Spatial Analysis Of Geotechnical Characteristics Of Soils In Perundurai

Raja K, Dheeran Amarapathi G, Santhosh Kumaar K

Abstract: In recent years, there has been a tremendous increase in the construction of buildings. The methods used for determining the engineering properties of undisturbed sample are quite difficult and most of the methods are rather expensive, time consuming and involve test procedures. On the other hand, test to determine index properties are quite simple and less expensive. The index properties of soil are used to predict or correlate the Engineering properties of soil. The present study is to predict the insitu density, permeability characteristics, shear strength parameters and subgrade strength of soil at Perundurai zone and to develop a spatial representation map by using GIS. This software is used for visual interpretation of data. The soil samples were collected from 21 places in and around the perundurai zone. The tests were carried out and the results obtained from index properties and Engineering properties were plotted using GIS.

Index Terms: GIS, Index properties, permeability, shear strength, subgrade

1. INTRODUCTION

The determination of properties of soil are entirely depend upon the number of bore holes the difficulty in obtaining undisturbed samples and most of the methods are rather expensive, time consuming and involve elaborate test procedures. To decide the quality of soil for construction purposes various tests are conducted both in the field and laboratory. It includes Moisture content, Atterberg limits, Specific gravity, Dry density of soil and Compaction test. Classification of soil is necessary as it gives overview of both index and engineering properties. There are number of classification systems have been developed depending on the intended purpose of the system. Soil classification has always served to be feasibility criteria to a soil Engineer nd general guidelines can be suggested from the experiences. It is classified based on grain size, Textural classification, AASHTO classification system, Unified soil classification system and BIS classification. Classifications for engineering properties should be based mainly on mechanical properties, e.g. shear strength, compressibility, permeability, sub grade strength. The need for a better understanding of soil properties, for engineering and safe construction proposes, a zoning study is carried out [1]. These components include Borehole position (position and altitude),Drilling Type (manual or machine),Groundwater level, Depth, Profile classification of soils at various depths, Atterberg Limits at different depths (including LL, PL and PI), Permeability at different depths, Shear strength parameters C and φ in direct shear at different depths, Elastic parameters at different depths in the loading page, NSPT at different depths, Soil density (in normal, dry and saturated) at different depths, Moisture content at different depths.

"Geographic Information System" (GIS) is a software tool that allows us to create, manipulate, analyze, store and display information based on its location. Different kinds of geographic information, such as digital maps, aerial photographs, satellite images and global positioning system data (GPS), along with associated tabular database information can be interpreted from GIS. Interpolation is used to determine the cell values by using a linearly weighted combination of a set of sample points. The surface is being interpolated and the variable is being mapped.

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2 MATERIALS AND METHODS

The samples are collected from the Perundurai zone of about 21 different locations around 2 Sq.km. The details of location from where sample is taken is shown in figure 1 and table1.The samples were collected in a distributed state, by manual excavations, in sufficient quantity to complete all the tests. The samples were air dried for three days. The samples were classified by index property tests like specific gravity, Sieve analysis are used for the identification of soil. In engineering property test, shear strength, subgrade strength, field density and Permeability are determined [2]. Soil tests are classified as Index Tests and Engineering tests. As the samples collected are heterogeneous in nature the classification and tests on index properties serves as a guidelines [3]. This soil classification will be used in future projects.

2.1 Specific Gravity

For Specific gravity helps in the calculation of void ratio, porosity and degree of saturation. It is used in computing the soil particle size by means of pyconometer. About 200 grams of oven dried soil passing through 4.75 mm I.S sieve is taken. Weight of the empty pyconometer is taken as W_1grams.Weight of pyconometer and dry soil is taken as W_2grams.Weight of the pyconometer ,soil and water is taken as W_3 grams. Weight of the pyconometer filled with water is taken as W_4.Specific gravity for all 21 samples in table 3 is computed using the formula,

$$G \text{ at } 27^0 C = \frac{W_2 - W_1}{(W_2-W_1) - (W_3-W_4)} \quad (1)$$

2.2 Sieve Analysis

Soil having particles larger than 0.075 mm size are termed as coarse grained soils. Dry sieve analysis is used for coarse grained soil classification based on their gradation. The grain size distribution curve gives an idea regarding the gradation of the soil whether the soil is well graded or poorly graded. About

1 Kg of soil is taken. Sieve the soil through sieves of size 4.75 mm, 2.36 mm, 1.18 mm, 600µ, 300 µ, 150µ and 75µ using a mechanical shaker for 10 minutes. Weight the soil retained on each sieve. The sum of retained soil is checked against the original mass of soil taken. The particle size distribution curve is obtained by plotting particle size in X-axis and % finer in Y-axis using semi log sheet. The classification of samples obtained from 21 locations based on particle size distribution is given in table 2.

2.3 Field Density

The density of the soil is determined by means of core cutter method. In this method the unit weight of soil obtained from the direct measurement of weight and volume of soil which is obtained from field. The inside dimension of the core cutter is measured and the volume is calculated. The inside portion of the core cutter is greased after weighed. The dolly is placed at the top of the core cutter and it is drived into the soil with the help of rammer until the dolly is levelled into the surface. The core cutter is digged out from the soil. The dolly is taken outside and it trimmed flat. The weight of the core cutter with soil is measured. The field density obtained in given in table 3.

2.4 Standard Proctor Test

Compaction can be generally defined as the densification of soil by the removal of air and arrangement of soil particles through the addition of mechanical energy. The standard proctor compaction test is a laboratory method to determine the optimum moisture content at which a given soil type behaves most dense and achieve its maximum dry density. It shows that the dry density of a soil for a given compactive effort depends on the amount of water the soil contains during the soil compaction. The chart for the dry density to moisture content is then plotted to establish the compaction curve. The maximum dry density is finally obtained from the peak point of the compaction curve and its corresponding moisture content, also known as the optimum moisture content. Degree of compaction is obtained from the ratio of field density to the density achieved in the laboratory is given in table 3.

2.5 Permeability

Permeability of porous medium is a key parameter to analyse the flow behavior and characterization of reservoir for the optimization of hydrocarbon production [4]. The seepage of water is important in soil, so the permeability plays a major role. The permeameter mould is filled with the soil sample and the weight is determined. The permeameter mould assembly with sample is kept at the bottom tank. The water is allowed to flow into the permeameter by opening the tap and the air valve is released. The water will comes out when the soil sample is saturated. The bottom valve is opened and the water is collected through the specimen and the average quantity of water is determined by Constant head method. The co efficient of permeability for all 21 samples is determined by constant head method and given in table 4.

2.6 Direct Shear Method

Shear strength is the principal engineering property of soil, which controls the stability of a soil mass under structural loads [5]. Determination of the shear parameters of soils such as angle of internal friction and cohesion is a major interest in the geotechnical structures. [6] Direct shear testing of unsaturated soils is desirable since less time is required to fail the soil specimen. A conventional direct shear apparatus was modified to use the axis-translation technique. The specimen is relatively thin and so the time to failure in the direct shear test is greatly reduced. The shear box assembly consists of a container in two pieces of 6cm x 6cm x 2 cm. The shear box assembly is put together using the pin. The bottom plate is placed in such a way that the groove in the grid plate should be perpendicular to the direction of shear. The soil is placed in layers and tamped. The top grip plate and loading pad is placed on the top of the soil sample. The normal load frame is placed on the loading pad. The proving ring is set to read zero. The pins from shear box assembly are removed. The hand wheel is rotated anticlockwise to apply the shear load. The maximum deflection is recorded in the proving ring which gives the maximum shear stress. The test is repeated with a fresh sample of soil for other loads. The angle of internal friction and minimal cohesion obtained is given in table 4.

2.7 Safe Bearing Capacity

The safe bearing capacity of the soil is computed manually by using Terzaghi’s method, Teng’s method and I.S Code method. The method which gives the effective value is taken as the safe bearing capacity of soil. Terzaghi's equation of the vertical bearing capacity and ultimate failure envelopes in the space of normalised loading variables. These formulas extend to more general conditions. [7] The efficiency factors have been computed individually to estimate the effects of cohesion, surcharge and soil weight using Terzaghi’s equation, both in a frictional soil with surcharge pressures and in a cohesive-frictional soil with surcharge pressures. The safe bearing capacities for all 21 samples suggested by comparing with different methods are given in table 4.

2.8 California Bearing Ratio

The study on CBR Prediction Model with GIS Application Technique serves to be an useful prediction tool for transportation works [8]. [9] observed the study of correlation between California Bearing Ratio (CBR) Value With Other Properties of Soil. CBR test depends upon the place and nature of moisture level and is differentiated as soaked and unsoaked. [10] The flexible pavement is generally referred to as the (C.B.R) design procedure. The stress induced by traffic so that when it reaches the underling layer they will not overstress. Flexible pavement consists of following layer that are Asphalt Layer, Base Layer, Sub Base Layer, subgrade layer. The CBR values for all 21 samples are given in table 4.

TABLE 1 *LOCATION DETAILS OF SAMPLES COLLECTED*

Sample no	Location	Latitude	Longitude
S1	KEC College	11016'27.02" N	77036'25.51" E
S2	KEC Library Gate	11°16'13.22"N	77°36'15.91"E
S3	(KEC Back Side) Vidya Nagar East	11°16'30.01"N	77°36'8.78"E
S4	KEC Bus Service Station	11°16'39.95"N	77°36'34.61"E
S5	Men's Hostel (1) Back Side	11°16'17.39"N	77°36'38.69"E
S6	Vengamedu Road(First Junction) (Mobitech Wireless Solution)	11016'45.04" N	77035'58.34" E
S7	Vaikkalmedu Road	11016'51.22" N	77036'45.62" E
S8	Men's Hostel (Kcp Nagar road)	11015'59.53" N	77036'42.65" E
S9	Bhavani Ladies Hostel Backside (Arch Road)	11016'2.23" N	77036'4.99" E
S10	Vengamedu Bus Stop	11016'49.90" N	77035'48.93" E
S11	Vaikkalmedu Road Via	11017'2.47" N	77036'53.25" E
S12	Subavalar Industry Road Kummakovil(Puthur)	11015'47.62" N	77036'51.43" E
S13	Arch Opposite (Road Side) (Railway Station Road)	11015'50.47" N	77055'54.70" E
S14	Kaadapalayam Bus Stop (Airtel Store)	11017'2.87" N	77035'30.62" E
S15	KMC Hospital (Backside Road)	11017'23.39" N	77036'21.57" E
S16	Vaikkalmedu Road Towards (KecClg) (Food Processing Industry)	11017'19.85" N	77036'57.53" E
S17	Veppampalayam (Kommakkovil) (Puthur Road)	11016'33.20" N	77037'28.72" E
S18	Bagavathi Amman Temple (PerunduraiRs)	11015'34.31" N	77037'0.70" E
S19	Chillout Water Theme Park (Gummu Mahal)	11015'24.42" N	77036'19.35" E
S20	Megha Mobiles And Travels Pannikampalayam Road	11015'40.17" N	77035'46.39" E
S21	Police Station Bus Stop (Thendral Nagar)	11016'37.87" N	77035'20.94" E

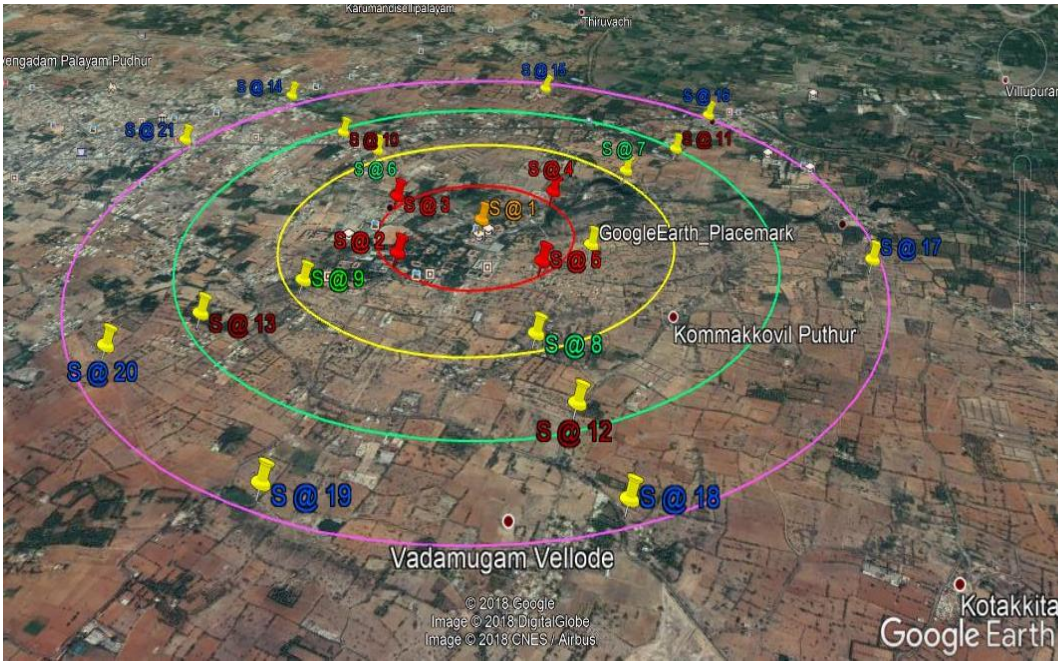

Fig.1 *Location Map of samples collected*

***TABLE 2 PARTICLE** SIZE DISTRIBUTIONS*

Sample	Gravel%	Coarse Sand, %	Medium Sand, %	Fine Sand, %	Silt & Clay, %	Uniformity Coefficient,Cu	Coefficient of Curvature, Cc	Classification
S1	10	19	42	25	4	6.3	0.3	SP
S2	11	18	40	27	3	6.1	0.5	SP
S3	9	20	41	26	2	5.6	0.36	SP
S4	13	19	39	28	0	4.7	0.85	SP
S5	14	20	40	24	2	7	0.40	SP
S6	12	22	37	23	5	9.6	0.5	SP
S7	13	19	38	24	6	4.8	1.5	SP
S8	11	20	39	22	7	14.2	0.3	SP
S9	10	21	40	22	5	6.25	0.6	SP
S10	12	22	39	22	4	10	0.42	SP
S11	13	20	43	21	3	8	0.8	SP
S12	15	24	35	21	5	9.16	0.47	SP
S13	11	23	42	19	4	6.3	0.309	SP
S14	13	22	40	19	6	7.5	0.4	SP
S15	10	21	42	18	8	10	0.45	SP
S16	8	24	40	22	4	7.3	0.3	SP
S17	7	21	65	7	0	7.3	1.83	SW
S18	12	24	42	18	3	6	0.6	SP
S19	14	20	41	20	5	9.13	0.4	SP
S20	11	22	41	20	6	10	0.34	SP
S21	10	21	42	22	4	6	0.5	SP

* SP – Poorly graded sand, SW – Well graded sand

2.9 Design of subgrade thickness based on CBR value

The thickness of pavement layers are obtained from IRC 37 for different categories based on CBR, traffic volume and standard axles are given in table 5 and shown in figure 2, 3 & 4.

$$N=365x[(1+r)^n-1]x\ A\ xD\ x\ F/r \quad (2)$$

Where,

A = initial traffic in the year of completion of construction in terms of the number of vehicle per day.

$$A=P(1+r)^x \quad (3)$$

P = number of commercial vehicles as per last count (as per code book it depends upon three category)

Assume that,

Category A = 150 (0-150)

Category B = 1000 (150-1500)

Category C = 2000 (more than 1500)

r = annual growth rate of commercial vehicles = 5% (i.e 0.05)

x = number of years between last count and the year of completion of construction =2 years

category A : $A = 150(1+0.05)^2 = 165.3$

category B : $A = 1000(1+0.05)^2 = 1102.5$

category C : $A = 2000(1+0.05)^2 = 2205$

Here,

r = 0.05

n = design life in years = 12 for village Roads (10-15 years)

D = lane distribution factor = 50% (i.e 0.50) for two-lane single carriageway Roads

F = vehicle damage factor (depends upon the traffic volume)

1.5 for traffic volume of 0 – 150

3.5 for traffic volume of 150 – 1500

4.5 for traffic volume of more than 1500

For category A,

$N = 356 \times [(1+0.05)^{12}-1] \times 165.3 \times 0.5 \times 1.5/0.05$

= 0.72 msa (minimum of 2 msa should be provided)

For category B,

$N = 356 \times [(1+0.05)^{12}-1] \times 1102.5 \times 0.5 \times 3.5/0.05$

= 11.20 msa

For category C,

$N = 356 \times [(1+0.05)^{12}-1] \times 2205 \times 0.5 \times 4.5/0.05$

= 28.82 msa

***TABLE 5** PAVEMENT THICKNESSES*

Description of pavement layers	Pavement thickness, mm								
	CBR15%			CBR 8%			CBR 4%		
	A	B	C	A	B	C	A	B	C
Bituminous layer	20	40	40	20	40	40	20	40	40
Granular base	30	60	65	50	60	100	50	70	120
Granular sub base	250	250	250	225	250	250	225	250	250
subgrade	100	200	200	150	200	200	215	300	300

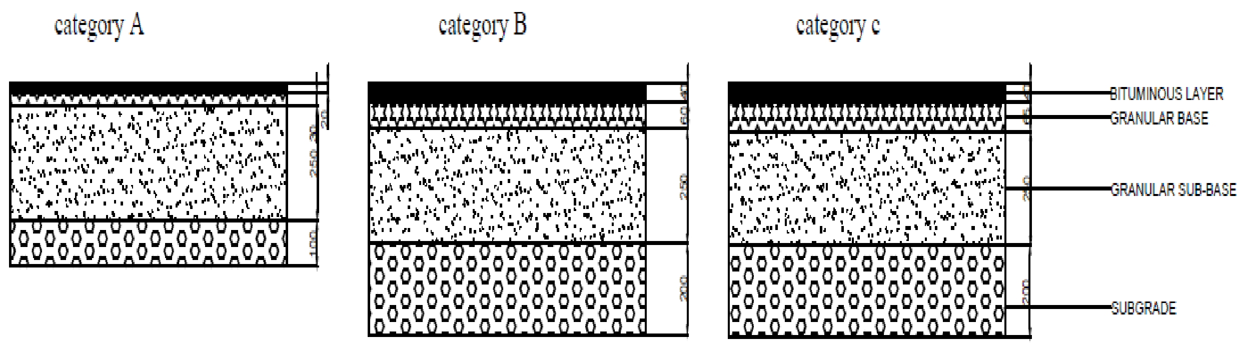

Fig.2 *Pavement thickness of CBR ≥ 15%*

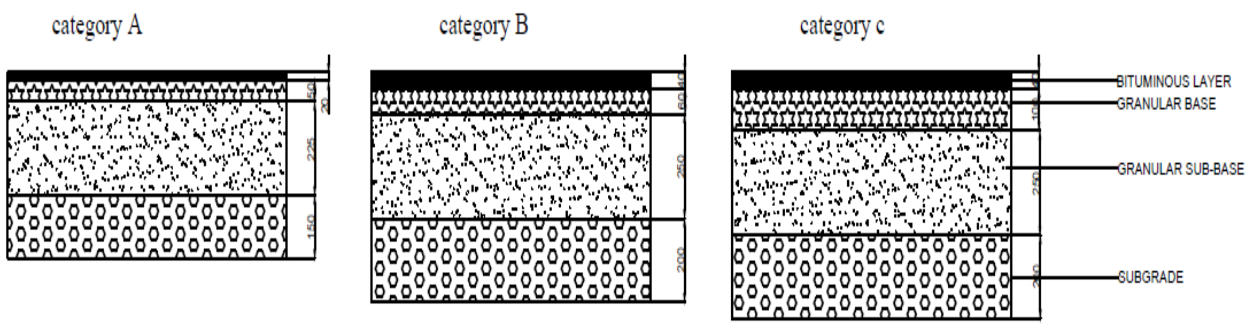

Fig.3 *Pavement thickness of 8% < CBR < 15%*

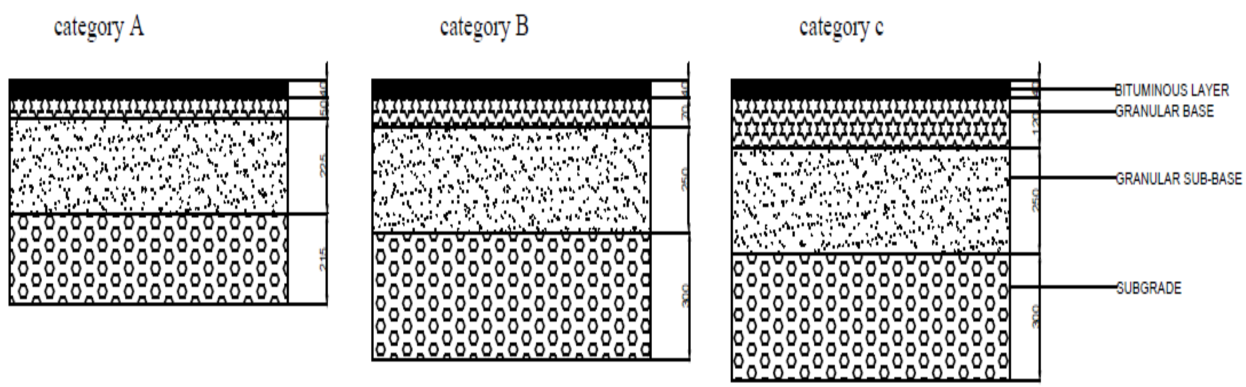

Fig.4 *Pavement thickness of CBR ≤ 4%*

3. GIS RESULTS

In geotechnical earthquake engineering, there have been several researches on GIS technology a spatial GIS-based tool, geotechnical information system (GTIS), was built for the presentation and reliable estimation of the geotechnical information over the selected small urban area, Hongseong, of Korea [11]. Geographic Information System (GIS) can integrate and relate any data with a spatial component regardless of the source of data [12]. It's easy to store, retrieve, manage and analyze geotechnical data. The GIS was used to manage the database and to develop thematic maps for depth, N value, free swell, liquid limit, plastic limit, plastic index, percentage gravel, percentage sand and percentage slit and clay [13]. Spatial map obtained for field density and permeability is shown in figure 5 and figure 6. The shear strength parameter of such as internal friction is determined by using direct shear test. The angle of internal friction obtained is incorporated by using GIS. The surface is being interpolated and the variable is being mapped. Natural Neighbour Inverse Distance Weighted (NNIDW) interpolation is used. The GIS obtained for angle of internal friction is given in figure 7.The Legend is marked for Loose sand, Medium dense sand and Dense sand. The Bearing capacity is determined by using Teng's method, Terzaghi' method and I.S code method. The minimum value among the three methods is adopted as safe bearing capacity. The surface is being interpolated and the variable is being mapped and shown in figure 8. The values of CBR ratio of 21 samples were found from the collected samples. The values obtained are incorporated in GIS. Kriging interpolation is used and given in the figure 9.

4. CONCLUSION

The determination of properties of soil are entirely depend upon the number of bore holes the difficulty in obtaining undisturbed samples and most of the methods are rather expensive, time consuming and involve elaborate test procedures.

- The shear strength characteristics, permeability and subgrade thickness can be evaluated from the available index properties of soil such as specific gravity, optimum moisture content and maximum dry density and California bearing ratio.

- From this CBR value finally we can determine the subgrade thicknesss through the traffic volume as per IRC recommendation.
- Natural Neighbour Inverse Distance Weighted (NNIDW) interpolations are used to determine the cell values by using a linearly weighted combination of a set of sample points.
- The surface is being interpolated and the variable is being mapped. The GIS mapping is used to interpret the locations with the help of latitude and longitude.

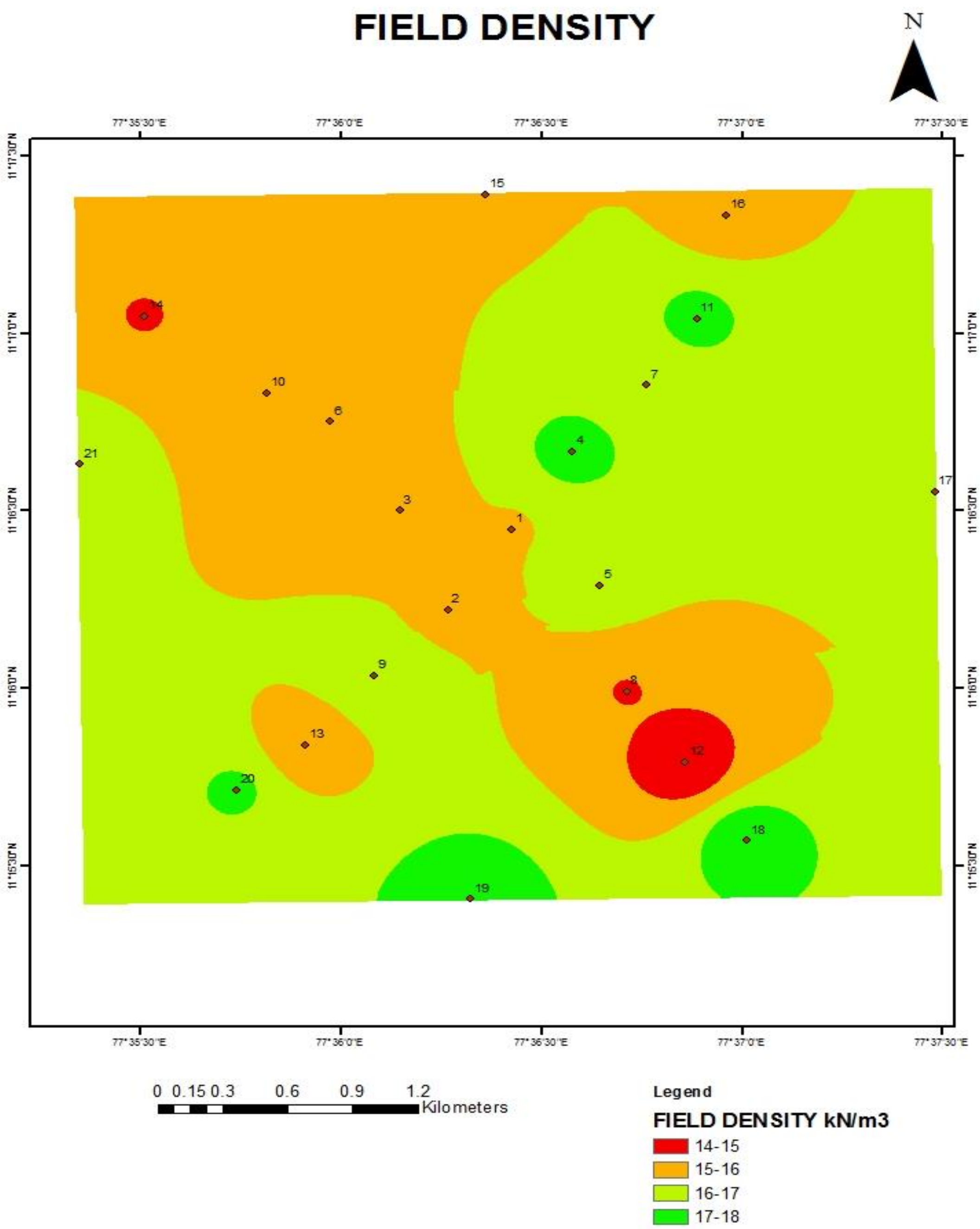

Fig.5 *Field Density Output in GIS*

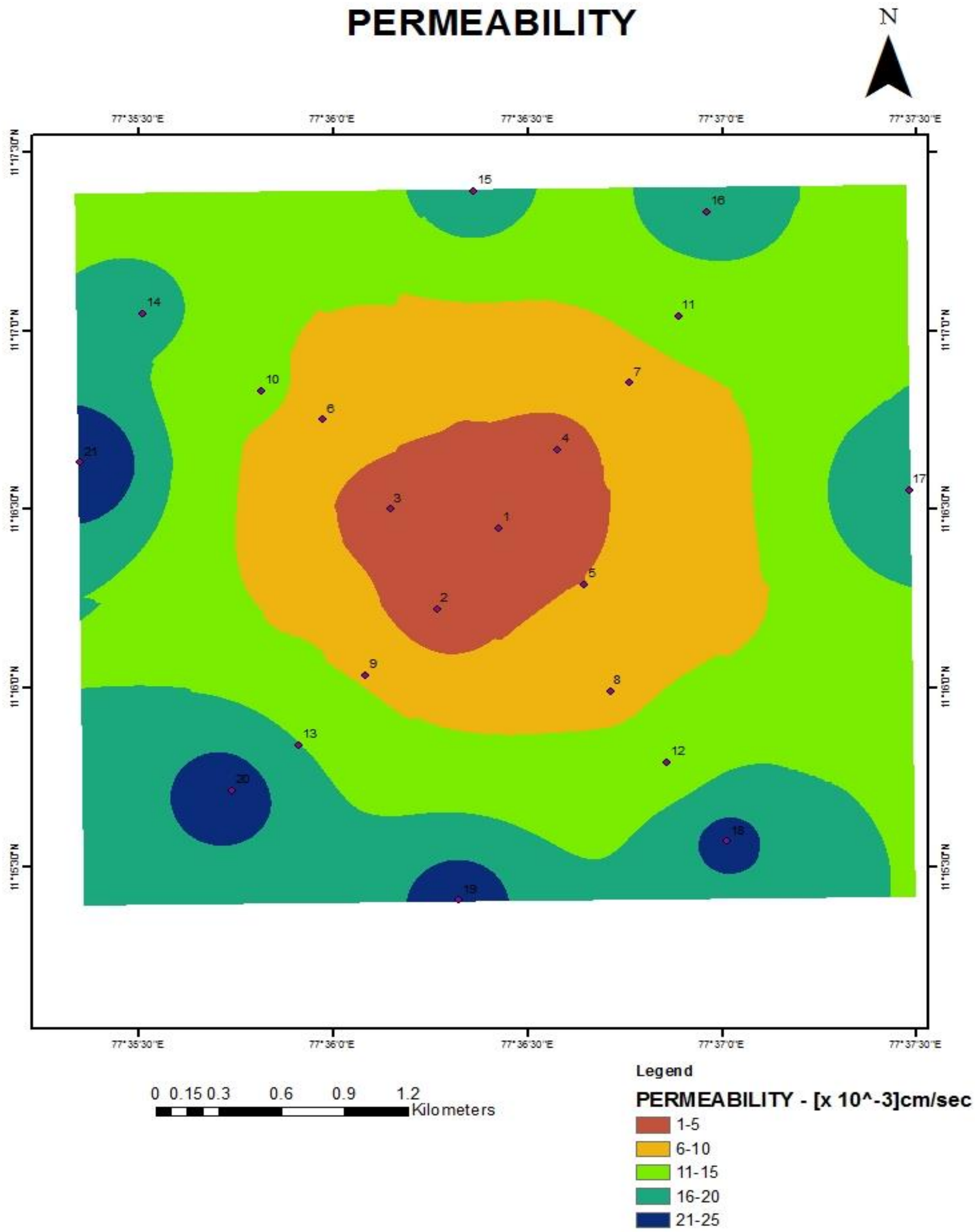

Fig.6 Permeability Output in GIS

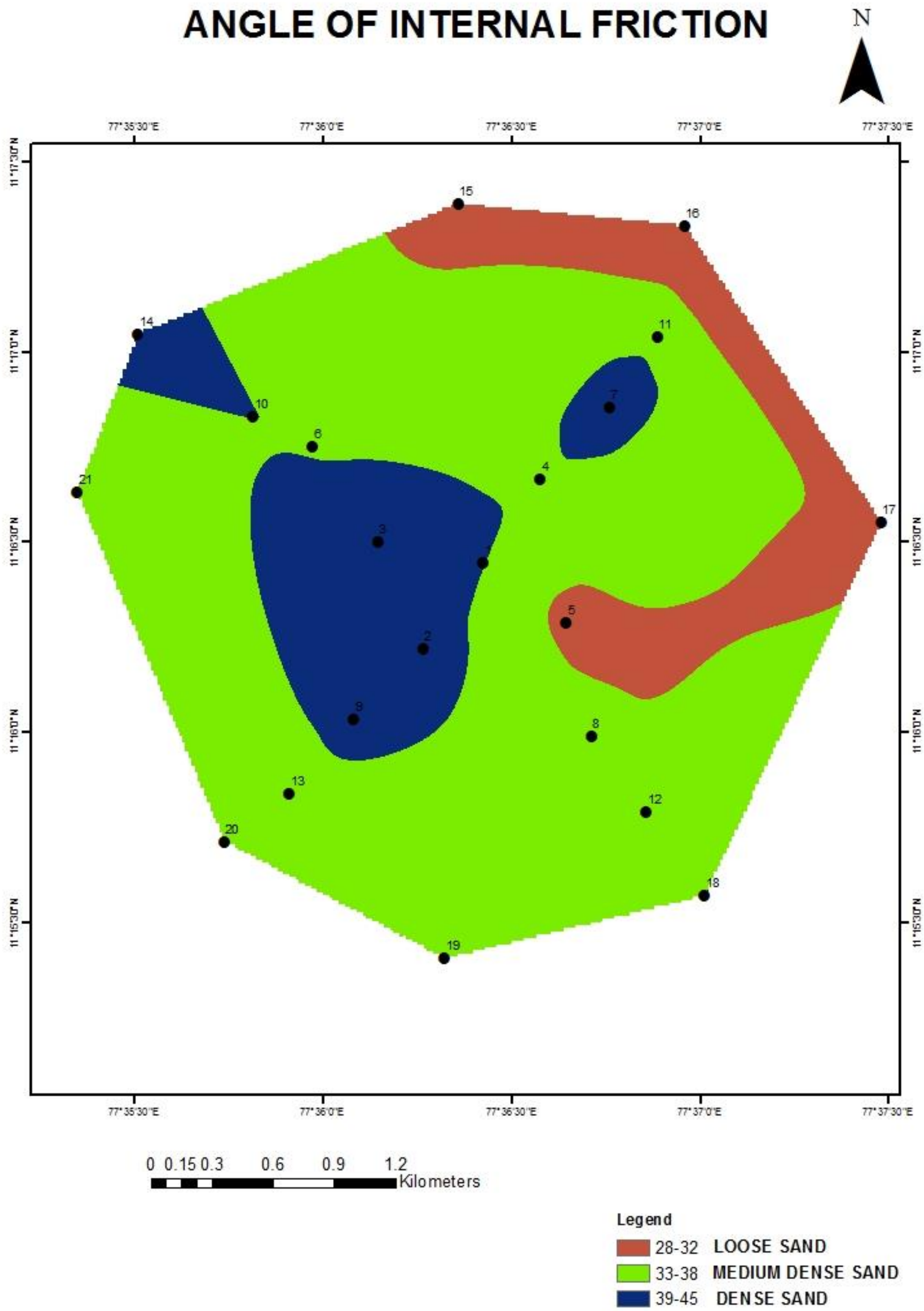

Fig. 7 *GIS obtained for angle of internal friction*

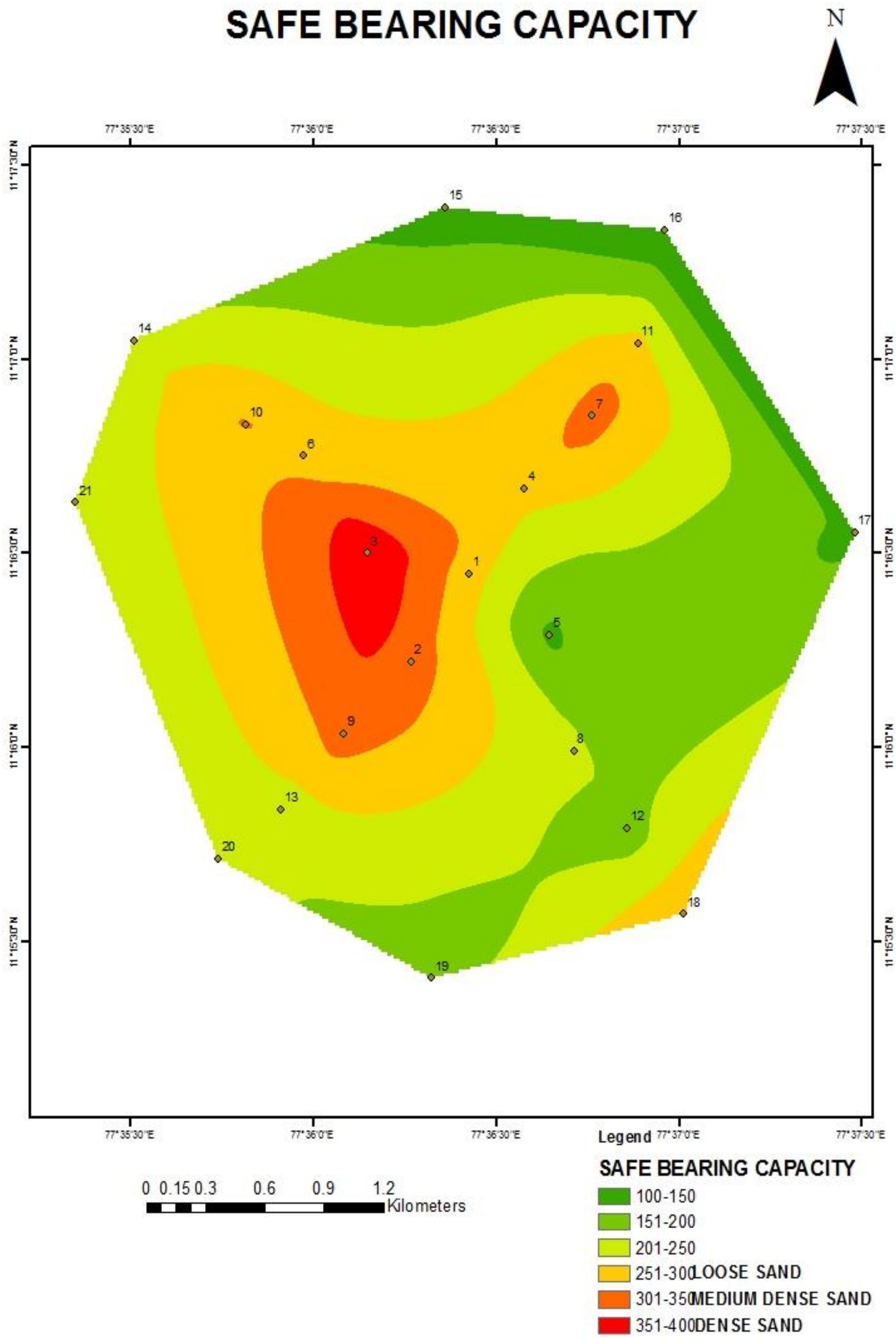

Fig.8 *GIS obtained for safe bearing Capacity*

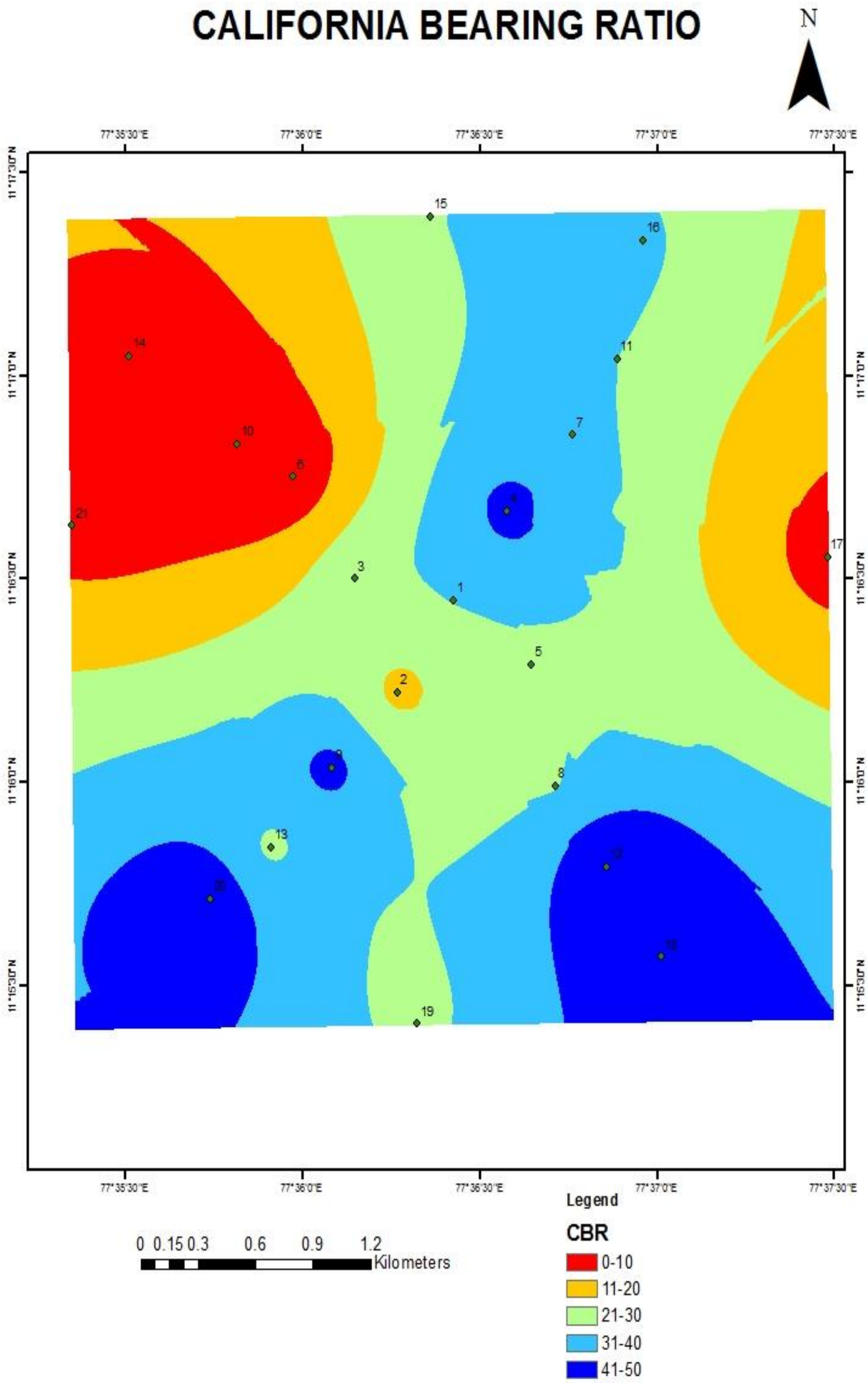

Fig.9 *Mapping of CBR Using GIS*

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