SOIL MAPPING USING GIS

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Abstract - *Pathanamthitta is one of the most developing districts in Kerala. Such a growing city does not have a proper Geodatabase or a soil property map which could make the civil engineering works easier. Soil samples from different sites was collected and tested to determine the index and engineering properties of the soil. The test was conducted according to IS code procedures. The soil properties thus evaluated was inputted to generate soil property maps for the area. All the maps were generated using ArcGIS 10.3.1 version. The main objective of this study is to create a database of soil properties and boring location plans and corresponding test boring logs and thus maximize the use of GIS techniques to access land use and soil classification. Geodatabase is obtainable and simply accessible; it'll be of great advantage for civil engineering works. This study aims to research the development of a Geographic system (GIS) to better manage and disseminate soils information, as developed from soil test results.*

Key Words: *Geodatabase, GIS, ArcGIS 10.3.1 version, Index properties, Engineering properties.*

1.INTRODUCTION

Pathanamthitta District is situated at the southern part of Kerala, India. The district headquarters is within the town of Pathanamthitta. The latitude and longitude of Pathanamthitta is 9.2648^{0}N and 76.7870^{0}E respectively. The district is 10.03% urbanized. Pathanamthitta district has an elevation of 18 m from the sea level. The district experiences a moderate climate including two rainy seasons (south-west monsoon and north-east monsoon). Soil properties play a vital role in civil engineering field and agricultural field. With the help of a proper Geodatabase civil engineering works done easier. The GIS (Geographic Information System) has been used as a vital tool in civil engineering fields in recent years for a variety of applications. In fact, geotechnical characterization of an area was an arduous task before GIS because of complexity of soil logs and their data representation. Thus, the necessity for the GIS which transforms all paperwork (hard copies) into digital forms to form data quickly accessed and simply analysed, is inevitable. Zonation maps can be used in different engineering disciplines for providing information on slope stability, seismic micro-zonation, groundwater quality, watershed, vegetation and landslide hazard assessment.

1.1. PROPERTIES OF SOIL

Soil is a natural material, made up of different type of particles, having variety of engineering properties and index properties, most of which are not uniform, and it differ from one place to another. The properties of soil which are used in the recognition and classification of soil are known as index properties. Various index properties of soil are water content, specific gravity, particle size, consistency, relative density, etc. The major engineering properties are permeability, compressibility and shear strength. The following are the brief description of few engineering and index properties of soil:

i. Moisture content is that amount of water which is contained in the voids of the soil. It is one of the important factors on which the shear strength of soil depends on .
ii. Permeability indicates the ease with which the water flow through soils.
iii. Compressibility is related with the deformations which soil undergoes when subjected to compressive loads.
iv. The shear strength helps in determining stability of slopes, bearing capacity of soils and the earth pressures on retaining structures
v. Dry density of soil mass is the ratio of mass of soil solids to the volume of soil mass.
vi. The specific gravity of soil solids is the ratio of the density of a given volume of soil solids to the greatest density (at +4°) of an equal volume of pure water.
vii. The principal soil grain properties are the size and shape of grains and the mineralogical character of the finer fractions. The important aggregate property of cohesionless soil is relative density and that of cohesive soil is consistency.

1.2 Soil Mapping

There are different types of soil all over the world, a fact that there are different agents responsible for the building and formation of soil (landscape, climate, geology, vegetation, time and man). In the past 50 years, many countries in the world have been included in making maps of their soils to identify the range of soil types in their territory, where the soils originated and how they can be utilized. Soil mapping involves finding and identifying the different soils that originated, collecting data about their location, nature, properties and potential use, and recording this data on maps and to show the spatial distribution of every soil.

In order to map and identification of different types of soil, it is essential to have a system of soil classification. In the case of plants, we have the Linnaean system, so a parallel approach is required for soils. Soil classifications have brought a major challenge, one that must be sufficiently solved. At present there is no single system that can be used universally. There are two international systems, FAO-UNESCO and US Soil Taxonomy, but several other systems have developed, and many countries have developed their own systems appropriate to local state of soil formation and to local knowledge.

Traditionally, the soil mapping is managed with an auger and spade at intervals throughout the area. The intervals between inspections can be done according to a pre-determined grid (grid-survey) are based upon the apprehension of the surveyor who uses their knowledge of the affinity between soil type and landscape, geology, vegetation, etc. to determine where to make checkup. Auger borings are augmented by excavating profile pits at pre-determined points in the landscape. These profile pits are used to indicate lateral changes in the soil as well as vertical ones and are important for the full information of soil types and the soil sample collected for chemical, physical and biological laboratory analysis. Thus, a picture of the soil in that region and its relationship to the landscape is generated.

2. GEOGRAPHIC INFORMATION SYSTEM

Geographic Information System (GIS) is a technological field that assimilate geographical features with tabular data in order to analyze map and identify real world problems. Geography is the key word of this technology - which means, a few portions of the data is spatial. On other hand, data that is referenced to locations on earth. Biformed with this data is usually tabular data and known as attribute data. Attribute data can be defined as additional information about the geographical features. It is the combination of these two data types which enables GIS to solve problems through geographical analysis.

A GIS is a computer system that capable of assembling, saving, manipulating and displaying geographically referenced information, i.e., data identified according to their regions. Users also regard the total GIS as including operating crew and the data that go into the system. USGS defines a geographic information system as a computerized tool for mapping and analyzing things that remain and events that occur on earth.

GIS operates on many levels. The basic level of GIS technology is computer cartography that is used for straight forward mapping. The actual power of GIS is using geographical and statistical methods to analyze attribute and geographic information. The result of the analysis can be a derivative information, interpolated information or formulated information. It can be noted that GIS is considered synonymously with geospatial technology. But there is two other parts to geospatial technologies. They are remote sensing and GPS.

2.1. Principles of GIS

i. Data capture: Data used in GIS generally come from many types and are stored in several ways. A GIS bring tools for the combination of different data into a format to be correlated and analysed. Data sources are mainly attained from manual digitization and scanning of aerial photographs, paper maps, and current digital data sets. Remote sensing satellite imagery and GPS are auspicious data input authority for GIS.

ii. Database Management and Update: After data being collected and combined, the GIS must bring facilities, which can be stored and maintained data. Effective data management should include the following aspects: data integrity, data security, retrieval, data storage and data maintenance abilities.

iii. Geographic Analysis: Data combination and alteration are not only a component of the input phase of GIS. GIS quantitatively and qualitatively analyse and interpret the collected data.

iv. Presenting Results: GIS technology is one of the most exciting aspects of different ways in which the information can be visualized once it has been handled by GIS. Traditional methods of calculating and graphing data can be augmented by maps and 3D images. Visual communication is one of the most intriguing aspects of GIS technology and is accessible in a differing range of output options.

2.2. Advantages

- Improved project efficiency and cost saving
- Better decision making
- Improved communication
- Better geographic information record-keeping
- Higher quality analysis
- Improving organizational integration

3. OBJECTIVES OF THE STUDY

i. To evaluate the index and engineering properties of soil samples collected from different parts of Pathanamthitta district.
ii. To create a database involving the geotechnical properties of soil in Pathanamthitta district.
iii. To collect the bore-log details at different locations of Pathanamthitta district.
iv. To determine the allowable safe bearing capacity of soil from SPT-N value.
v. To generate the soil property maps using ArcMap 10.2.

   a. Variation in particle size distribution of soil
   b. Variation in compaction characteristics of soil
   c. Variation in physical and index properties of soil
   d. Variation in engineering properties of soil
   e. Variation in consistency limits of soil

vi. To generate the SPT N value zonation map at 10ft, 25ft, 50ft, 75ft and 100ft depth using GIS.
vii. To generate the allowable safe bearing capacity value map using GIS.
viii. To identify issues with soil samples collected.

4. SCOPE OF THE STUDY

- Reference for consultancies doing major geotechnical engineering projects and works
- Provide an aid for researchers to do their project on geotechnical engineering
- Help the organizations to know the type and suitability of different soils for different works

5. METHODOLOGY

In order to apply GIS in geotechnical engineering, the licensed software from ESRI is important. The free version of GIS is QGIS which is also very user friendly. Digital elevation model of any place under the world can be obtained from USGS website. This will be in the form of a shape file which can directly added into the GIS worksheet. The required area can then be extracted using GIS tools. The primary data (soil properties tested) regarding a site with geographical coordinates was incorporated into GIS worksheet from excel file using conversion tools in the Arc tool box. Thus, the exact latitude and longitude of data are incorporated into worksheet. The sampling points can be incorporated into the Google Earth Pro to create the Google Earth scene of sampling points and boundary of study area. Using Spatial analyst tools, different operations like interpolation, trend, etc. can be done to know the features of locations whose data are unavailable. The file can be saved in as a shape file and can be converted into a map using layout features and exported as a image file.

Soil samples were collected from 22 different sites in Pathanamthitta district.

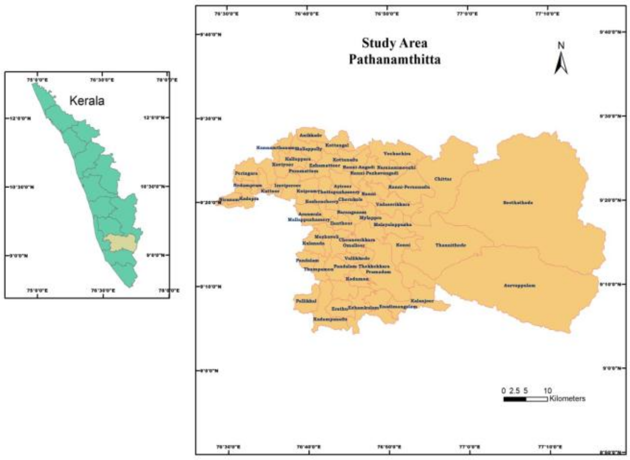

Fig -1: Map of Pathanamthitta

Table -1: Site points

Sample No.	Place	Latitude	Longitude
1	Parakode	N9.152108	E76.753262
2	Karuvatta	N9.161148	E76.725260
3	Puzhikad	N9.206456158	E7667100079
4	Koodal	N9.140323	E76.855804
5	Adoor	N9.164094481	E76.74452638
6	Kulanada	N9.230953692	E76.69960536
7	Adavi	N9.245845834	E76.90966676
8	Pandalam	N9.223124	E76.676277
9	Pathanamthitta	N9.256121	E76.773119
10	Aranmula	N9.326759	E76.684475
11	Parumala	N9.334918	E76.54991
12	Ranni	N9.376046	E76.784484
13	Pathanamthitta Bus Stand	N9.266476	E76.789965
14	Pathanamthitta Jail	N9.265121	E76.792619
15	Seethathod	N9.323736	E76.977033
16	Niranam	N9.341062	E76.516750
17	Kozhencherry	N9.333247	E76.707649
18	Pathanamthitta	N9.263443	E76.787239
19	Chandanapally	N9.2088888	E76.766850
20	Adoor Bypass	N9.164094481	E76.74452638
21	Mylapara	N9.272341	E76.799908
22	Thiruvalla	N9.380862	E76.572862

6. RESULTS

Fig. 2 shows the variation in moisture content. The range of moisture content obtained from oven dry method varies 12.3% to 47.29%.

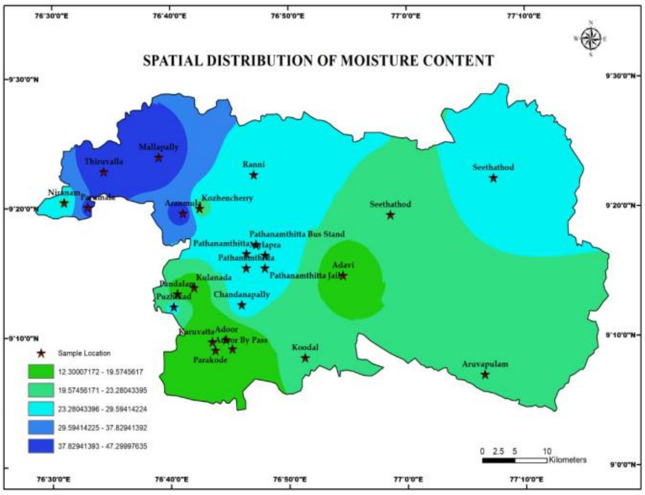

Fig -2: Variation in moisture content of soil

Fig. 3 shows the variation in specific gravity of soil. The range of specific gravity varies 2.64% to 2.70%. According to the specific gravity the soil can be classified as:

Table -2: Typical values of specific gravity

Soil type	Specific gravity
Clean sand and gravel	2.64-2.68
Silt and silty sand	2.66-2.70
Inorganic clays	2.70-2.80
Soil high in mica, iron	2.75-2.85
Organic soil	<2

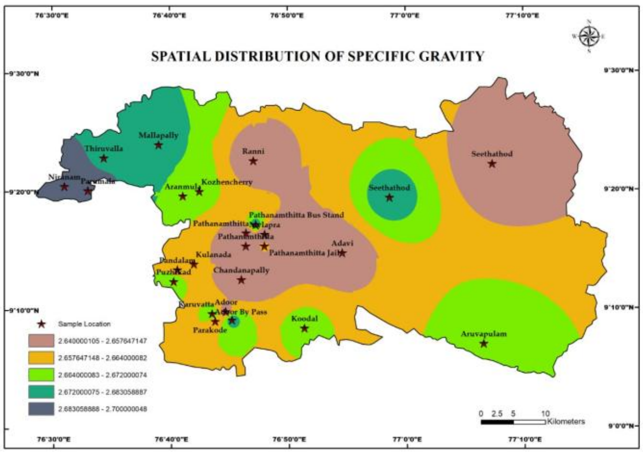

Fig -3: Variation in specific gravity of soil

Fig. 4 shows the variation in angle of internal friction of soil. The range of angle of internal friction varies 22.53% to 41.99%, which is obtained by direct shear test.

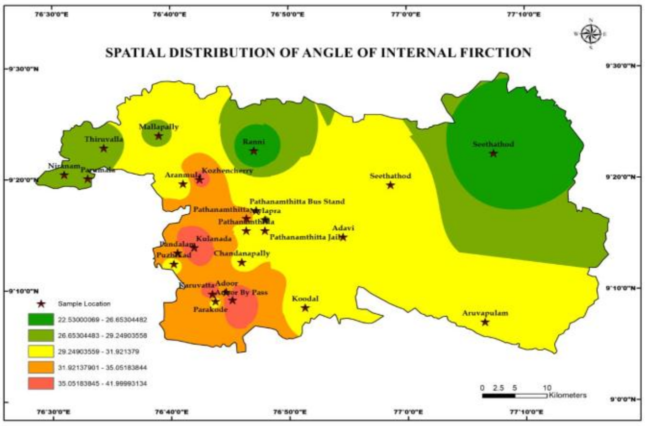

Fig -4: Variation in angle of internal friction of soil.

Fig. 5 shows the variation in optimum moisture content of soil. The range of optimum moisture content varies 0.16% to 35%, which is obtained by compaction.

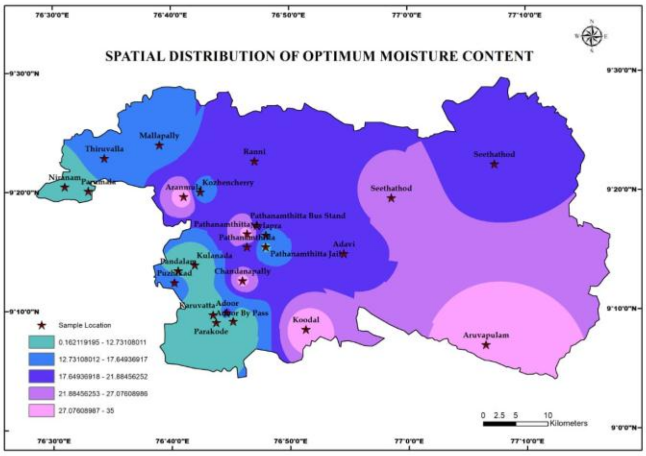

Fig -5: Variation in optimum moisture content of soil

Fig. 6 shows the variation in maximum dry density of soil. The range of maximum dry density varies 1.10% to 1.85%, which is obtained by compaction.

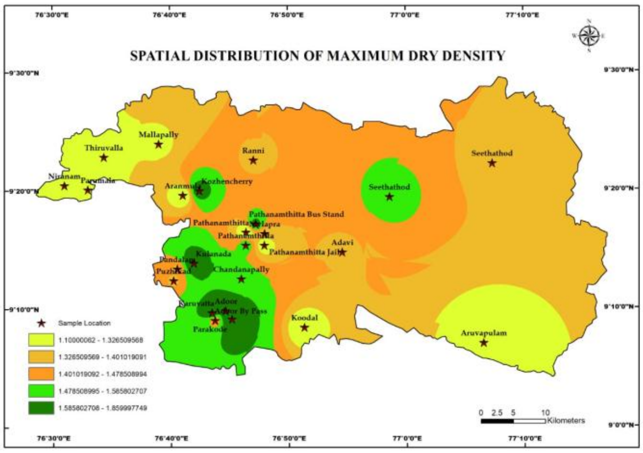

Fig -6: Variation in maximum dry density of soil

Fig. 7 shows the variation in bulk density of soil. The range of bulk density varies from 1.40% to 2.04%.

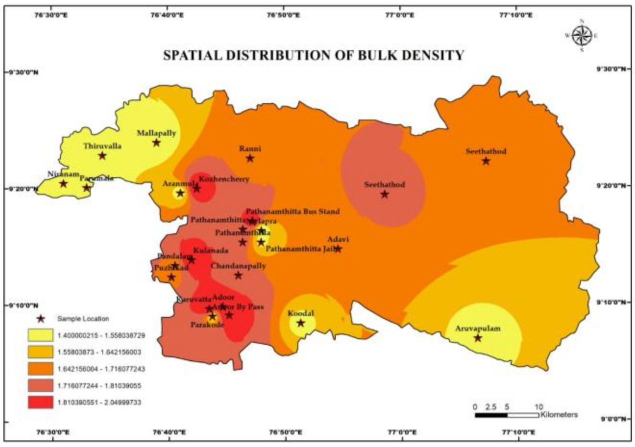

Fig -7: Variation in bulk density of soil

Fig. 8 shows the variation in relative density of soil. The range of relative density varies from 1% to 84.99%.

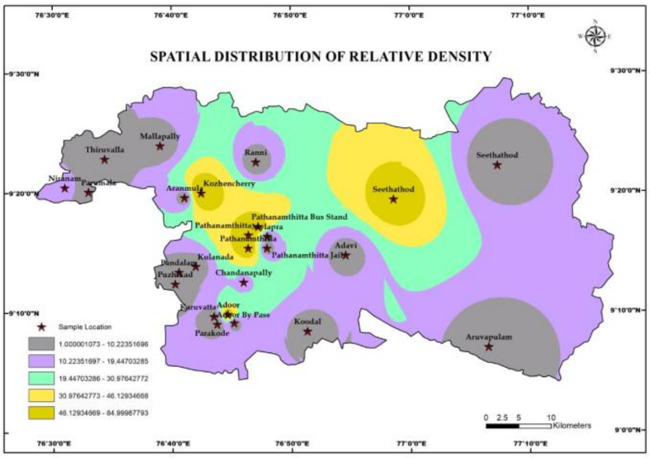

Fig -8: Variation in relative density of soil

Fig. 9 shows the variation in unconfined compression strength of soil. The range of unconfined compression strength varies 0.25% to 4.62%.

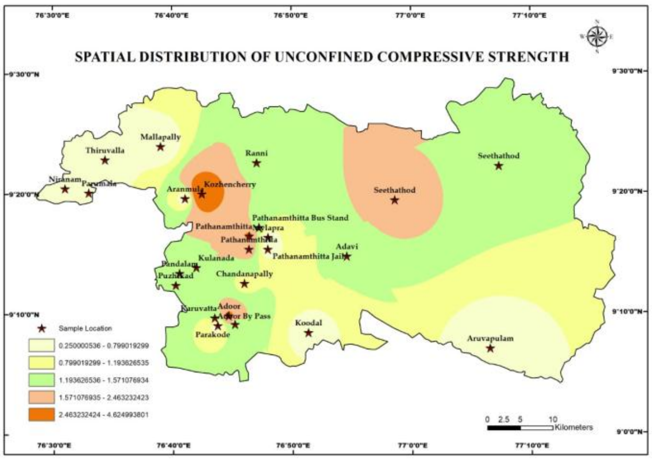

Fig -9: Variation in unconfined compression strength of soil

Fig. 10 shows the variation in cohesion of soil. The range of cohesion varies 0.05% to 0.08%.

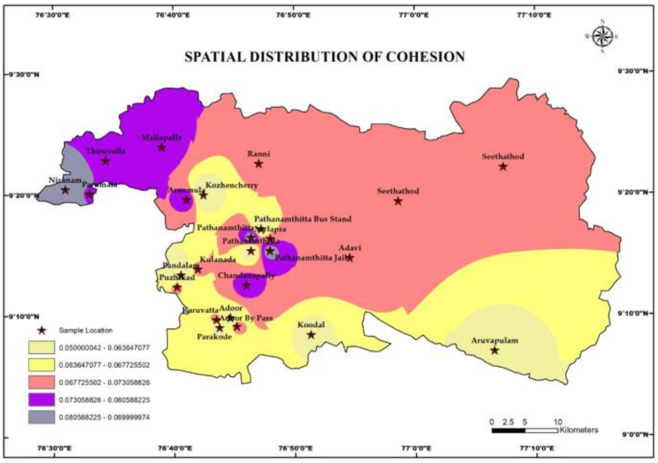

Fig -10: Variation in cohesion of soil

Fig. 11 shows the variation in SPT-N value of soil. The range of SPT-N varies 1% to 39.99%, which is obtained by standard penetration test.

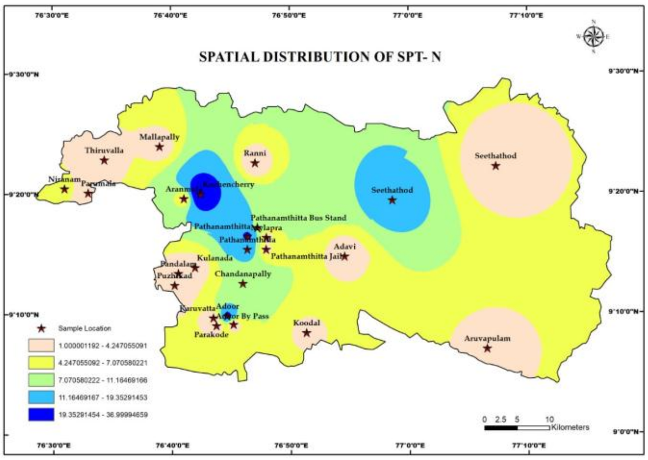

Fig -11: Variation in SPT-N value of soil

3. CONCLUSION

Geographic system (GIS) is cheaper and faster technique than the normal ones in delineating and mapping soil properties. Pathanamthitta is one amongst the rapidly developing districts because of budgetary constraints, small projects often overlook site characterization. Thus, the requirement for the GIS which transforms all paper work (hard copies) into digital forms to create data quickly accessed and simply analysed is inevitable. There comes the social relevance of this subject. Creation of geodatabase and generation of soil property maps using geographic information system helps in resolving the problem to certain extend. Soil samples from 22 different regions in Pathanamthitta district was collected and tested as per IS specifications. Index and engineering properties of soils present over Pathanamthitta regions was estimated for creating a database and these properties were represented within the type of soil maps using Geographic information system (GIS). Geotechnical engineers can run more queries of varied combinations regarding the soil properties which can help in decision making process. The GIS maps produced gives a concept on the soil properties over the specified study area. Thus, this project is going to be beneficial to the Geotechnical Engineers, Consultants, Investigators and Clients.

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