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Research Article

A Web-based Consolidated Geotechnical Site Investigation (CoGSI) of Sarawak Soils

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Abstract

A web-based Consolidated Geotechnical Site Investigation (CoGSI) of the Sarawak Soils is aim to presents a well-organized, systematic and easy to access digital geotechnical database. This database system was developed to allow users to search, view, and digitally download boreholes of the available Sarawak subsurface information with data entry functionality. This CoGSI provides many opportunities to explore the data, and web-based can be accessed anywhere through the computer and smart phones with internet access, where all SI information is stored in a digital format and function as a database management system. This will ensure that the CoGSI database can be used by the engineering community, especially practitioners and academics by making the data freely available in digital form. The user-friendly digitized CoGSI database would be valuable contributor for future planning of infrastructure developments; making preliminary design estimates for earthwork/foundation assessment; and future decision making with early identification of potential areas for construction purposes, which will produce an economic and safe design.

***Keywords*:** Soil-Database; Web-Based; Data Entry; Openstreetmap; Spatial Data

1. Introduction

The lack of geotechnical investigation lead to a high level of financial and technical risk with construction time over-runs has been discussed for many years. The risk of a construction failure is dependent on the information obtained from the geotechnical site investigation, which aimed at characterizing the underlying soil conditions in order to produce a safe and satisfactory design (Goldworthy, 2004). A quality geotechnical evaluation of a project site can save a project considerable time and expenses, by providing the design team and contractors with the subsurface information and design parameters during the initial design and planning stages. Many factors have been recognized by the geotechnical engineers for the uncertainties outcomes when dealing with the ground condition which are presented in Table 1.

Thus, to maximizing the benefit of geotechnical information, a document management system is needed to be replace with the digital version. The geotechnical SI reports are electronically upload, store and available to access, which increased the availability by creating a means for field engineers and authorized consultants using the system. A study by Okunade (2010) indicated that the geotechnical databases has been developed for units of different area ranging from individual project sites, to cities or municipal areas, counties, states countries and regions consisting of several countries or whole continents. Thus, this paper presented the development of a complete prototype Consolidated Sarawak Geotechnical Site Investigation (CoGSI) system for Sarawak soil into a digitized database management system. The system aims to enables data to be retrieved faster and worthwhile tools to promote user-friendliness, effective dissemination, and efficient administration for current and future development geotechnical databases for public officials, geotechnical experts and public users. The CoGSI database uses OpenStreetMaps (OSM) to display pins of the borehole logs for each designated project which defined through recording coordinates using Borneo-RSO (Rectified Skew Orthomorphic) or BRSO system. The BRSO system is a system that use in East Malaysia and also Brunei. Each pin is linked to the data collected from the specific location and the information associated with pin is displayed. The development of CoGSI system is significant to the construction industry and serve differently with the existing developed system known as GEOINFOS by Jabatan Kerja Raya (JKR) (Sahadan and Seman, 2003) as the latter serve as a document management system function. The difference between the current development of the CoGSI database system when compared with GEOINFOS is the Geotechnical information stored in a digital format rather than as images. The CoGSI is kept in digital format, thus the system allows for quick loading, searching as well as displaying of geotechnical data and can be further

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analysed to produce a sub-surface cross-section or other related applications in the future upgrade system.

Table 1
Examples of geotechnical uncertainties (Clayton, 2009)

Geotechnical Uncertainties	Source of Uncertainties
Ground model	Software performance
Contaminant model	Constitutive Model
Spatial and temporal variability	Construction management
Parameters needed	Whole-life performance
Groundwater model	Engineering competence
Required volume of data	Engineering knowledge
Method of calculation	Engineering experience

In addition, the current developed system also focusing on the compilation of the previous verified and approved hardcopy Geotechnical SI report locally available, allow the user to key-in for the verified future/new collected borehole logs and performed integration of ground information that serve potential users who requires the geotechnical information. The objectives of the current studies are given as follows: (a) To collect, compile and digitized the validated and verified Sarawak Geotechnical Site Investigation (SI) report from the data providers; local government agencies (JKR), private developers and other civil engineering consultants and/or contractors; (b) To construct intelligent software via Microsoft Azure SQL Database to facilitate the stored Geotechnical SI information for future decision making with minimum requirement to perform detailed SI and early identification of the potential areas for future development; and (c) To develop efficiently a web-based application through OpenStreetMap (OSM), Leaflet, PHP and JavaScript in order to allows users to search, view, provide downloadable data of the available ground information as well as serve data entry for future Geotechnical SI information efficiently.

2. Backgrounds

The evolution of the collection and use of geotechnical data into a database management system has evolved tremendously over the few decades starting from Lee *et al.* (1990) to an extensive geotechnical database compilation by SoilVision Systems Ltd, (2019). This geotechnical information is a valuable data for future projects and the data can be gathered from numbers of sources within the local authorities and consultants. The majority of the data collected during the early stages of the project, but some information is collected during construction, while some during the life of the project for the monitoring purposes. The transition of the geotechnical data collection initially started from manually operated, where the files are kept within filing cabinet or card index to a computerized storage system for compact stored on computer hard disk and followed by further development through a digitized data management system. To-date, many available internet-based on geotechnical database management has made accessible by many national and international organizations and agencies. In addition, Chang and Park (2004) stated that, the data collected from many construction projects should be standardized, structured, archived and properly used through suitable system and applications for efficient management. Also, the application of Web-based GIS is very essential to maximize the sharing collected information in order to solve problems related to geotechnical engineering.

According to Kunapo *et al.* (2005), storing the digital information in databases rather than as images, has allowed the distribution of the designated borehole logs over the internet, which provides the opportunity to explore the geotechnical database using web-based. Another important aspect needs to be highlighted while developing the digitized databases is ensuring the data integrity and accuracy of database management system. This can be done through reducing the possibility of the insertion of incomplete and illogical data, as outlined by Coronna (2006). In summary, the current study, provides a systematic interface and function in one system that convenience to public officials, geotechnical experts, and public users and the system provides easy-to-use functions to identify borehole logs of interest by simple mouse click on the map.

3. CoGSI Database Design Framework

3.1. CoGSI webpage database

The digital CoGSI webpage database is developed to provide an effective geotechnical data management system, which capturing and storing significant amounts of data comprises of borehole log information (i.e., project, strata information and in-situ results) and properties from the laboratory testing. The CoGSI have several functions which are Login, Project, Borehole, and Map tabs. Each of these tabs was designed with different functionality. Figure 1 below shows a screenshot of the CoGSI webpage prototype Login page by the authorized person. Upon successful login, a CoGSI main webpage will display the image as presented in Figure 2.

Fig. 1. Login page of CoGSI webpage

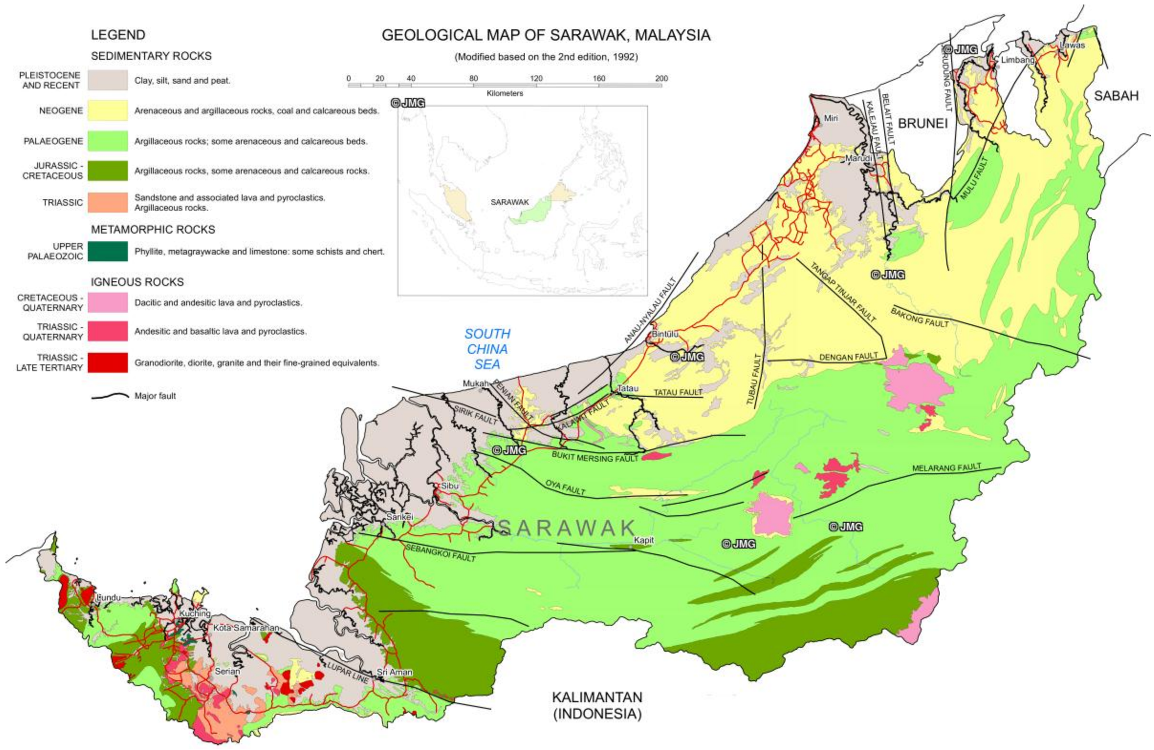

Fig. 2. Main webpage of CoGSI interface

3.2. Web-Based CoGSI Architecture

The CoGSI webpage architecture is shown in Figure 3 consists of three layers, which are divided into (a) database, (b) interpretation and (c) representation layers, which provides flexibility and security for the system developed. The database layer lays the foundation of the system. This layer holds all the data that correspond to each borehole: Project, Location based on Division, SPT N-Value, and Laboratory test. The data are securely stored in a relational database. The interpretation consists of various computer algorithms to perform the state-of-the-art dynamic computation to enable visualization of the borehole data into some form of visualizations such as stratigraphy, and SPT-N value plots. The interpolation of the borehole also happens in this layer. The representation layer objective is to enable representing information from the database to be shown in any web-browser.

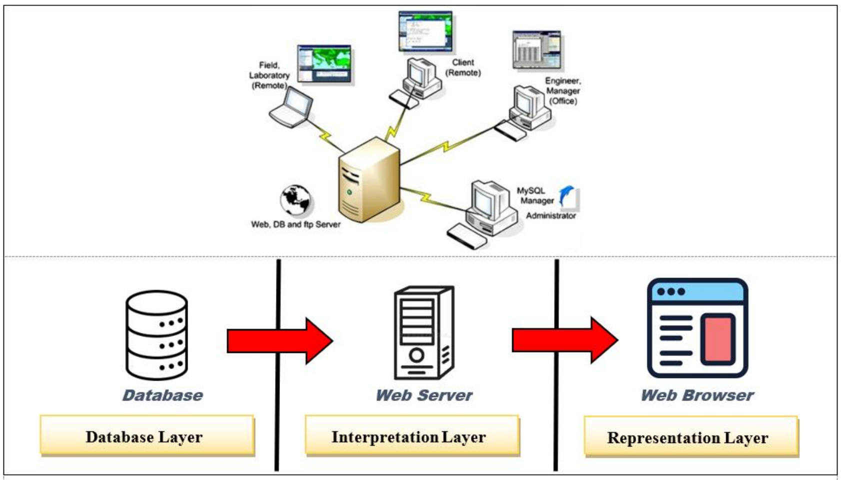

Fig. 3. Architecture of CoGSI web-based schemes

3.3. The CoSI entity framework

The CoGSI database management system uses Microsoft Azure SQL. It is a relational database service that is provided as a Platform as a Service (PAAS) on the Microsoft Azure cloud. This database is highly scalable where there are varieties of Cores, memories and Database Throughput Unit (DTU). The Microsoft Azure SQL is supported by Entity Framework, which is an open-source object-relational mapper (ORM) framework for .Net applications. Entity Framework 6.0 is used for this project.

The conceptual model for Entity Framework is shown in the Figure 4.

Entity Framework provides connection between the business entity and data tables in the database. The stored data can be saved and restored in the properties of business entities automatically. It can use LinQ Queries to manipulate the data in a database instead of SQL queries.

In the project, 5 entities are created. They are: (i) Project where project names are stored, (ii) Borehole info where the details of each borehole log are stored, (iii) Stratigraphy which store the depth, thickness and soil type of each stratigraphy in borehole log, (iv) SPT-N value to store n-value of SPT blows where number of blows of each depth in stratigraphy, (v) LabTest to store the laboratory testing details of each borehole log. Models of each entity are created using Entity Framework. The interface is shown in the Figure 5 below.

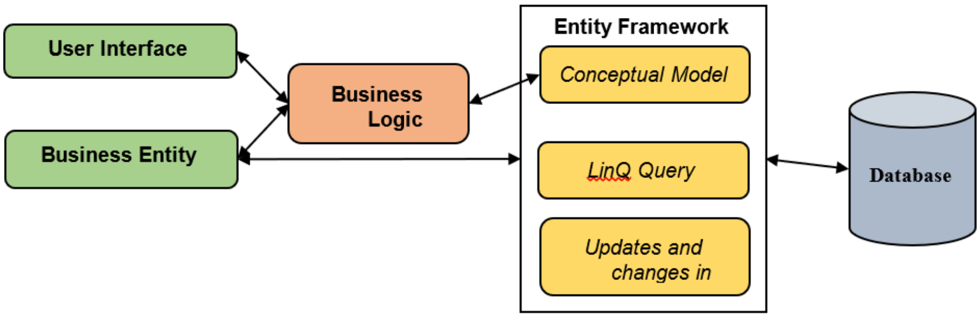

Fig. 4. Conceptual model of entity framework

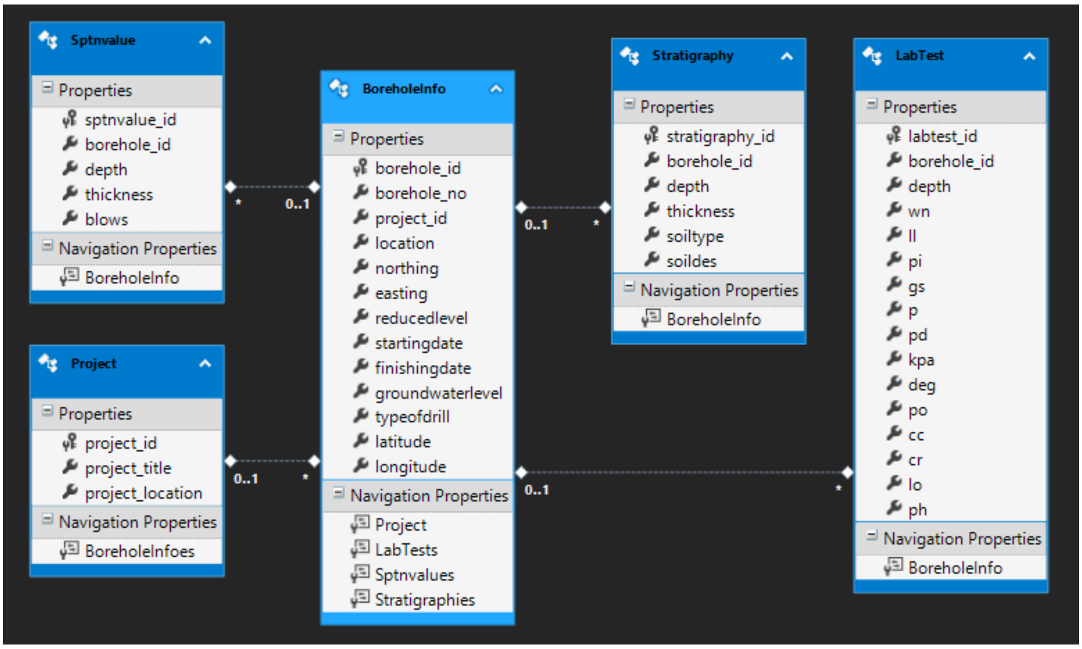

Fig. 5. Entity framework model

There are 2 web development architectures that are used for CoGSI namely Asp.Net web application and Leaflet (PHP). Both applications are using the same Microsoft Azure SQL database. The Asp.Net web application is used to create, retrieve, update and delete borehole logs. All the projects and borehole logs are organized to ease user in terms of retrieval, update and printing borehole logs. Figure 6 presented the screenshot of the digitized borehole lists collected and arrange according to the Division. All the verified borehole logs from the key-in database is marked on the map to view the location of the borehole log. This is achieved by using OpenStreetMap (OSM), Leaflet, PHP and Javascript. OSM is known as editable map of the world where it stored geodata with Leaflet and PHP. The markers are clickable so the details for the selected borehole log can be viewed as shown in Figure 7. Leaflet is used to mark the location on the OSM and PHP is used to retrieve data from database and display them on the interface as presented in Figure 8. In the figure also shows the comparison of the current hardcopy version and the CoGSI digitized database of the borehole logs. In addition, the Python software is used in plotting the SPT N-value graph.

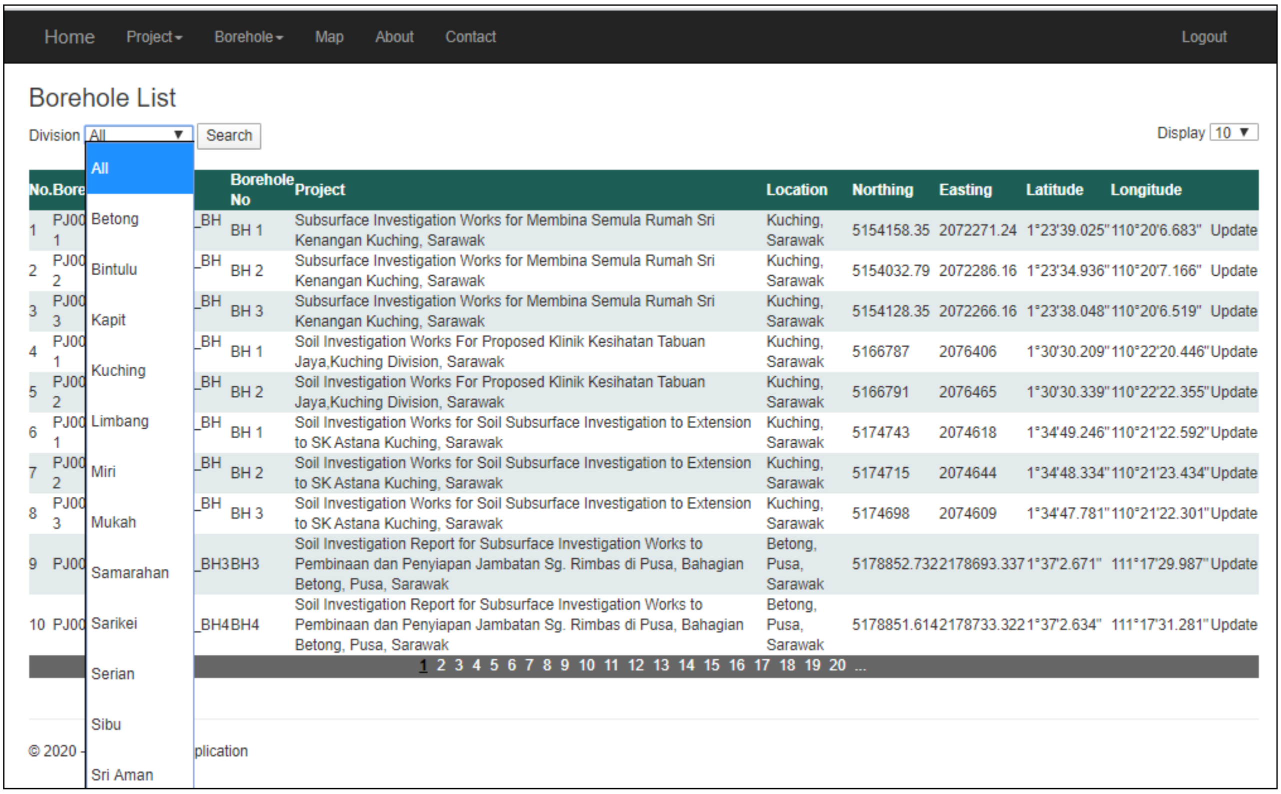

Fig. 6. Borehole list search according to division in Sarawak

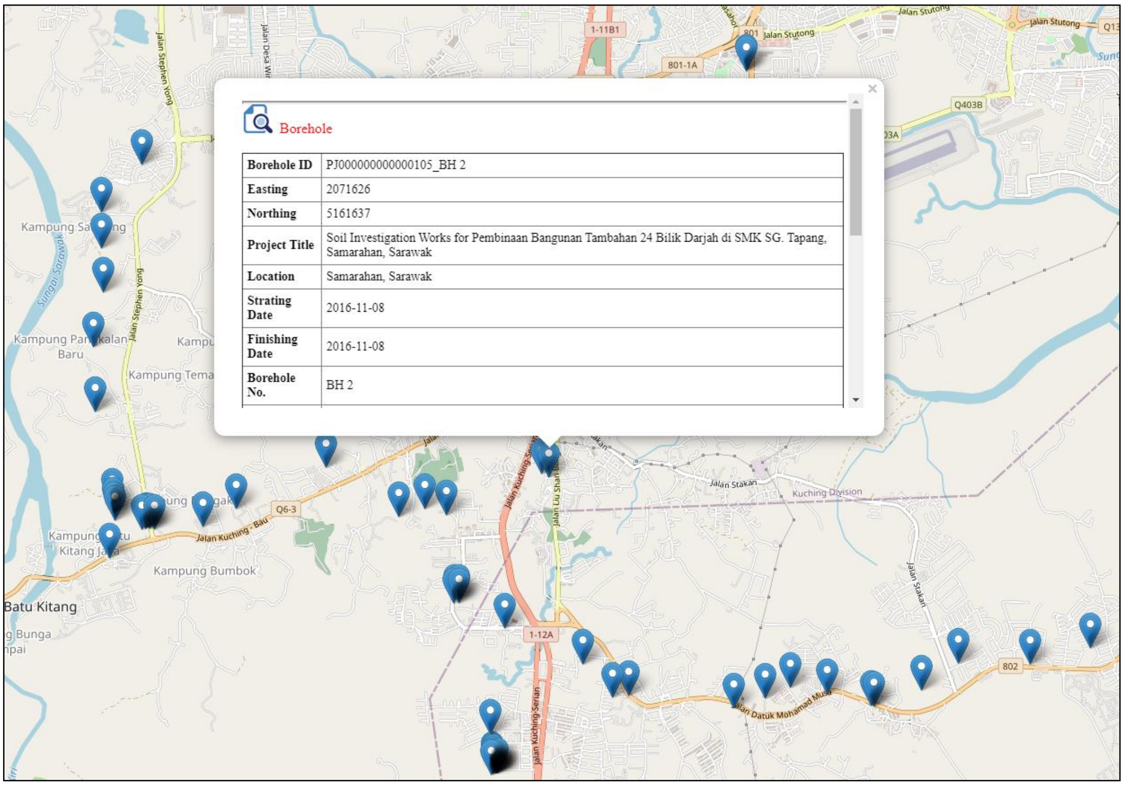

Fig. 7. Digitalized boreholes of the CoGSI via OpenStreetMap (OSM)

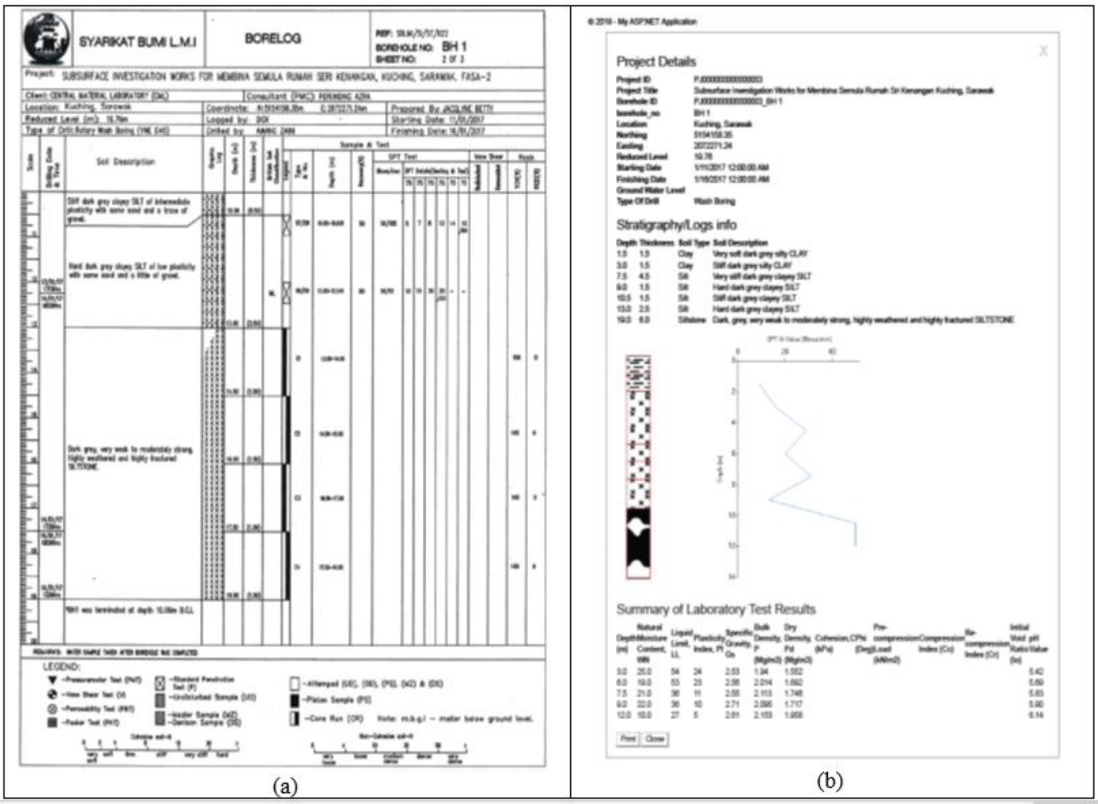

Fig. 8. Comparison between (a) Current hardcopy and (b) Digital CoGSI borehole logs

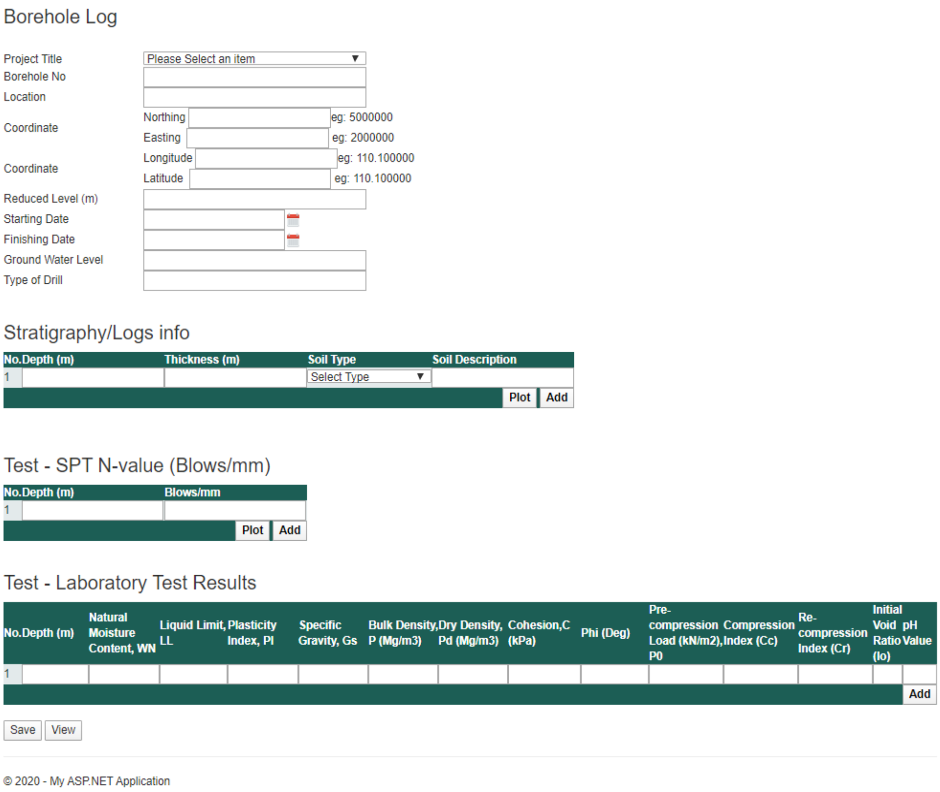

Fig. 9. CoGSI data entry webpage template

3.4. CoGSI data entry function

Another feature available in the CoGSI digital webpage is the data entry function, which presented in Figure 9. This function allows users to key-in old and new verified and approved Geotechnical Site Investigation (SI) information as a record in the database system. These data will be automatically stored, updated in the CoGSI database and thus, reduced the numbers of the Geotechnical SI hardcopy version and contributes to big SI database compilation not only for Sarawak but Malaysia as a whole. Also, CoGSI promoting the growing of the database for future use with easy and user-friendly to access, view, retrieved and to download the required borehole logs.

4. CoGSI Subsurface Cross-Section

This section presents the potential of the CoGSI database to enable in visualizing the subsurface cross-section view via multiple boreholes on the webpage. This application is able to automatically plot a 2-D cross-section based on x-y axes data for each subsurface measurement made. Noted that, most of the borehole logs data collected in 80's and 90's does not record the z-axis and only data in 90's and onwards are provided with z-axis coordinates. The cross-section of boreholes in Figure 10 shows the plot correlation between 3 borehole logs in a designated project. Each soil layer has its own characterizes and the height of the layer is based on sea level. In this application, it has been striven to preserve the data in digital form as much as possible not only for retrieving for reusable, but also for decision making process through dynamic cross-sectioning. The cross-section was implemented using PyPlot in Python 3.4. The function is able to accept up to 8 borehole logs. The cross-section algorithm developed for CoGSI database is presented in Figure 11.

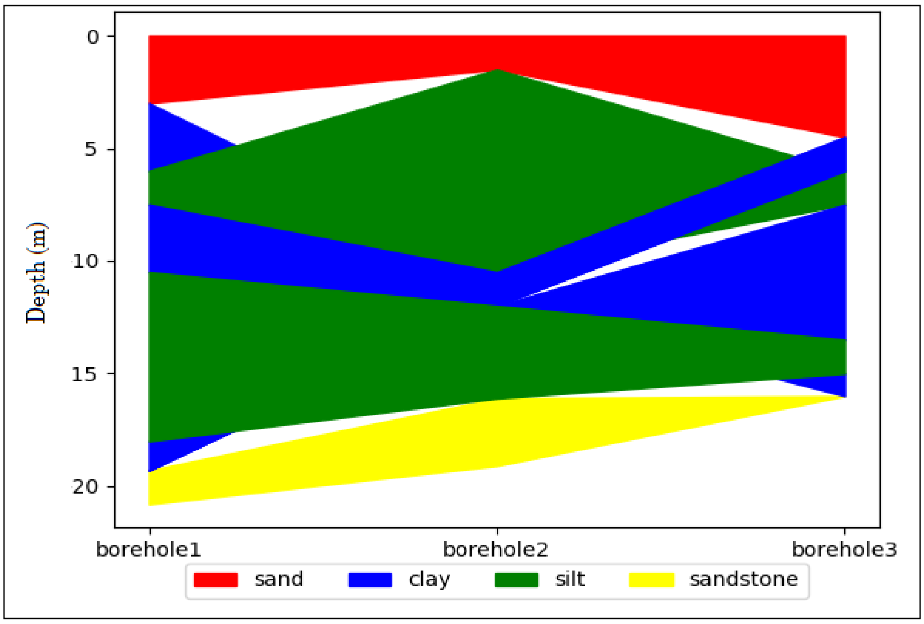

Fig. 10. Interpolated cross-section between three boreholes

Given n given borehole points, where n>=2.

For each *n* and *n+1* borehole log:

Determine the total numbers of layers for the soil type in each borehole points, determine the highest number of layer, *m*.

Store *n* and *n+1* soil layer and depth in an array, A_n and A_{n+1}.

While m>0 (starting from bottom to top),

If the last layer A_n is identical to last layer of A_{n+1} plot the line.

Color the layer with predefined soil color. (The height are the lowest and highest points of the two points of same layer that have the same soil type)

Else, *m*=*m*-1 (move to upper layer).

n=*n*+1

Fig. 11. The algorithm cross-section

The fundamental interpolation method that is used in most Geographic Information Systems (GIS) is the spatial interpolation which it uses for approximated the location in a multi-dimensional space, multivariate scalar, vector or tensor field. Furthermore, the method can estimate the elevations, climate phenomena, soil properties, population densities and fluxes of matters (Mitas, & Mitasova, 1999). There are a few assumptions of the spatial interpolation which the attribute data is continuously over space. This assumption is dedicated to the estimated attribute at any location if the data is within the boundary data. Furthermore, the attribute is stated as a spatial dependant, where the values that are close together are more probably to be the same as the values further away is one of the assumptions. These assumptions will then be used to formulate the interpolation model. This method is widely used to create continuous data where the data are collected at discrete locations (Bakkali & Amrani, 2008).

The CoGSI database management system is able to perform an interpolation given that any borehole log data (currently, limited to three boreholes from the consecutive locations). The Figure 10 shows an interpolation cross-section of three boreholes in Kuching Sarawak. The lithology in the figure displayed using colours to represent the strata or soil type. The lithology is basically showing the layer of strata where it uses to differentiate the soil layer. The data inserted is based on the collected SI data, which is stored in the CoGSI database. The negative value shown is mean the depth of the borehole.

The cross section is plotted according the lithological profiles of each borehole. The algorithm initially plots each soil layer according to the depth of the top and bottom value for each soil type. Only the same layer will be connected if they have identical layer. However, there are cases some borehole has additional layer, we regarded such layer as pocket where the layer will converge accordingly to the layer depth. To connect to the other boreholes, the soil of the same type between the borehole points are connected with straight lines. They are connected in such a way that the depth value of top of the soil in point B is to be connected to the depth value of top soil in point B, the depth value of the bottom of the soil in point A is to be connected to the depth value of bottom soil in point B. The same process is repeated if there is a point C. For example, if the first layer of point A is a clay, but the first layer that is a clay is at the 5th layer of point B. The first layer of point 1 will be connected to the 5th layer of point B.

5. Conclusions

The research has successfully developed the CoGSI database management system via Microsoft Azure SQL Database, where the system is able to digitized the borehole log data visualization, recording the laboratory and field-testing results and performing the cross-section interpolations. The CoGSI is able to be searched in multiple platforms via smartphones, desktop, portable laptop through web-based application, which spatially located in OpenStreetMap (OSM). In summary, this digitized database system focuses on Sarawak soils and is a secure website that will be very significant to the local government agencies, civil engineering consultants, contractors, universities, researchers and policy makers in planning for future development and making cost effective decisions. In addition, the CoGSI also serve as an efficient data entry for future recording Geotechnical SI information, thus contributes to big SI database compilation. Future upgrade CoGSI system will include a tighter integration with geological map, topographical data, hydrology, which then allows construction of 3-D subsurface images with all required data.

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