Interpolating Engineering Soil Parameters in Terrain Regions of Rinchending using Geostastical Tools in ArcGIS

Manish Sharma[1] Manoj Pradhan[2], Pem Jigme[3] Sonam Choden[4] Dr. Cheki Dorji[5]

Research and Publication Board, Department of Civil Engineering, College of Science and Technology, Royal University of Bhutan
* E-mail: edc2011022@cst.edu.bt[1], edc2011023@cst.edu.bt[2], edc20009056@cst.edu.bt[3], edc2009084@cst.edu.bt[4], cdorji@cst.edu.bt[4]

Abstract

Geotechnical investigation is a perquisite to any civil engineering project. Soil parameters like Specific Gravity, Moisture content, Dry Density, Plasticity Index, Grain Size Distribution, etc… are very important for geotechnical studies since they determine the engineering behavior of the soil. Knowledge of these parameters are crucial to any engineering project. These parameters vary spatially along the surface and the depth of earth strata.

This project is on geospatial mapping of engineering soil parameters and each engineering soil parameter has its own significance and is indicative of a particular soil property. For instance shear strength parameters C and ϕ are related to the soil's ability to take up shear stress while optimum moisture content is indicative of the maximum compactness of the soil. Thus the maps developed with the project can be used for varied purposes. The grain size distribution parameters (Cu and Cc) have further been used to classify the soils into different soil classes as per the IS standards.

In recent years, Geographic Information System has been widely gaining popularity in geotechnical field. GIS has been used in many geotechnical application ubiquitously all over the world (Haider et al., 2013). The attempt of this project is to develop thematic maps for various engineering soil parameters from ground investigated soil samples using interpolation techniques in ArcGIS Geostatistical Analyst extension. The soil maps are to help enhance decision making process for engineers on assessing soil suitability as shallow foundations and providing easy access to geotechnical data of any area of interest with minimum effort.

Key Words : *Geographic Information System (GIS), ArcGIS 10.1, Krigging, Geostastical Analyst*

1. INTRODUCTION

Characterizing engineering properties of the soil and analyzing their spatial pattern has a key role in managing soils for every engineering use since soil physical properties are a predictor of Soil Strength (Roopnarine R. 2011). With development, a sound geotechnical assessment requires a thorough quantification of soil properties. While traditional approaches of site characterization are expensive and provide location specific values for the soil parameters posing challenges in evaluating the variability of soil parameters in space.

The soil attributes are not randomly distributed within the environments or in the landscape and they are made up of regionalized variables. As such, some soil samples are more similar than others based on the distance separating their positions (Gonzalez Zak, 1994). The recognition of this spatial variability is essential in better understanding the spatial distribution of soil properties and to develop more precise estimates of the properties.

That necessity to understand the spatial behavior of soil properties has conditioned the use of several spatial prediction methods, going beyond sample points to the construction of continuous surfaces, the soil maps, using deterministic interpolators, such as Inverse Distance Weighted and geostatistical methods, like Ordinary Kriging, Simple Kriging, etc…

Geostastical tools have gained popularity in mapping of soil parameters. But much of the studies have been carried out for plain region and very few studies till date have been carried out in hilly or mountainous regions.

2. STUDYAREA

With increasing development and hike in population constructions are looming and the line of urban settlements extending from the main Phuentsholing town towards its outskirts, into Kabraytar and Kharbandi regions. The project study focuses on the Kharbandi region, reaching boarders of Toribari. The study extent encompasses an area approximately 3.144 km2 with an elevation difference of 524 meters extending from 89 ° 22' 57.98 " East to 89 ° 24' 21.23" to West and 26 ° 50' 30.14" towards South to 26° 51' 47.73" to North, rising right from the Indian Plains towards the South to the majestic Himalayas in the North.

vegetation cover with major coverage of broad leaved forest.

3. ETHODOLOGY

3.1 Data Collection and Laboratory Testing

24 geotechnical bore logs are compiled for the study. 12 trial pits were dug to obtain the soil samples for laboratory testing. Data obtained from 5 trail pits dug inside CST campus areas for Geotechnical Site Characterization of CST campus was used as well and the remaining data were acquired from geotechnical reports by Department of Geology and Mines (DGM) for Rinchending checkpost area, Goenpa area and Phuentsholing FCB construction data. More data existed but couldn't be used since they had used

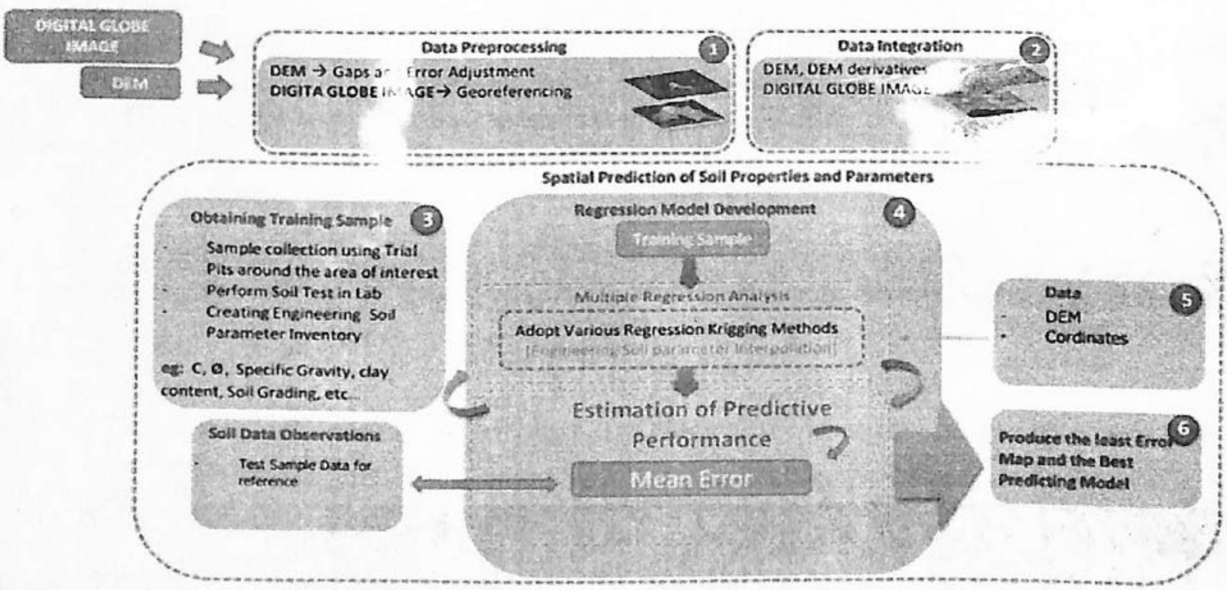


Fig. 1 Detailed methodology for the study

The project started with a test model development with CST campus as the main area of interest. Later the area was extended into the area represented with the prior coordinates. The study region has a record of multiple landslides, still active and widening. This area has a very humid-summer receiving heavy downpour from early May to late August and remains basically dry in the winter. The area has more or less the same

traditional methods for their sampling i.e., the trial pit's locations were referenced with respect to nearby features and thus accurate location couldn't be obtained due to unavailability of geographic coordinates.

The samples obtained using the trail pit method were then tested in the laboratory to obtain the engineering soil parameters.

3.2 Methodology

The engineering soil parameters thus obtained are then fed to ArcGIS as attributed to point vectors and interpolated using the Geostastistical Analyst extension. Following a structured procedure is important while interpolation with proper data exploration prior to obtaining a continuous surface. The detailed methodology that has been applied to the study is as presented in *figure 1*.

The borelogs data are imported to ArcGIS 10.1 as digital layers and converted to assessable formats by Geographic Information System (GIS). This technique has been utilized to produce digital zonation maps for the study area. The application of interpolation techniques allows the production of zonation maps and brings together years of geotechnical data.

The first step was the collecting of geotechnical data from the geotechnical investigation reports. These data were available in many different locations and forms. Next, data has been tabulated by using Excel to make it familiar with the GIS environment.

The spatial locations of boreholes have been designated by using GPS coordinated. Google Earth coordinates based on boreholes' actual locations can be used but the maps would be less accurate compared to the GPS coordinates. By calculating the distances between separate boreholes and the distance between the borehole itself and the adjacent boundaries on the site plan, boreholes' coordinates can be acquired from Google Earth. Then six interpolation techniques in the Geostatistical Analyst in ArcMap 10.1 were used. The six interpolation techniques examined were:

1. Inverse Distance Weighing
2. Ordinary Kriging
3. Simple Kriging
4. Universal Kriging
5. Disjunctive Kriging
6. Cokriging

Comparison between these 6 interpolation methods has been conducted to identify which technique gives better representation for the soil data in the study area among the other interpolation techniques.

4. DATA ANALYSIS

4.1 Relationships and their applications

Data analysis is very important to draw inferences in any project. Our project mainly focuses on analysing the field data and performing regression analysis to generate logical and strongly correlated relationships. These relations give logical trends on how each engineering parameters change with respect to elevation and other soil parameters.

These relations are particularly used to predict other parameters from a single parameter to facilitate in determining values without having to con-tuct tests for each and every parameter. This annalysis also features validating relationships. The relations help us in validating the numerical model used to produce the map.

a. Validating Correlations

These relations are build among the soil parameters and their elevation from the sea level to check their interdependency. Two cases are showcased concening maps build using co-kriging as the model.

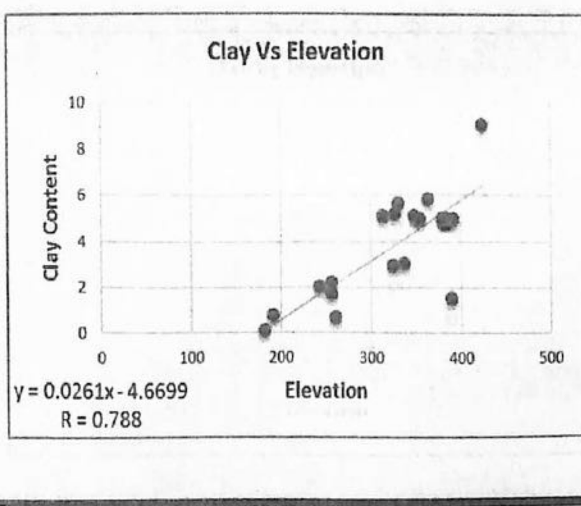


Figure 2 validates that clay is related to elevation with very good correlation of 78%. The numerical model used to produce map for clay content was Cokriging. Therefore this strong relation validates that clay is strongly related to elevation and the numerical model used to produce the map is also correct.

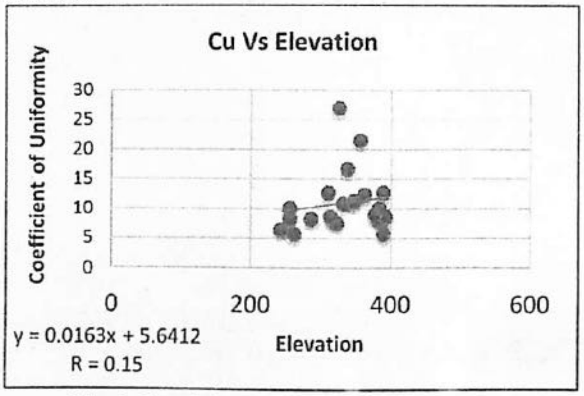


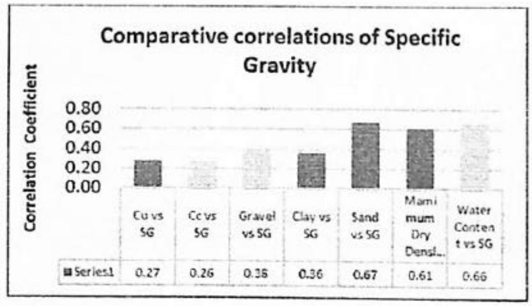
Fig. 3 Correlation between Cu and Elevation

Figure 3 is specifically chosen to validate that coefficient of uniformity is not at all related to the elevation as the maximum error was given by Co-kriging while performing interpolation.

b. Relations for prediction

Although correlation between the soil parameter is not a causal relationship but it can still be used to predict one from another parameter and made more accurate by taking more data. These relations hold importance mainly at our area of interest. The relations can be a guidance to relate soil parameters at other areas as some parameters in our area of interest has very strong correlation and can be logically backed by theories, on how they are related.

Stanovich (2007) points out that "once correlation is known it can be used to make predictions. When we know a score on one measure we can make a more accurate prediction of another measure that is highly related to it. The stronger the relationship between/among variables the more accurate the prediction."



Positive Correlation Negative Correlation

Fig. 4 Comparative correlation of Specific Gravity with other engineering parameters

Figure 4 shows the correlation coefficients we can infer that specific gravity has very good correlation with sand content. Theoretically specific gravity is directly proportional to its porosity and sandy soil is very porous. Therefore this relation is much valid in terms of theoretical background and that of regression analysis performed above.

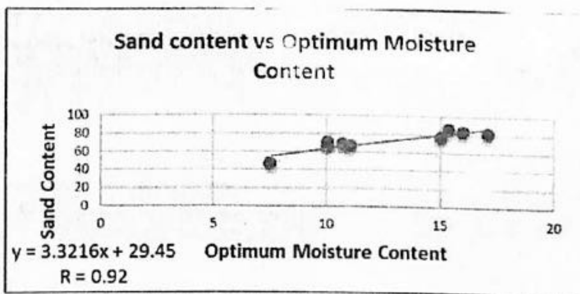


Fig. 5 Sand Content Vs Optimum Moisture Content

After few more analysis, a strong relation between the sand content and the optimum moisture content was found.

Sand is porous soil which can retain less water compared to clay and silt. These porous soil needs more water content to reach its maximum compaction and the graph above clearly validates it.

With increase in sand content in a soil, more water is required to reach its maximum density. Therefore we can calculate the maximum dry density and the optimum moisture content from sand content as a very high correlation of 92% is between them. As learned earlier, maximum dry density is highly related with liquid limit and plastic limit. Therefore sand content can be indirectly related to the Atterberg's limits. Sand also has good correlation with specific gravity. These interconnected relations are very important to find as it becomes easier to determine many parameters by knowing a single parameter as said by Stanovich (2007).

5. CONCLUSION

This Research mainly concludes that geostastical analysis can be successfully employed for predictive soil mapping even as has been applied in the mountainous region: the first rising Himalayan terrains of Rinchending. GIS and specifically Geostastical Analyst extensions can be used to map engineering soil parameters within reasonable error range.

Some of the inferences made from the data analysis are as follows,

a. It was also found that not all the engineering soil parameters show relation with one another. Of all the studied parameters Plastic Limit and liquid limit was the most related parameter (90.1%). The major soil type in the study area was found to be Well Graded Sand (72 % of entire area of interest).

b. The data analysis also fetched results confirming CST area to have well graded gravel along its area as it was found to be well graded sand previously. After several correlation computations we can conclude that optimum moisture content and dry densities have very strong relations with the soil parameters.

c. The regression analysis between clay and elevation validates that clay is related to elevation with very good correlation of 78%. The numerical model used to produce map for clay content was Cokriging. Therefore this strong relation validates that clay is strongly related to elevation and the numerical model used to produce the map is also correct.

d. Sand being a porous material has to have high moisture content to have maximum compaction. Therefore its relation with optimum moisture content was built and seen very positive result, having 92 % relation among themselves.

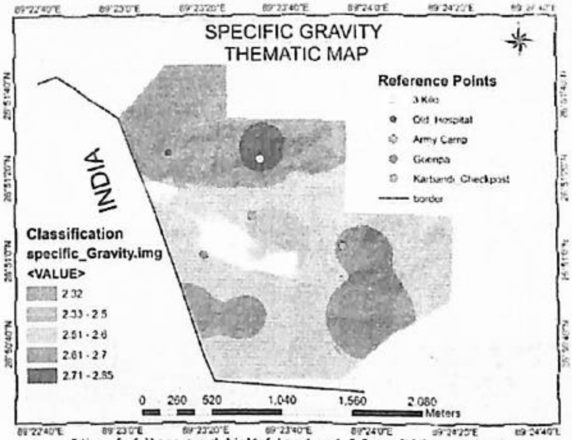


Fig. 6 Clay and Silt Content Map (Thematic)

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