

DIAGNOSTIC OF SOIL SUITABILITY FOR HOUSING AND ROAD CONSTRUCTION: A CASE STUDY OF SUBURBAN TOWNS AROUND LUCKNOW CITY OF UTTAR PRADESH, INDIA

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Abstract

Settlements of buildings in a particular area is common. These settlements poses a threat to safety and well being of the residents of that particular area. Development of cracks or ultimate failure i.e collapse of the structures may result due to unsuitable /unstable soils on which these structures are constructed. From engineering point of view soil is considered in terms of its suitability as building materials or as support medium for roads, buildings and other structures. Soil characteristics assessment is essential for the stability of the building constructed at particular place/area. It's not only provides the constructors to select a better locality for the development of buildings or roads to minimise the losses due to settlement but also reduces the cost of construction. A comparative study was conducted among seven towns around Lucknow city ranging from 4 to 15km from the existing boundary. The present developments of the Lucknow city indicates that the selected towns will be the part of the Lucknow city in near future. The samples were collected for each selected town site were used for investigation. The soil samples collected were subjected to specific gravity, natural moisture content, particle size analysis, consistency limits, void ratio, porosity, compaction, permeability and direct shear tests. The statistical analysis was used to obtain the mean values of the result obtained from each variable. Soil and site rating score was designed using the evaluation key to determine the suitability of the soil for housing and road construction for each area.

Keywords: Settlement, Particle Size Analysis, Specific Gravity, Natural Moisture Content, Consistency Limits, Direct Shear Test.

1. INTRODUCTION

Upgradation of a town into city involves the construction of almost all type of civil engineering structures e.g. residential & commercial buildings, roads, overhead tanks, civil works related to sanitary and water supply etc. If the settlement is uniform or within the limit the structure/civil works constructed over it is safe while if differential settlement takes place it results in either the development of cracks or the failure of the structures. Soil characteristics of the ground/land is primarily responsible for the differential settlement. An assessment of soil properties around Lucknow city was carried out on all roads outgoing the city where the possible growth or extension of the city is inevitable. This ensures not only the safety of the structure as well as people but also the constructors to select a better locality for the development. Further it enables reducing the construction cost and helps to determine the corrective measures to improve the ground condition thus reducing the settlements within the permissible limit. Thus the settlement problems which is likely to occur in future may be avoided. The inherent soil properties which are natural ability of the soil to function and are permanent and do not change easily. These properties of the soil are used to compare the ability of one soil against another and to assess the suitability of soils for specific purposes. The physical attributes of the soil which may be used as indicators of soil

qualities are soil texture, stoniness, soil structure, bulk density, porosity, soil crusting, compaction, drainage, water retention, infiltration, hydraulic conductivity and topsoil depth. The considerations of the properties depend upon the use/purpose for the construction of embankments for highways and railways shear strength is the main property to be considered. Physical properties particle size gradation, void ratio, atterberg's limit, density, strength, compressibility, permeability etc are of main concern if the soil is used as a foundation material. Lucknow is the capital city of most populous state named Uttar Pradesh in India covering an area of approx. 2400-2700 sq. Km. situated in stretch ranging from 80° 30' to 81° 13' East longitude and 26° 30' to 27° 10' North latitude. It is surrounded by Barabanki district on the east, Sitapur & Hardoi district on north, Unnao on the west and Raebareli in the south. Road and railway connectivity from the prominent places of India exist and evidence of proper functioning of communicational network. It is connected by Delhi, Bhopal, Bihar (Mokama) and Varanasi through NH 24, 25, 28 and 56 respectively and Hardoi, Raebareli, Sultanpur and Mohaan through State highway 25, 36, 56 and 40 respectively. Intercity connectivity is achieved through numerous bridges on Gomti river, which divides the city in almost two halves i.e. Hardinge/Pakka/Lal bridge, Iron bridge, University Bridge, Nishatganj bridge in old Lucknow and Gomti

barrage, Gandhi setu and Ambedkar bridge in new Lucknow. Recent development in the field of intercity communication is 23km long elevated Amar Shahid Path starting from Faizabad road passing through Sultanpur road and Raibareli road and ends at Kanpur road. With the facility of Metro rail project under progress covering the whole city this city is presently in the rapid development stage. The main aim of this paper is to identify the area of foundation suitability keeping in view the radial expansion of city along the outgoing roads of the city so that economic planning for future expansion of city may be achieved and the settlements of the buildings which is likely to occur in future may be avoided or corrective measures at the construction stage can be executed for the stability of the civil structures constructed on these.

2. METHODOLOGY

2.1 Measured Soil Properties

The safety and strength of a building depends to a large extent on soil properties. Even a great construction plan may have certain limitations depending on the kind of soil may lead to either to an added expense or the tumbling of the structure, which ultimately shows the failure of the plan. Hence it is the requisite of construction is the awareness of the soil characteristics. For the purpose of measuring the soil properties of the selected towns the properties based on the particle size analysis, consistency limits, shear strength and compressive strength and properties relating to flow through soils were determined of all the selected sites as shown in table 1.

Table-1 Measured Soil Properties of Selected Sites

SL. No.	Parameter	Measured Properties
1	Particle Size Analysis	Soil Texture(gravel, sand ,silt ,clay percentage), Percentage Finer
2	Consistency Limits	Liquid Limit, Plastic Limit, Shrinkage Limit, Moisture Content, Dry Density, Specific Gravity
3	Shear Strength	Cohesion, Angle of Internal Friction,
4	Compressive Strength	Optimum Moisture Content, Maximum Dry Density, Compression Index, Swelling Potential
5	Flow Properties	Permeability, Void Ratio, Porosity, Depth of Water Table

2.2 Collection of Samples

Seven representative towns/sites were selected on outgoing/passing National & State highways around the Lucknow covering the circumference of the Lucknow City where possible growth of the city is inevitable. It was assumed that first the radial expansion along the existing road will take place. The study areas ranging from towns/village, Tehsil headquarters, to district head quarters shown in figure 1.



Fig -1: Map Showing The Selected Towns/ Sites

The location of the selected sites ranging from 19 Kms to 35 Kms from Charbaag Railway Station in different directions and 4 to 15 km from the present existing boundary of the city. All the selected sites are located either on National Highway or State Highway.

Table-2-Selected Towns Around The Lucknow City

Selected Town/Location	Description	Road Link	Distance From Charbaag
Mohanlalganj	Tehsil Headquarter of Lucknow District	Lucknow-Raibareli Road(SH-40)	19Km
Itaunza	Town & Nagar Panchayat in Lucknow District	Lucknow-Sitapur Road(NH-24)	31km
Banthara Bazar	Town/Village in Sarojini nagar Tehsil in Lucknow	Lucknow-Unnao Road(NH-25)	22km
Barabanki	District Headquarter of U.P.	Lucknow-Fazabad Road(NH-28)	32Km
Gosaiganj	Town & Nagar Panchayat in Lucknow District	Lucknow-Sultanpur Road(NH-56)	21km
Malihabad	Town and Tehsil head quarter in Lucknow District	Situated on Lucknow - Hardoi Road(SH-25)	35Km
Bhauli	Sub location(Town or Village) under Bakshi Ka Talab, Lucknow	Lucknow-Sitapur Road(NH-24)	20Km

Sample collection and test performance were carried out from January to April month nearly three months closing of the rainy season and before the starting of the summer season so that measured parameters are not influenced by rain water / summer heat and show the stable and true picture. However since the worst condition of the shear strength of the soil is in moist stage the direct shear test was carried out in wet condition. For the collection of soil samples 1sq km area on both sides of the existing road for each location was undertaken for study. Samples were taken at the corner points of the square having sides of approx. 0.5 km.

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1 Experimental Observation and Analysis

Soil samples taken from eighteen trial pits of each site/location at depths of 1m and 2m were used for the investigation. Both disturbed and undisturbed samples at two depths in low lying areas and six soil samples at two depths within the Lucknow city representing the whole area covered by the city to serve as control sample for comparative study. The location of the control pits are at Indiranagar, Gomtinagar, Rajabajar, Alambaag, Nishat Ganj and Medical College. The various tests/analysis required for the properties mentioned in table 1 were carried out.

3.2 Particle Size Analysis

Both sieve analysis and sedimentation analysis was carried out and test results are shown in table 3.

Table-3-Particle Size Analysis

Selected Town/ Location	SIEVE ANALYSIS				SEDIMENTATION ANALYSIS	
	4.75mm	2mm	0.425mm	0.075mm	0.002mm	<.002mm
Mohanlalganj	98	72	64	35	12	23
Itaunza	100	84	70	65	39	26
Banthara Bazar	100	95	84	73	56	17
Barabanki	97	75	65	32	18	14
Gosaiganj	100	83	78	68	46	22
Malihabad	100	84	73	62	40	22
Bhauri	100	97	87	75	62	13

From the results of sieve and sedimentation analysis the percentage gravel, sand, silt and clay content for soils of each sites were determined and are shown in table 4 and figure 2.

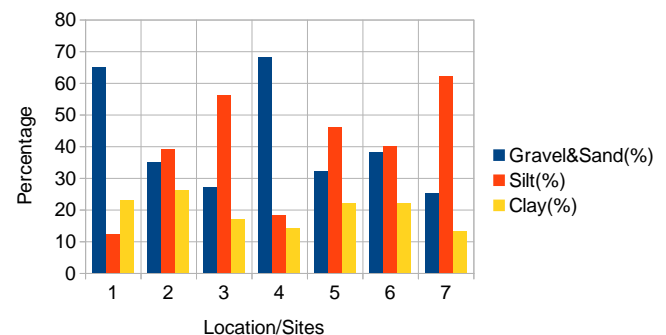


Fig 2-percentage gravel, sand, silt and clay content

Table-4 -Percentage silt, gravel, clay content of the soil

Parameter	Mohanlal ganj	Itaunza	Banthara Bazar	Bara banki	Gosai ganj	Maliha bad	Bhauri
Percentage Finer	35	65	73	32	68	62	75
Gravel&Sand(%)	65	35	27	68	32	38	25
Silt(%)	12	39	56	18	46	40	62
Clay(%)	23	26	17	14	22	22	13

3.2.1. Consistency Limits Analysis

For the identification of characteristics the tests of liquid limit, plastic limit, shrinkage limit, moisture content, and

specific gravity were carried out as per Indian Standard test procedure of the collected samples and mean values of the test results are shown in table 5

Table-5 -Consistency Limit Analysis

Location/Town	Liquid Limit	Plastic Limit	Plasticity Index	Shrinkage Limit	Moisture content	Specific Gravity
Mohanlalganj	38	23	15	21	24.3	2.56
Itaunza	42	30	12	28	25.8	2.68
Banthara Bazar	49	38	11	30	27.4	2.80
Barabanki	40	24	16	20	24.6	2.54
Gosaiganj	45	32	13	27	26.2	2.72
Malihabad	46	32	14	29	26.0	2.65
Bhauri	52	42	10	32	27.7	2.76

3.2.2 Shear Strength and Compressive Strength Analysis

Estimation of soil shear strength and compressive strength is required for the design of foundation so that stability of slopes and soils can be assessed. This may also be used to constitute the ability of soil to withstand stresses and strains associated with naturally occurring substances such as pore pressure, cracking, swelling, leaching and weathering. For

the shear strength assessment direct shear box test was carried out on soil samples collected in moist condition since shear strength is lowest in saturated soil. The parameters determined for shear strength were cohesion and angle of internal friction whereas for compressive strength were maximum dry density, optimum moisture content, compression index and swelling potential.

Table-6 -Shear Strength and Compressive Strength Analysis

Location/Town	Cohesion	Angle of Internal Friction	Maximum Dry Density	Optimum Moisture Content	Compression Index	Swelling Potential
Mohanlalganj	0.46	12	1.58	16.50	0.140	21.00
Itaunza	0.10	15	1.80	22.50	0.148	25.00
Banthara Bazar	0.22	18	1.72	18.00	0.142	23.50
Barabanki	0.42	11	1.60	15.00	0.135	19.00
Gosaiganj	0.32	08	1.65	19.50	0.146	22.00
Malihabad	0.40	14	1.76	18.00	0.145	24.00
Bhauri	0.12	16	1.78	21.00	0.152	27.50

3.2.3 Properties Relating To Flow Through Soils Analysis

Engineering behavior of the most types of the soils is affected by water, which plays an important role in the occurrence as well as solution of geotechnical problems. The flow of water through soil medium takes place through interconnected pores. For characterizing the soil it is very essential to be aware of the flow of water through soils to

assess the properties related to the water movement of the soil and depth of water table below ground level to incorporate corrective measures during the planning and design stages for the structures to be constructed over these foundations. The test results of the measured properties i.e. Voids ratio, porosity, permeability and depth of water table below ground level for each site in this regard are shown in table 7.

Table-7 - Properties Relating to flow through Soil's Analysis

Location/Town	Void Ratio	Porosity	Permeability	Depth of Water Table
Mohanlalganj	0.550	35.00	0.0400	32m
Itaunza	0.720	42.00	0.0450	8m
Banthara Bazar	0.650	40.00	0.0440	15m
Barabanki	0.580	37.00	0.0420	34m
Gosaiganj	0.645	39.00	0.0430	20m
Malihabad	0.670	40.00	0.0450	22m
Bhauri	0.680	41.00	0.0460	6m

3.3. Comparative/Statistical Analysis

The mean values of r different parameters of each site/location along with mean value of test results obtained from soil samples collected from the six locations i.e.

Indiranagar, Gomtinagar, Rajabajar, Alambaag, Nishat Ganj and Medical College inside the city to serve as control points for comparative analysis are tabulated in table 8.

Table-8-Summary of Geotechnical Properties

Para meter	Control Sample	Mohanlal ganj	Itaunza	Banthara Bazar	Bara banki	Gosai ganj	Malihabad	Bhauri
Percentage Finer	30	35	65	73	32	68	62	75
Sand & Gravel(%)	72	65	35	27	68	32	38	25
Silt(%)	15	12	39	56	18	46	40	62
Clay(%)	13	23	26	17	14	22	22	13
Liquid Limit	32	38	42	49	40	45	46	52
Plastic Limit	14	23	30	38	24	32	32	42
Plasticity Index	18	15	12	11	15	13	14	10
Shrinkage Limit	12	21	28	30	20	27	29	32
Natural Moisture Content	25.8	24.3	25.8	27.4	24.6	26.2	26.0	27.7
Specific Gravity	2.65	2.56	2.68	2.80	2.54	2.72	2.65	2.76
Cohesion	0.50	0.46	0.10	0.22	0.42	0.32	0.40	0.12
Angle of Internal Friction	24	12	15	18	11	08	14	16
Maximum Dry Density	1.75	1.58	1.80	1.72	1.60	1.65	1.76	1.78
Optimum Moisture Content	15	16.50	22.50	18.00	15.00	19.50	18.00	21.00
Compression Index	0.135	0.140	0.148	0.142	0.135	0.146	0.145	0.152
Swelling Potential	15.00	21.00	25.00	23.50	19.00	22.00	24.00	27.50
Void Ratio	0.340	0.550	0.720	0.650	0.580	0.645	0.670	0.680
Porosity	25	35	42	40	37	39	40	41
Permeability	0.035	0.040	0.045	0.044	0.042	0.043	0.045	0.046
Depth of Water Table	40	32	08	15	34	20	22	06

These mean values has been compared with the mean values of the control sample i.e the samples collected from the locations inside the city as percentage above/ below/ not

distinguished category and average percentage variation for each site has been shown in table 9.

Table-9- Percentage Variation in Geotechnical Properties

Para meter	Control Sample	Mohanlal ganj	Itaunza	Banthara Bazar	Bara banki	Gosai ganj	Malihabad	Bhauri
Percentage above the mean values of soil samples collected inside the City								
Percentage Finer	30.00	16.67	116.67	143.33	06.67	126.67	106.67	150.00
Clay(%)	13.00	76.92	100.00	30.77	07.69	69.23	69.23	00.00
Liquid Limit	32.00	18.75	31.25	53.13	25.00	40.63	43.75	62.50
Plastic Limit	14.00	64.29	114.29	171.43	71.43	128.57	128.57	200.00
Shrinkage Limit	12.00	75.00	133.33	150.00	66.67	125.00	141.66	166.67
Optimum Moisture Content	15.00	10.00	50.00	20.00	00.00	30.00	20.00	40.00
Compression Index	0.135	03.70	09.63	05.19	00.00	08.15	07.41	12.59

Swelling Potential	15.00	40.00	66.67	56.67	26.67	46.67	60.00	83.33
Void Ratio	0.340	61.76	111.76	91.18	70.59	89.71	97.06	100.00
Porosity	25.00	40.00	68.00	60.00	48.00	56.00	60.00	64.00
Permeability	0.035	14.29	28.57	25.71	20.00	22.86	28.57	31.43
Percentage below the the mean values of soil samples collected inside the City								
Sand & Gravel(%)	72.00	09.72	51.38	62.50	05.56	55.56	47.22	65.28
Plasticity Index	18.00	16.67	33.33	38.89	16.67	27.78	22.22	44.44
Cohesion	00.50	08.00	80.00	56.00	16.00	36.00	20.00	76.00
Angle of Internal Friction	24.00	50.00	37.50	25.00	54.16	66.67	41.67	33.33
Depth of Water Table	40.00	20.00	80.00	62.50	15.00	50.00	45.00	85.00
Not Distinguished								
Silt(%)	15.00	20.00	160.00	273.33	20.00	206.67	166.67	313.33
Natural Moisture Content	25.80	05.81	00.00	06.20	04.65	01.55	00.78	07.36
Specific Gravity	02.65	03.40	01.13	05.66	04.15	02.64	00.00	04.15
Maximum Dry Density	01.75	09.71	02.86	01.71	08.57	05.71	0.571	01.71
Average(%)	17.81	5.19	19.48	27.47	03.18	23.83	16.60	29.07

Out of the total Twenty parameters, it is observed that eleven parameters have values exceeding than mean value of control sample while five parameters have values less than the mean value of the control sample. The four parameters are in non-distinguished category since some

some location shows higher values whereas some locations have less value than the control sample mean value. The mean value of the control sample and mean value of the parameters along with standard deviation and percentage variation are shown in table10.

Table10. Comparative study of Parameters With Control Sample

Parameter	Control Sample Mean Value	Mean Value of the Selected Locations	Standard Deviation	Percentage Variation
Percentage Finer	30.00	55.00	17.68	83.33
Clay(%)	13.00	18.75	04.07	44.23
Liquid Limit	32.00	43.00	07.78	34.38
Plastic Limit	14.00	29.38	10.87	109.82
Shrinkage Limit	12.00	24.88	09.10	107.29
Optimum Moisture Content	15.00	18.19	02.25	21.25
Compression Index	0.135	00.14	0.006	05.83
Swelling Potential	15.00	22.13	05.04	47.50
Void Ratio	0.340	00.60	0.187	77.76
Porosity	25.00	37.38	08.75	49.50
Permeability	0.035	00.04	0.005	21.43
Sand & Gravel(%)	72.00	45.25	18.92	37.15
Plasticity Index	18.00	13.50	03.18	25.00
Cohesion	00.50	00.32	00.13	36.50
Angle of Internal Friction	24.00	14.75	06.54	38.54
Depth of Water Table	40.00	21.13	12.64	44.69
Silt(%)	15.00	36.00	14.85	140.0

Natural Moisture Content	25.80	25.98	00.12	00.68
Specific Gravity	02.65	02.67	0.014	00.75
Maximum Dry Density	01.75	01.71	0.032	02.57
Average(%)	17.81	20..59	6.11	27.97

4. CONCLUSION

For arriving at final conclusion soil site rating for each site on seven point scale based on soil properties i.e the

laboratory test results and a three point scale based on the uses of soil was developed/designed and carried out as shown in table 11.

Table-11- Soil & Site Rating of Selected Town/ location

Parameter	Mohanlal ganj	Itaunza	Banthara Bazar	Bara banki	Gosai ganj	Malihabad	Bhauri
Based On Soil Properties							
Particle Size Analysis	07	04	02	06	05	03	01
Consistency Limits	06	02	04	07	03	02	01
Shear Strength	07	01	03	05	04	06	02
Compressive Strength	06	02	05	07	03	04	01
Flow Properties	07	01	04	07	03	05	02
Based On Uses of Soil							
Overhead tank/Buildings	03	01	02	03	02	02	01
Absorption Capability for Septic Tank	01	03	02	01	02	02	03
Shallow Excavation	01	03	02	01	02	02	03
Local Roads & streets	03	02	02	03	02	03	02
Sand & gravel Availability	03	02	02	03	02	02	01
Road Filling Material	03	02	01	03	02	02	02
Total Score=53	47	23	29	46	30	33	19

On the basis of the study the following conclusions can be drawn:

- It is observed from the above table that location Malihabad and Barabanki may be categorised as best location whereas bhauri and Itaunza are the worst locations. Banthara Bazar, Gosaiganj and Malihabad falls under moderate category.
- The development/design/planning on Lucknow-Raibareilly Road (SH-40) and Lucknow-Faizabad Road NH-28 need no special attention and normal design of foundation practices will be sufficient and civil structures to be constructed on these locations will not impose any extra expenditure on account of the ground suitability of foundations.
- The locations falling under moderate category need to be designed for the type of structure to be located on particular location after the detailed soil investigation and adopting/mentioning proper compaction technique /soil improvement techniques.
- For Bhauri and Itaunza i.e. Lucknow-Sitapur Road (NH-24) as the soil is not suitable for development of civil engineering structures, the foundations are not

desirable until the special ground improvement technique such as mechanical stabilization, addition of admixtures (soil, lime, cement or other), thermal stabilization by heating the ground at temperature more than 500 degree centigrade, preloading, Dynamic compaction/replacement, geotextile reinforcement is adopted.

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