An Experimental Study on GIS for Highway Bearing Capacity Evaluation

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Abstract: The bearing capacity of soils under highway engineering differs from that of soils under the building foundation as a result of different superstructure types and foundation forms. Determining the characteristic value of highway bearing capacity by directly adopting the evaluation method from building codes is conceptually indefensible because such codes do not represent the real bearing capacity of highway foundations. By analyzing the superstructure types and foundation forms of highway sub grade, bridge, culvert, and building, the evaluation methods of highway foundation, bridge, and culvert are determined. Furthermore, a three-level classification system of highway foundations is presented and a highway engineering bearing capacity evaluation system based on Geographical Information Systems (GIS) is established. By using the spatial data management and spatial data analysis platform of GIS and by combining the plate-loading testing data and engineering properties of different soils, the system accomplishes the effective evaluation of the bearing capacity beneath the highway subgrade, bridge and culvert and provides a theoretical basis and practical reference for the evaluation of the bearing capacity and the choice of ground improvement in engineering design and construction.

***Index Terms* - Road engineering, Subgrade, Bridge and Culvert, Bearing Capacity, GIS, Evaluation Method, Classified System.**

1. INTRODUCTION

In designing buildings, the ground, foundation, and superstructure of buildings interact with and mutually restrict one another under load. The determination of bearing capacity should be undertaken alongside the characteristics of the superstructure and the foundation. In contrast to buildings, the superstructure of highways includes the sub grade, bridge, and culvert, and their foundation forms are different. The Specifications for Design of Highway Subgrades (JTG D30 - 2004) [1] does not consider the evaluation method and requirements of the bearing capacity of subgrade foundation. The Code for Design of Ground Base and Foundation of Highway Bridges and Culverts (JTG D63 - 2007) [2J does not involve the" culvert- soil structure" of the culvert foundation. As such, the evaluation of bearing capacity in highway construction is often inaccurate and beset by gaps. In this study, the bearing behavior and evaluation method of highway subgrade and bridge and tunnel ground are discussed, and a classification system of highway engineering bearing capacity (HEBC) is proposed .The bearing capacities of foundational soils from different regions are of various types. To utilize existing research on buildings and highways, the evaluation system of HEBC is constructed based on GIS. This system provides a reference in the evaluation of bearing capacity and the selection of ground improvement in engineering design and construction.

2. EVALUATION TECHNOLOGY OF HEBC

2.1 BEARING CAPACITY OF HIGHWAY SUBGRADE

The requirements of load characters and the deformation of the superstructure of highway foundations differ from those of building foundations. These differences are as follows:
(1) The load distribution form of a highway subgrade is a trapezoidal load, whereas that of a building is a uniform load.
(2) A highway sub grade has a flexible foundation, whereas a building has a rigid foundation.
(3) The total deformation of the sub grade top surface is reduced for layer filling, whereas the rigid foundation of buildings does not change. Because highway sub grade and buildings differ in foundation type and load for, the bearing capacity method for building foundation cannot be directly applied for highway subgrade.

The meaning of the characteristic value of bearing capacity includes the designed values of resistance to ensure the normal functions of the superstructure. The values of ground bearing capacity can be determined by the stress deformation and normal serviceability requirements of the soil. Thus, rigid load and stress deformation should be considered in determining highway engineering bearing capacity. Relative deformation has been modified based on the building. The results show that the relative settlement of a flexible foundation is higher than that of a rigid foundation under the same foundation pressure. Based on the subgrade width, the settlement standard of soft soil, and the relationship between total settlement and settlement after construction, the allowable relative deformation of expressway or first-class highway foundations IS O. 023, and that of secondary highway foundations IS 0.036. The building maximal value ranges from 0.010 to 0.015.

According to the allowable deformation of foundation, the bearing capacity characteristic value of highway subgrade, should be larger than bearing capacity characteristic value of building fek .The corrected formula of highway subgrade bearing capacity is as follows:

$$f_{ake} = kf_{ak}$$

Where,

f_{ake} = the characteristic value of the bearing capacity of highway subgrade,

K = the correction coefficient,

f_{ak} = the characteristic value of the bearing capacity of building foundation.

2.2 BEARING CAPACITY OF HIGHWAY SUBGRADE

The deformation properties of a highway bridge's foundations and a building with the same rigid foundation differ only slightly. To meet the demands of strength and deformation, the characteristic value of a bridge's bearing capacity as recommended by the Code for the Design of Ground Base and Foundation of Highway Bridges and Culverts (JTG DG3-2007) employs the same evaluation method as that of buildings. The characteristic value of a building can be directly applied to a highway bridge.

2.3 BEARING CAPACITY OF HIGHWAY SUBGRADE

The foundation pressure p is less than that beside the culverts because the middle of the culvert is hollow. Thus, the traditional sliding surface does not appear and the foundation soil of the culvert cannot be extruded from the surface. In addition, the filling load beside the culvert can limit the lateral sliding of the base soil, which can improve the anti-shear ability of the culvert.

3. METHODOLOGY

The base (study area) map, Drainage, Slope and Contour maps were prepared with help of SOIL Toposheet (on 1:50000 scale). High resolution LANSAT satellite data of 2009 was used and by using Digital Image Processing techniques the following thematic maps such as geomorphology, Land se/Land Cover were generated. The base (study area) map, Drainage, Slope and Contour maps were prepared with help of SOIL Toposheet (on 1:50000 scale). High resolution LANSAT satellite data of 2009 was used and by using Digital Image Processing techniques the following thematic maps such as geomorphology, Land se/Land Cover were generated. The Digital Elevation Model (DEM) was generated using various GIS based analysis, such as overlay, raster network analysis. The DEM is used in order to understand the terrain condition, environment factors and social economic status in this study area. Finally possible/feasible route was identified based on various physical and cultural parameters and their inherent properties.

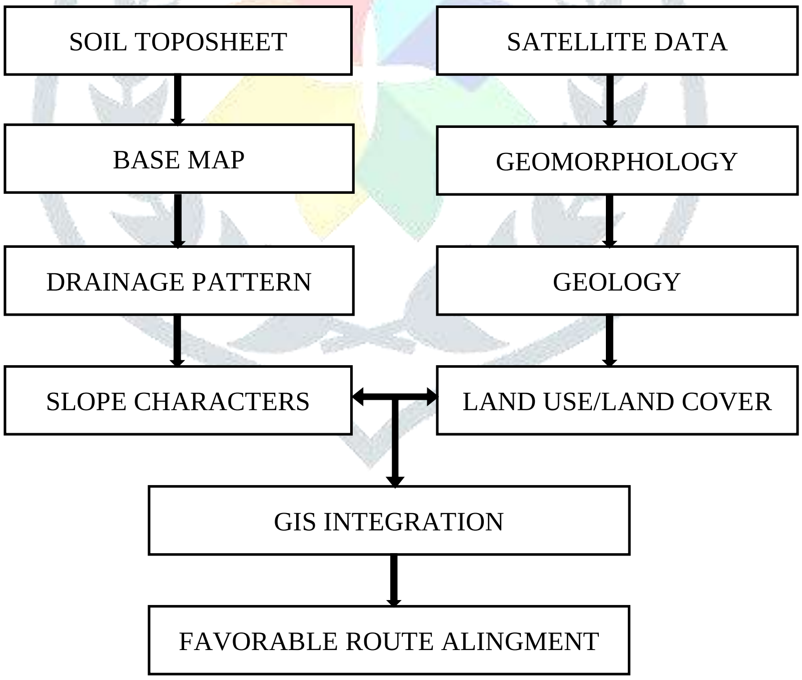

Fig 3 Data Interpretations

4. MATERIALS AND METHODS

4.1 SOIL SAMPLING:

The soil sample was collected for this project from the following sites:

Erode Tk- Perundurai (S1), Kaasipalayam (S2), Railway colony (S3), Moolapalayam (S4), Indra nagar (S5), Solar (S6), Lakkapuram (S7), Muthugoundan Palayam (S8). By using auger boring the soil sample is taken from the following sites at below 1m depth.

4.2 LABORATORY ANALYSIS OF SOIL SAMPLE:

Soil Experiments were conducted to determine the characteristics of soil sample. Experiments consist of Grain size Distribution-Sieve analysis, Specific Gravity of soil, Plastic and Liquid limit analysis, Determination of density of soil and evaluation of bearing capacity of soil samples.

4.3 DETERMINE BEARING CAPACITY OF SOILS:

Plate Load Test is a field test for determining the ultimate bearing capacity of soil and the likely settlement under a given load. The Plate Load Test basically consists of loading a steel plate placed at the foundation level and recording the settlements corresponding to each load increment. The test load is gradually increased till the plate starts to sink at a rapid rate. The total value of load on the plate in such a stage divided by the area of the steel plate gives the value of the ultimate bearing capacity of soil. The ultimate bearing capacity of soil is divided by suitable factor of safety (which varies from 2 to 3) to arrive at the value of safe bearing capacity of soil. For better understanding, this Plate Load Test can be sub-divided into the following heads,

1. Test
2. Testing
3. Interpretation
4. Limitations of the test.

4.4 INTERPRETATION OF RESULTS:

The load intensity and settlement observations of the plate load test are plotted in the form of load settlement curves

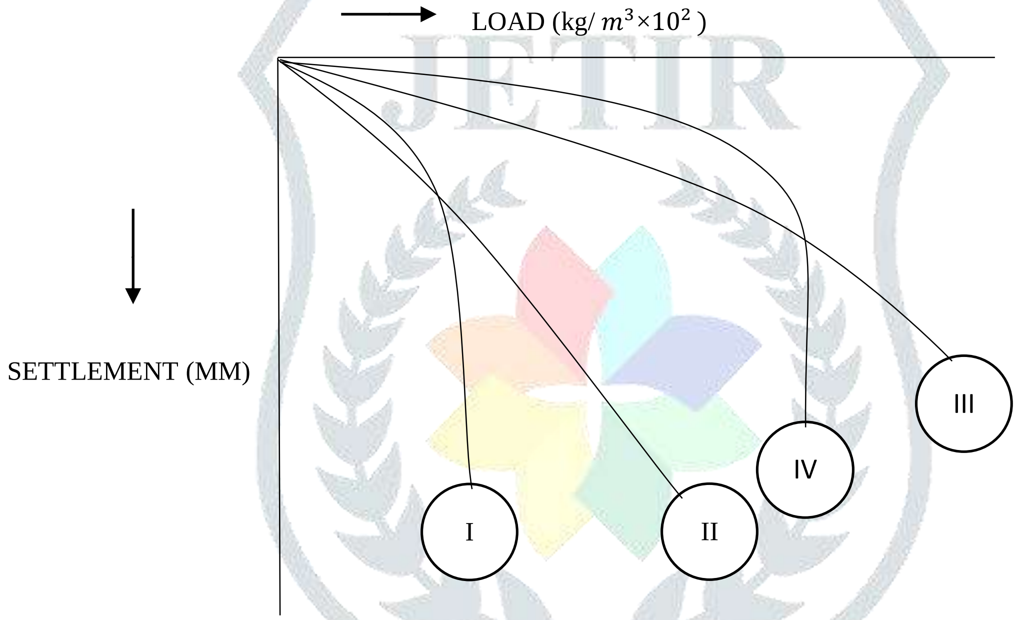

Fig 2 Load settlement curve

The figure below shows four typical curves applied to different soils.
Curve I is typical for loose to medium non-cohesive soils. It can be seen that initially this curve is a straight line, but as the load increases it flattens out. There is no clear point of shear failure.
Curve II is typical for cohesive soils. This *may* not be quite straight in the initial stages and leans towards settlement axis as the settlement increases.
Curve III is typical for partially cohesive soils.
Curve IV is typical for purely dense non-cohesive soil.

4.5 BEARING CAPACITY CALCULATION:

The safe bearing capacity is obtained by dividing the ultimate bearing capacity by a factor of safety varying from 2 to 3. The value of safe bearing capacity thus arrived at, is considered to be based on criterion of *shear failure.* Safe bearing capacity (SBC) based on permissible settlement. As indicated earlier the settlement of footing is also related to the SBC of the soil. The value of ultimate bearing capacity and hence the SBC in this case, can be obtained from the load settlement curves by reading the value of load intensity corresponding to the desired settlement of test plate. The value of permissible settlement (S_f) for different types of footings (isolated or raft) for different types structures are specified in the l.S. code. The corresponding settlement of test plate (S_p) can be calculated from the following formula,

$$S_f = S_p\{[B\ (B_p + 0.3)\ ]/[\ B_p\ (B + 0.3)\ ]\}^2$$

Where,

B = width of footing in mm.

B_p = width of test plate in mm.

S_p = settlement of test plate in mm.

S_f = settlement of footing in mm.

5. DATA COLLECTION:

5.1 LOCATION OF ERODE BLOCK:

Survey of India Toposheet No. (58 I/2, 58 I/3, 58 I/4, 58I/6, 58I/8) on the scale of 1:50,000. Land Sat (Mss) Data 2007 Maps, field work and remote sensing techniques are necessary for proposed road design and construction. Topographic maps, Geomorphology, Land use /Land cover, Drainage, DEM road, Slope and Contour maps were used for this proposed route. The favorable path analysis, using various data and GIS analysis was intended to confirm the best transport route within this site.

5.2 SOFTWARE DATA:

Different software packages are important for GIS. Central to this is the GIS application package. Such software is essential for creating, editing and analyzing spatial and attribute data, therefore these packages contain a myriad of GIS functions inherent to them. Extensions or add-ons are software that extends the capabilities of the GIS software package. Component GIS software is the opposite of application software. Component GIS seeks to build software applications that meet a specific purpose and thus are limited in their spatial analysis capabilities. Utilities are stand-alone programs that perform a specific function. For example, a file format utility that converts from on type of GIS file to another. There is also web GIS software that helps serve data through Internet browsers.

Data is the core of any GIS. There are two primary types of data that are used in GIS. A geo database is a database that is in some way referenced to locations on the earth. Geo databases are grouped into two different types: vector and raster. Vector data is spatial data represented as points, lines and polygons. Raster data is cell-based data such as aerial imagery and digital elevation models. Coupled with this data is usually data known as attribute data. Attribute data generally defined as additional information about each spatial feature housed in tabular format. Documentation of GIS datasets is known as metadata. Metadata contains such information as the coordinate system, when the data was created, when it was last updated, who created it and how to contact them and definitions for any of the code attribute data.

5.3 SHORTEST PATH ANALYSIS:

The inputs required for shortest path analysis are a source and a destination raster, cost raster surface, cost weighted distance, direction raster. After preparing all the required inputs Spatial Analyst is used to generate the shortest path and the results for analysis.

How GPS Work

The Global Positioning System (GPS) is a technical marvel made possible by a group of satellites in earth orbit that transmit precise signals, allowing GPS receivers to calculate and display accurate location, speed, and time information to the user. By capturing the signals from three or more satellites (among a constellation of 31 satellites available), GPS receivers are able to use the mathematical principle of trilteration to pinpoint your location. With the addition of computing power, and data stored in memory such as road maps, points of interest, topographic information, and much more, GPS receivers are able to convert location, speed, and time information into a useful display format. GPS was originally created by the United States Department of Defense (DOD) as a military application. The system has been active since the early 1980s, but began to become useful to civilians in the late 1990s. Consumer GPS has since become a multi-billion dollar industry with a wide array of products, services, and Internet-based utilities. GPS works accurately in all weather conditions, day or night, around the clock, and around the globe. There is no subscription fee for use of GPS signals. GPS signals may be blocked by dense forest, canyon walls, or skyscrapers, and they don't penetrate indoor spaces well, so some locations may not permit accurate GPS navigation.

Study Area - Erode City

Erode is a city, a municipal corporation and the headquarters of Erode district in the South Indian state of Tamil Nadu. It is situated at the center of the South Indian Peninsula, about 400 kilometers (249 mi) southwest from the state capital Chennai and on the banks of the rivers Cauvery and Bhavani, between 11° 19.5" and 11° 81.05".North latitude and 77° 42.5" and 77° 44.5" East longitude. As per Census 2011 alignments. It has population around 156,953.Erode Local planning Area extends up to 54sq.km. Within the city, and will be extended to 109 km2. The roadway connects all the parts of the state and nearby states such as Kerala, Karnataka and Andhra Pradesh with the city.

5.4 SHORTEST PATH ANALYSIS:

Erode district is drained by Cauvery and Ponnaiyar river basin. The Cauvery River forms the western and south-western boundary of the district. The domestic and industrial usage of water is being satisfied by Cauvery river water. As far as the drainage fabrication of the study area is concerned, it is covered by third order and fifth order streams in the North and Northeast part..

OVERVIEW OF SOFTWARE- Arcgis

ArcGIS is a suite consisting of a group of geographic information system (GIS) software products produced by Esri. There are also server-based ArcGIS products, as well as ArcGIS products for PDAs. Extensions can be purchased separately to increase the functionality of ArcGIS. ArcGIS 8.x in late 1999, Esri released ArcGIS 8.0, which ran on the Microsoft Windows operating system. ArcGIS combined the visual user-interface aspect of ArcView GIS 3.x interface with some of the power from the Arc/INFO version 7.2 workstation. This pairing resulted in a new software suite called ArcGIS, which included the command-line Arc Info workstation (v8.0) and a new graphical user interface application called Arc Map (v8.0) incorporating some of the functionality of Arc Info with a more intuitive interface, as well as an ArcGIS file management application called Arc Catalog(v8.0). The release of the ArcGIS suite constituted a major change in Esri's software offerings aligning all their client and server products under one software architecture known as ArcGIS, developed using Microsoft Windows COM standards .One major difference is the programming (scripting) languages available to customize or extend the software to suit particular user needs.

6. TEST AND CALCULATIONS:

Table 6.1 Sieve analysis of different soil sample:

S.NO	SIEVE SIZE (mm)	% OF FINESS		
		Perundurai	Railway colony	Moolapalayam
1	4.25	46.5	41.535	41.985
2	2.6	40	34.211	35.16
3	1.18	28.6	22.202	28.648
4	0.850	19.3	27.216	17.625
5	0.300	13	16.274	13.599
6	0.150	7.5	10	7.163
7	0.075	3	4.386	3.165
8	Pan	0	0	0

Table 6.2 Specific gravity of different soil sample:

t	LOCATION OF SAMPLE	SPECIFI GRAVITY (g)
1	Perundurai(S1)	0.424
2	Kaasipalayam(S2)	0.225
3	Railway colony(S3)	0.228

Table 6.3 Plastic limit test:

Container No.	14B	14B
Wt. of container + lid,W1	23	23
Wt. of container + lid + wet sample,W2	44g	44g
Wt. of container + lid + dry sample,W3	40g	40g
Wt. of dry sample	17g	17g
Wt. of water in the soil	4g	4g
Water content (%)	23.52%	23.52%

$$\text{Plastic Limit} = [(W2-W3)/ (W3-W1)]$$
$$= [(50-22)/\log (15/16)]$$

Average Plastic Limit =......62.34.........

Table 6.4 Liquid limit test:

Determination Number	1	2
Container number	45	16
Weight of container	12B	12C
Weight of container + wet soil	46g	48g
Weight of container + dry soil	42g	40g
Weight of water	4g	8g
Weight of dry soil	18g	16g
Moisture content (%)	22%	50%

Table 6.5 Evaluation of safe bearing capacity from the field plate method:

Soil sample	Width of foundation (m)	Size of Plate (cm)	Observed Settlement (mm)	Safe Bearing Capacity (KN/m2)
Alluvial soil	1	30	10.4	156
Coarse grained	1	30	10.4	148
Clayey soil	1	30	10.4	140
Red soil	1	30	10.4	170
Black cotton soil	1	30	10.4	150
Brown loamy soil	1	30	10.4	168

7. RESULT AND DISCUSSION:

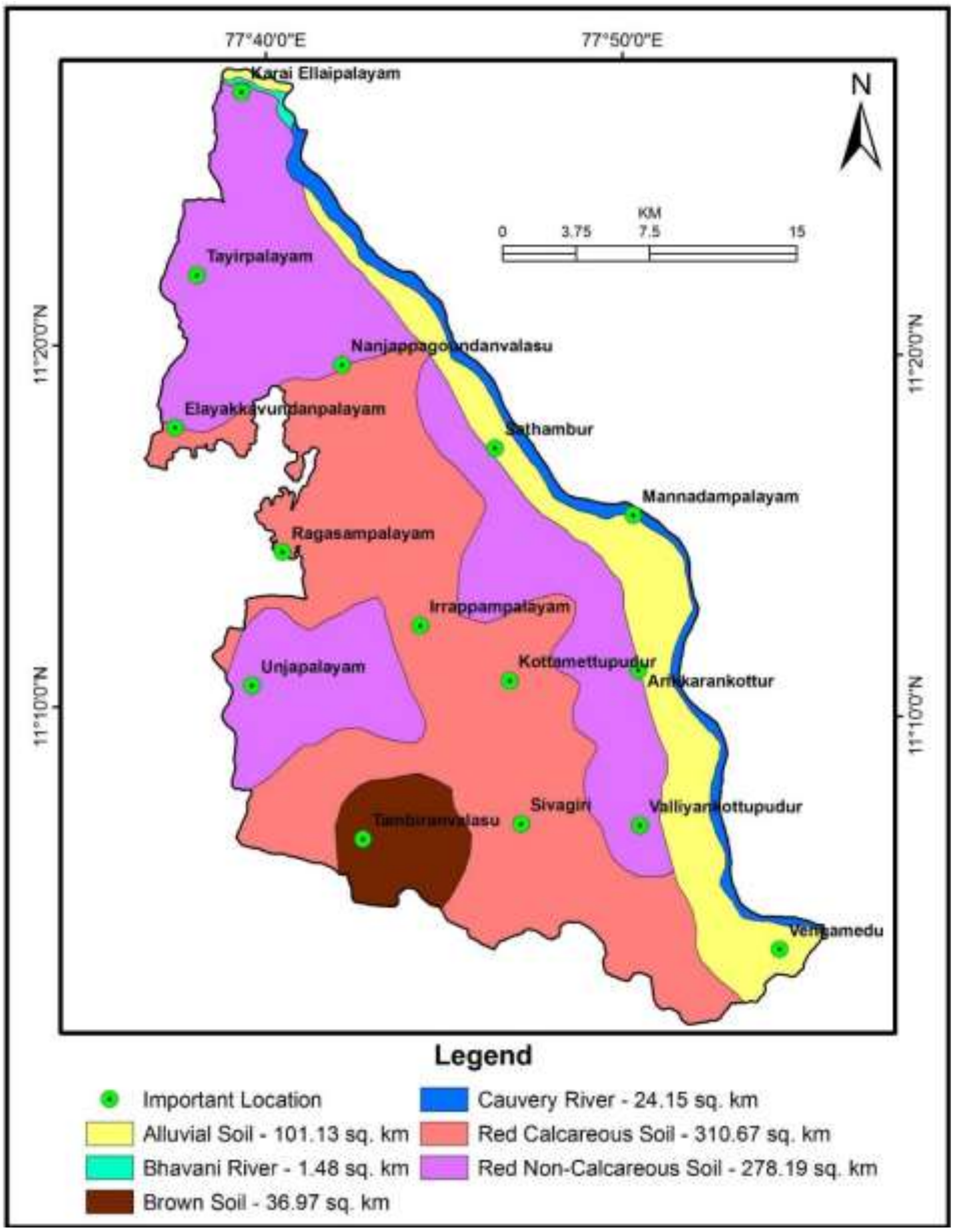

Fig 3 Erode map by GIS analysis

Terzaghi's Bearing Capacity Theory:

To determine bearing capacity under strip footing we can use

$$q_u = C'N_c + y\ D_f\ N_q + y\ 0.5\ B\ N_y$$

For adopting a strip footing condition,

Breath of foundation B = 1.0 m

Depth of foundation D = 1.0 m

Cohesion C = 0

Φ = 200

Soil sample	Width of foundation (m)	Cohesion	Safe Bearing Capacity (KN/m^2)
Alluvial soil	1	22	154.5
Coarse grained	1	14	146
Clayey soil	1	20	138.2
Red soil	1	20	168
Black cotton soil	1	22	148.5
Brown loamy soil	1	20	164

8. CONCLUSION:

In this study, the differences of the superstructure and foundation form of highways subgrade and buildings were analyzed. The corresponding evaluation method for the bearing capacity of highway engineering was determined. The concrete principle and method of classification of HEBC were proposed, and an evaluation system based on GIS was established. Based on the strong space data management and information process of GIS, the GIS of HEBC is constructed, and its evaluation is effectively realized. The purpose of this study was to develop a tool to locate a suitable less route between two points. The GIS approach using ground parameters and spatial analysis provided to achieve this goal. Raster based map analysis provided a wealth of capabilities for incorporating terrain information surrounding linear infrastructure. Costs resulting from terrain, geomorphology, land use, drainage and elevation resulting the shortest routes for the study area. Thus, finally the approximate bearing capacity of soil drawn from GIS software and the actual bearing capacity of erode taluk soils were analyzed and compared. This analysis of SBC from GIS data can provide a precise values and it reduce the cost, time and man power.

9. REFERENCE:

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