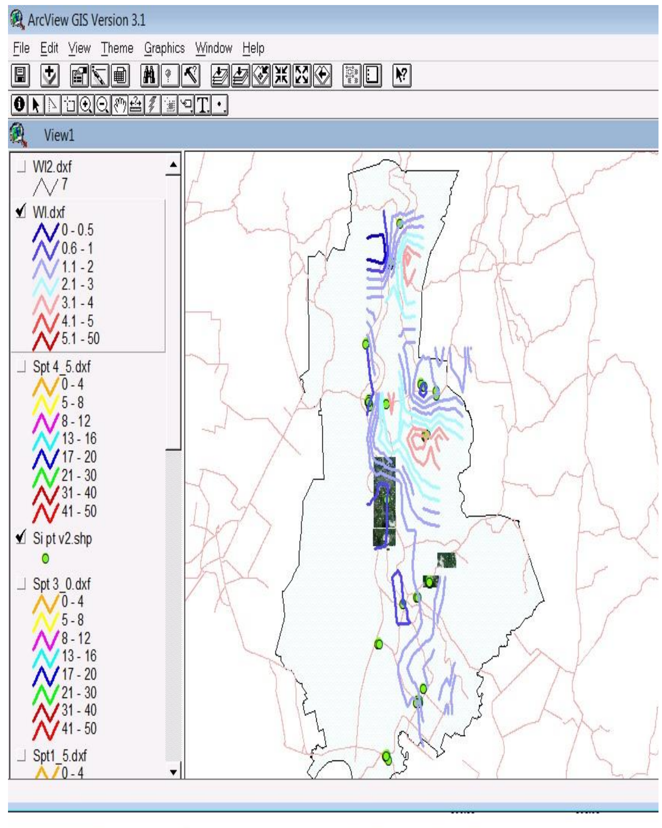


Figure 6 Ground water level

In Figure 6, mapping of ground water depth level from the existing ground level can be abstracted; this info would help the designer to identify influence of water in project area. The contour and colour plot will make the mapping more meaningful. In future, when more data available the contour information will be more accurate. There is a possibility where the water level not very accurate but the data is useful for designer for desk study purpose. As mentioned earlier, water level gives a major impact on the soil strength.

As we know in Malaysian practice the SPT are taken at the interval of 1.5m. Hence the SPT value are keyed in at increasing of 1.5m, in any case where there test done in between the increment the lower value are used. As an example output as shown in Figure 6, mapping of SPT results at 1.5m would be very essential information for designer to indicate the top layer condition. Generally, from the map the southern part show it governs by very soft ground which matches with ground water level mapping. With mapping of 1.5m, 3.0m and 4.5m SPT results contour layer mapping, would indicate the extend of ground condition as specially the soft ground level. This information alone can be used by designer to use shallow foundation or deep foundation. Beside that it can use as information for earth work planning, excavation works and other purpose during construction. If all the layers viewed at the same time, it would not show a clear picture since there will be over lapping. So the best way is to view each layer at a time. This is very easy step just by ticking and unticking the layers.

The designer can customize the data's as they required. Based on experience and rule of thumb precast bearing would set at SPT 30. Mapping also can be done where by indicating SPT more than 30 for depth less than 24m (assuming 3 numbers of 12m pile). As shown in Figure 7 and 8, the symbols, colours and size can be customized as user wanted. In this map layer the pink coloured triangular symbols indicate there is SPT 30 layer above 24m, where else green coloured round indicates vice versa. Designer will have a picture in the suggested project area whether deep foundation can be applicable and economical. At early stage client can be informed about the cost may incur for foundation. In a way this would give benefit for both parties. Government agency as specially can optimize this data by choosing good ground location for development.

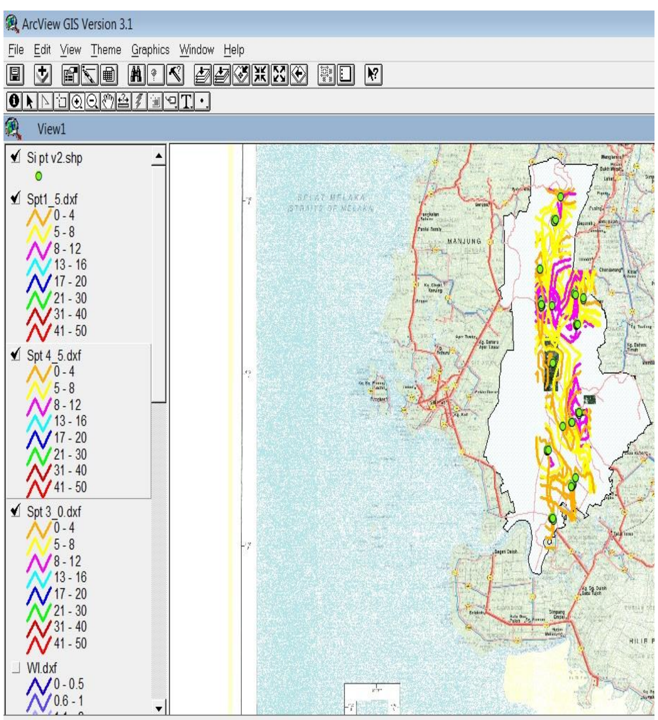


Figure 7 Profile shows the SPT values in graphical up 4.5m

In Figure 9, mapping plotted for SPT above 8 for less than 4m depth. As mentioned about this set of mapping can be used for determine suitability of shallow foundation, where foundation such as pad or strip footing resting layer. Due to bulb pressure from footing, SPT values mapping layers can be in cooperated for suitability of shallow foundation.

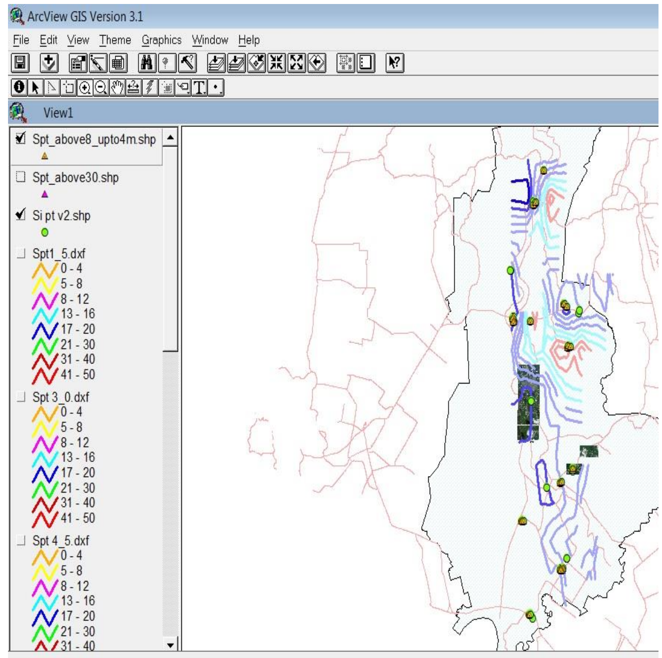


Figure 8 SPT above 30 for less than 24m depth.

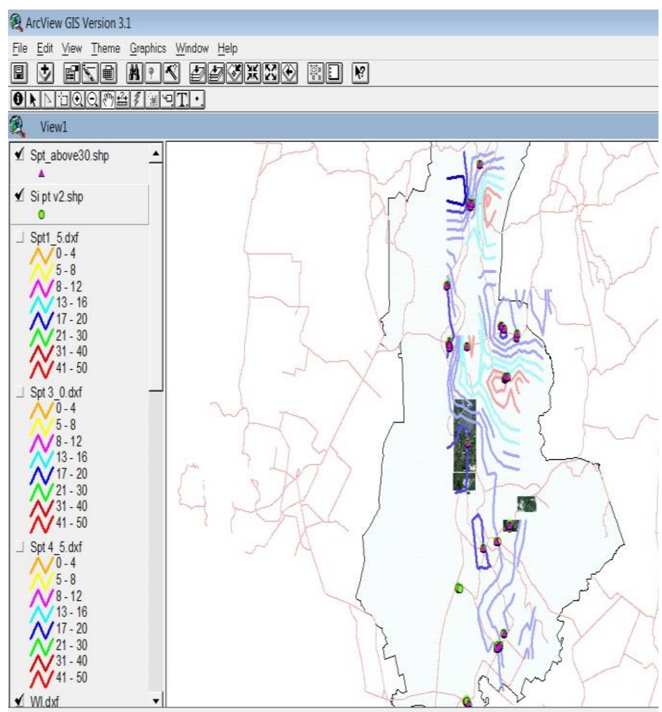


Figure 9 SPT above 8 for less than 4m depth

5.0 CONCLUSION

Data of soil investigation reports have been archived in GIS format and easy to recall/search by the designer and any personal with basic knowledge of computer usage. This has helped filing management at the office. The usage of software made the information and data being stored easily in graphical presentation and a meaning full format for geotechnical engineer. At this stage the user need to know the basic level to operate ArcView GIS. The output gives the designer a picture the site condition and help designer to plan for further investigation or using the data for designing. With the existing basic database the systems have been useful, and as more data and reports are added into the database it will give more accurate interpretations. A more accurate data interpretation will be helpful in reducing cost of new soil investigations works. The easily available information will not only save cost but also time.

Acknowledgement

Most of the SI data used in this study are provided by the Public Works Department of Malaysia especially the Perak State Branch. The authors would like to record our sincere appreciation for the assistance and look forward to greater cooperation in the future.

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