Creating a System for Storing, Processing and Presenting Geotechnical Information for Ghana

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Abstract. Site investigation is crucial to any civil engineering or land development project. The geotechnical information acquired through site investigations is essential for the safe and economical design of buildings and infrastructural works. The field and laboratory tests (critical components of site investigations) required to obtain this geotechnical information can be expensive, time-consuming, and destructive. Acquiring preliminary geotechnical details on a site for a proposed civil engineering infrastructure helps make design and construction decisions. It can also help guide the detailed investigations that have to be conducted at proposed sites. Such preliminary geotechnical information will help reduce the cost and time required to carry out these investigations.

Geotechnical engineers would preferably want to obtain preliminary geotechnical information on a site from existing field logs and geotechnical reports. However, such documents are often not readily available because they are usually kept in hard copies instead of in a central place. A central repository for storing these data in an online database will be handy for accessing preliminary geotechnical information for civil engineering projects. This paper describes a project to create a system that stores, analyses, updates data, and provides geotechnical information in tables and maps. The project relied on secondary data from past and present geotechnical investigations. Available field and laboratory testing results from various site investigations conducted across some parts of Ghana were compiled in Excel and then stored and processed using Python Geopandas. The project team created geodatabase and thematic maps, which showed the spatial variations of some selected soil parameters.

The created geodatabase and thematic maps supply preliminary geotechnical information on sites that enable engineers to obtain such information on proposed civil engineering projects more efficiently, cheaply, and sustainably.

Keywords: Geotechnical Data/Information · Geopandas · Ghana

1 Introduction

Soils are naturally occurring materials that have intrinsic spatial variability due to natural factors and influences. It is difficult to estimate or predict the characteristic values to obtain reliable geotechnical designs with low cost and less effort (Ali and Shakir 2022).

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Thus, knowledge of the characteristics of soil at a particular site is essential to commence the construction of a structure. This aids in the choice of the type of foundation and its performance as well as the cost of the project (Gandhimathi et al. 2010).

For any civil engineering project, certain parameters/properties such as the depth at which the foundation will be placed, the allowable bearing pressure of the soil, swell potential, the soil types amongst others are of importance (Gandhimathi et al. 2010). These parameters are acquired through detailed field and laboratory investigations however, the site investigations can be expensive and time consuming.

Site investigations provide critical information on the soil characteristics of a location and are used for decision-making and designs. It involves desk studies, field investigations, laboratory testing, analysis, and reporting. The scope of investigations varies in areal extent, and details required depends on the type, size, stage, costs, environmental and social factors of the project. Desk studies are relevant and critical at the early planning stages where a wide range of factors need to be considered. This stage allows for effective planning of the field investigations usually entailing the study of past documents especially from nearby projects, studying maps, photographs (if available) and other relevant information (Manual for low volume design roads B 2019).

Time and cost are reduced by following this process. Unfortunately, it is sometimes difficult to obtain some of these information in Ghana when doing a desk study. There are some satellite images and geological maps that aid with the study of the geology of the areas but limited geotechnical information.

Information/Data gathered during Geotechnical investigations are usually stored in reports, and locked away in either agency offices, consultants, or clients. This makes the risk in losing the data through floods, fires, earthquakes extremely high (Examples can be cited all over the world where fire has gutted down structures that housed important documents, likewise floods).

Over the past four decades, Geographical Information Systems (GIS) has emerged as the preferred medium for storing and presenting geospatial data, including geotechnical, geological, and hydrological information. The use of GIS can reduce the time required for desk studies and make data more easily accessible and retrievable (Rogers et al. 2004; Wan-Mohamad and Abdul-ghani 2011).

In one study, GIS was used to store and present soil characteristics data from Seri Iskander, Malaysia. Maps describing soil types and soil strengths (SPT values) at various depths were constructed, and the data was always readily accessible and retrievable, reducing the time required for desk studies (Wan-Mohamad and Abdul-ghani 2011).

Another study was carried out in Coimbatore city, India, where 138 boreholes were used to develop a Soil Characteristics Prediction Model. The model was used to determine parameters such as allowable bearing pressure of soils, swell potential, and depth of placement of foundations. The researcher used GIS to manage the database and to develop thematic maps for depth, N value, free swell, and other parameters.

A study was also conducted in the Karso catchment in Bihar, India, where GIS was used to determine the sediment yield. The Integrated Land and Water Information System (ILWIS) package was used for spatial segmentation of the catchment into a network of cells with unique drainage directions, and for determining the physiographic parameters of the grids (Kothyari and Jain 1997).

Therefore, the objective of this project is to create a central repository that stores, analyses, updates data, and provides preliminary geotechnical information in tables and maps for civil engineering projects. By compiling and processing available field and laboratory testing results from various site investigations in Ghana, the project aims to supply geotechnical engineers with preliminary geotechnical information that can help reduce the cost and time required to carry out detailed investigations for proposed civil engineering projects. The system will provide this information more efficiently, cheaply, and sustainably, by using a geodatabase and thematic maps to show the spatial variations of selected soil parameters.

2 Methodology

This study utilized a cost-effective and efficient method of leveraging secondary data from past and present geotechnical investigations conducted by colleagues in the geotechnical engineering section of the civil engineering department at KNUST. The data mainly consisted of results from their private work for clients. In the future, the project team aims to expand data collection by collaborating with agencies and individuals willing to contribute to the database. However, the team anticipates challenges regarding data quality, particularly when sourced from individuals, and identifying contributors.. While the data extraction process for this study was manual, the team intends to use automated systems in the future. Private companies will be consulted on any legal implications for sharing their data, and a mutual system will be established to facilitate beneficial contributions.

Data Source:

The data used for this paper was collected from colleagues in the geotechnical engineering section, mainly from old site investigations conducted between 2016 to date.

Data Extraction:

Reports and summaries of laboratory and field data sheets from past and present geotechnical investigations were the sources of the data used in this study. The extracted data included GPS coordinates, soil types, index properties, and other attributes.

Data Compilation:

A total of 297 data points were compiled and tabulated in excel based on their GPS coordinates, soil types, index properties, and other attributes. The excel sheet was then formatted to make it easier to load into Geopandas. While the data extraction was done manually, automated systems like Tabula and other software that can help extract data directly from PDF files and the like will be utilized in the future.

Database:

The geodatabase is being built using Access. As the pool of data grows, other data management systems will be utilized.

Loading Data into Geopandas:

The compiled data was loaded into Geopandas, a Python library used for working with geospatial data, as a Pandas Data Frame, a data structure used for working with tabular data.

Data Analysis:

Geopandas was used to analyze the data and create thematic maps that showed the spatial variations of selected soil parameters. These maps provided preliminary geotechnical information on sites that could help engineers make design and construction decisions.

Data Presentation:

The compiled data, thematic maps, and spatial maps were presented in tables and figures in the paper to provide a clear and concise presentation of the data and the methodology used.

3 Results and Discussions

The present study has successfully developed a comprehensive database that includes 297 geographical locations across Ghana. This database provides relevant information, such as geographical location and index properties, extracted from various reports. The data is presented using Geopandas in Jupyter notebook, as shown in Fig. 1, while Fig. 2 displays the various data points overlaid on a shapefile of the Ghana Map.

The majority of data points are concentrated in the Ashanti Region (157) and the Greater Accra Region (61), indicating that these regions have seen more development and infrastructure projects compared to other areas in Ghana. Notably, a significant proportion of the data points in the Ashanti Region (129) were located within the Kumasi Metropolitan Assembly, indicating a high degree of urbanization and development in the area. This information is useful for policymakers and investors in identifying areas for further infrastructure development.

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Run Code

In [5]: point_data

Out[5]:

	TOWN	Location	Latitude	Longitude	Elevation	DEPTH	AVG. MC	LL	PL	PI	GRAVEL	SAND	SILT	CLAY	geometry
0	MBROM	BH3	6.704290	-1.623169	284.0	1.00-2.60	21.51	50.2	34.2	16.0	25.3	41.9	19.4	13.4	POINT (205408.831 225002.310)
1	MBROM	BH1	6.704034	-1.623152	284.0	1.00-4.00	19.92	49.6	34.2	15.5	28.0	47.9	15.0	9.1	POINT (205410.674 224973.947)
2	MBROM	BH2	6.704174	-1.623157	284.0	0.00-1.75	8.53	36.4	21.5	14.9	63.8	22.4	5.6	8.2	POINT (205410.141 224989.427)
3	PATASI ESTATE	DH2	6.676980	-1.647242	248.0	2.00-4.00	29.30	35.3	23.3	12.0	10.7	32	39.5	17.8	POINT (202743.764 221986.059)
4	PATASI ESTATE	DH1	6.676893	-1.647402	248.0	2.00-4.00	25.30	24.0	16.1	7.9	5.3	40.8	36.2	17.6	POINT (202726.063 221976.463)
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
292	TEMA	BH3	5.617544	-0.018916	10.0	3.30-4.00	22.30	40.9	23.2	17.7	1.3	61.1	11.5	26.2	POINT (382963.865 104899.201)
293	ACHEAMPONG ACCRA	DH1	5.531530	-0.347804	65.0	0.20-2.20	9.30	36.0	17.0	19.0	0.0	54	13.0	33.0	POINT (346542.713 95338.304)
294	ACHEAMPONG ACCRA	DH2	5.531661	-0.347769	64.0	0.70-1.50	10.30	43.3	19.6	23.7	0.0	36	16.6	47.3	POINT (346546.575 95352.792)
295	ACHEAMPONG ACCRA	DH3	5.531857	-0.347805	63.0	0.40-2.20	13.30	37.0	17.0	21.0	0.0	51	15.0	35.0	POINT (346542.563 95374.458)
296	ACHEAMPONG ACCRA	DH3	5.531857	-0.347805	63.0	2.20-2.70	8.80	33.8	16.9	16.9	NaN	0.3051.8	16.6	31.3	POINT (346542.563 95374.458)

297 rows × 15 columns

Fig. 1. GeoDataframe of compiled data

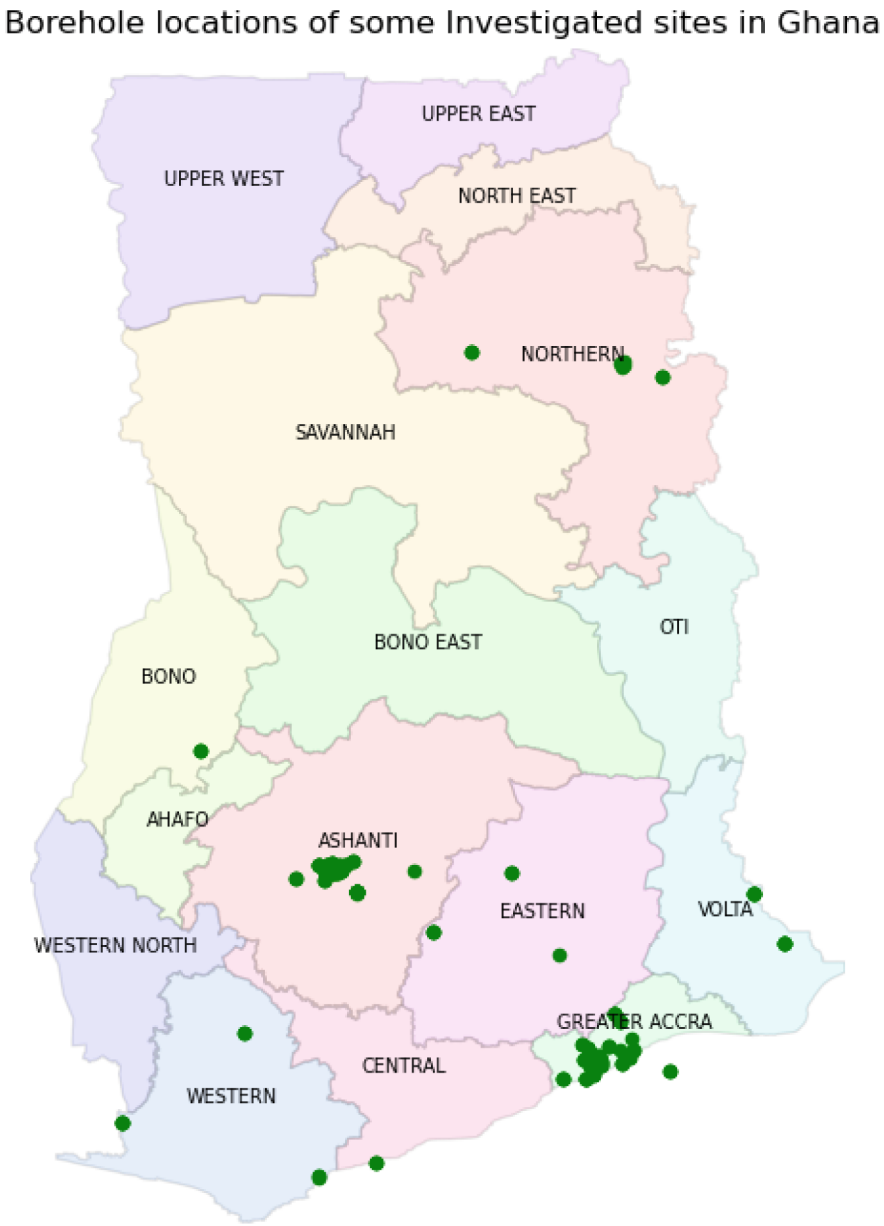

Fig. 2. Map of Ghana with borehole locations of some investigated sites across the country

By using GIS technology, the developed system provides geotechnical engineers with preliminary geotechnical information that can help reduce the cost and time required to carry out detailed investigations for proposed civil engineering projects. The system provides a more comprehensive database, including previously inaccessible data, and

allows users to make informed decisions about their projects. The use of GIS technology reduces the time required for desk studies and makes data more easily accessible and retrievable, leading to more efficient and effective infrastructure development.

It is important to note that this is a pilot project, and the database built is limited to the geotechnical engineering section of the civil engineering department of KNUST. After testing and approval, the section will liaise with other agencies to expand the database and roll it out on a national basis. At this stage, all modalities and how to contribute to the database and benefit from it will be discussed.

The central repository created by this study stores, analyzes, and updates data, and provides preliminary geotechnical information in tables and maps. This supplies geotechnical engineers with preliminary geotechnical information that can help reduce the cost and time required to carry out detailed investigations for proposed civil engineering projects, aiming to improve the efficiency and effectiveness of infrastructure development in Ghana.

Overall, the results of the present study suggest that the creation of a comprehensive database using GIS technology can provide valuable information for policymakers and investors and help geotechnical engineers make informed decisions about proposed civil engineering projects. The use of this database can ultimately lead to more efficient and effective infrastructure development, which is crucial for the economic growth and development of Ghana.

One of the major challenges encountered for this project was that some site investigations conducted more than five years ago did not have GPS coordinates, which prevented the plotting of data on the map. This may also be a challenge with other sources. As part of the cleanup process, the team will come up with ways to trace back to some of these projects to pick up coordinates to build a more robust system.

4 Conclusion

Building a comprehensive and accurate geotechnical geodatabase for Ghana is not without challenges. These challenges include limited resources and technical expertise, inconsistent data collection methods, data security and privacy concerns, and a need for coordination and collaboration among stakeholders.

Additionally, there are limitations to the accuracy and reliability of the results obtained from the geodatabase. These limitations include data quality, completeness, bias, spatial resolution, data accessibility, data updating, and generalizability.

To address these challenges and limitations, stakeholders must collaborate and coordinate their efforts. Standardized data collection methods must be adopted, and data accessibility and updating must be prioritized. Strict privacy regulations must be adhered to, and the quality and completeness of the data used must be assessed. Any biases and limitations that may affect the accuracy and generalizability of the results must also be carefully considered.

Overall, building a geotechnical geodatabase for Ghana is crucial for sustainable land development and civil engineering projects. Overcoming these challenges and limitations will result in a comprehensive database that accurately represents the geotechnical landscape of the country, supporting evidence-based decision-making.

To accommodate growth and expansion of the database, and to get stakeholders on board, the team plans to liaise with other stakeholders who are well-versed in data management. Their support will be crucial in developing a robust system for the future.

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References

Ali, H. M. And Shakir, R. R. (2022) 'Applying A Python Script to Predict the Geotechnical Properties of The Nasiriyah Soil Applying A Python Script To Predict The Geotechnical Properties Of The Nasiriyah Soil', Pp. 0–13. Doi: https://doi.org/10.1088/1755-1315/961/1/012004.

Gandhimathi. A., Arumairaj. P. D., Lakshmi Priya. L., M. T. (2010) 'Spatial Analysis Of Soil In Coimbatore For Geotechnical Engineering Purposes', *International Journal Of Engineering Science And Technology*, 2(7), Pp. 2982–2996.

Highway, M. Of R. And (2019) *Manual for Low Volume Roads Part B*.

Kothyari, U. C. And Jain, S. K. (1997) 'Sediment Yield Estimation Using GIS Sediment Yield Estimation Using GIS', *Hydrological Sciences Journal*, 6667(2009), Pp. 833–843. Doi: https://doi.org/10.1080/02626669709492082.

Rogers, J. D., Rogers, J. D. And Luna, R. (2004) 'Scholars' Mine Impact of Geographical Information Systems On Geotechnical Engineering Geotechnical Engineering', Pp. 0–23.

Wan-Mohamad, W. N. S. And Abdul-Ghani, A. N. (2011) 'The Use Of Geographic Information System (GIS) For Geotechnical Data Processing And Presentation', *Procedia Engineering*, 20, Pp. 397–406. Doi: https://doi.org/10.1016/J.Proeng.2011.11.182.