Sub Soil Investigations and Improvement of Internal Roads

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Abstract- *In India the major problem is maintaining the internal roads in plant areas where the stagnation of water is take place in rainy seasons due to heavy vehicle loads. Now a day's India is currently engaged in the construction and improvement of their existing roads in their plant area.*

For construction and improvement of internal roads the first step is to investigate the soil properties or road conditions at the respective sites. In order to investigate samples for performance or characteristics field tests and laboratory tests are done. The stagnation of water and heavy vehicle load creates the soft conditions on the existing roads or Sub grade. Hence we are taking standard penetration test (SPT) and California Bearing Ratio (CBR) test to evaluate their geotechnical characteristics.

Initially a site is selected where the improvement and new construction in need 4 or 6 bore holes are made based on the site conditions in the part of standard penetration test and California Bearing Ratio test also conducted to know the site geotechnical characteristics. After investigation, based on the results we propose thickness of the road for strengthen of the road and new construction of the road in the plants.

Keywords- Subsoil, Stabilization, Internal Roads, Standard Penetration test, California Bearing ratio.

I. INTRODUCTION

1.1 General

In India, the area covered by expansive soils is nearly 20% of the total area. They normally spread over a depth of 2 to 20m. In Rainy season, structures on this soils experience large-scale damage due to heaving accompanied by long strength, where as in summer season, they shrink and gain density and become hard. Their alternative swelling & shrinkage damages structure severely. This is severe for lightly loaded structures.

The deformations produced as a result of swelling or shrinkage is significantly greater than elastic deformation and classical elastic or plastic theory cannot predict them elastic deformation and classical elastic or plastic theory cannot predict them. During summer, POLYGONAL SHRINKAGE CRACKS appear at surface, which may extend to a depth of about 2m indicating the active zone in which volume change occurs.

Because of the swelling of black cotton soils during rainy season & their shrinkage during summer, extensive damages have been carved such as "Building Cracks", canal LANDSLIDES, beds of canal heave, healing &rutting of pavements, damage to conduits etc.

Soil is a natural body consisting of layers (soil horizons) that are primarily composed of minerals which differ from their parent materials in their texture, structure, consistency, and colour, chemical, biological and other characteristics. It is the unconsolidated or loose covering of fine rock particles that covers the surface of the earth. Soil is the end product of the influence of the climate (temperature, precipitation), relief (slope), organisms (flora and fauna), parent materials (original minerals), and time.

1.2 Improvement of Roads on Black Cotton Soils

Generally, lands with black cotton soils are fertile and very good for agriculture, horticulture, sericulture and aquaculture. Good irrigation systems exist, rainfall is high and people are affluent in these areas. Though black cotton soils are very good for agricultural purposes, they are not so good for laying durable roads. Good road network is a basic requirement for the all round development of an area. Unfortunately, poor road network is hampering the full fledged development of the otherwise prosperous areas.

For developing a good and durable road network in black cotton soil areas, the nature of soils shall be properly understood. Black cotton soils absorb water heavily, swell, become soft and lose strength. Black cotton soils are easily compressible when wet and possesses a tendency to heave during wet condition. BC soils shrink in volume and develop cracks during summer. They are characterized by extreme hardness and cracks when dry. The stability and performance of the pavements are greatly influenced by the sub grade and embankment as they serve as foundations for pavements. On such soils suitable construction practices and sophisticated methods of design are to be adopted. In the present paper, reasons for poor condition of roads in B.C soils and measures to be taken for construction and improvement of roads on BC soils are presented.

Following are some of the important reasons for poor condition of roads in BC soil terrain.

- Nature of BC soils
- Poor drainage facilities
- Use of gravelly soil in base and sub-base
- Improper estimate preparations
- Plying of overloaded vehicles and iron wheeled tractors trolleys/carts
- Damage of roads during collection of materials
- Forming roads on canal banks and tank bunds

1.3 Scope of the Study

The experimental study is concerned with the selection of approximate type of soils to achieve a very high degree of compaction and to expose the compaction properties of soil. The geo-technical investigation works were entrusted and carried out the fled investigations and followed it with the necessary laboratory testing on the soil and rock samples collected. Based on all the results determined from field and laboratory tests we can provide the recommendations for the road pavements as per the recent approved Indian Roads Congress (IRC) code IRC: 58-2002.

1.4 Objectives of the Study

The following are the main objectives of our project work.

- Conducting SPTs at regular depth intervals;
- Collecting disturbed and undisturbed soil samples;
- Conducting relevant field and laboratory tests on soil and rock samples;
- Collecting barrow samples from the excavated material of the reservoir and carrying out necessary tests for suitability of the material.
- Collection of Fly Ash samples and conducting relevant chemical analysis and tests for other parameters.
- To Provide the recommendations for the road pavements as per the recent approved Indian Roads Congress (IRC) code IRC: 58-2002

II. LITERATURE RIEVIEW

2.1 Classification of Roads in India:

As per the Nagpur Pl, the roads are classified as

i) National highways
ii) State highways
iii) District highways
  a) major district roads
  b) minor district roads
iv) village roads

NECESSARY OF CLASSIFYING ROADS:- To plan a road network for efficient and safe traffic operation , and for knowing the clear information of a particular root in a country, the classification of roads is necessary.

a. NATIONAL HIGHWAYS:- These are the important roads of the country. They connect state capitals, ports and foreign highways. They also include roads of military importance. They are financed by the central government.

b. STATE HIGHWAYS :- these are the important roads of a state. They connect important cities and district head quarters in the state , national highways & state highways of neighboring states. They are financed by state government roads and buildings department of the state government constructs & maintain these roads.

c. DISTRICT ROADS :- these are the roads within a district . they are financed by zillaparishads with the help of grants given by state government.

i. THE MAJOR DISTRICT ROADS:- They are roads connecting district head quarters, taluk head quarters and other important town in the district production and market centers with each other and with state & national highways & railways.

ii. OTHER DISTRICT ROADS :- They are district roads of less importance

g. VILLAGE ROADS:- they connect villages with each other and to the nearest district road.

2.2 Poor Drainage Facilities

For Indian roads drainage is a badly neglected aspect. Special publication of Indian Roads Congress, IRC: SP 42 clearly gives guidelines for providing surface and sub surface drainage systems. The main objective of road drainage is to prevent early damage of the pavement due to entry of excess of water and preventing saturation up to a depth of 1 meter below the top of sub grade.

Various types of damages arising due to inadequate drainage are listed below.

- Reduction in bearing capacity of sub grade soil.
- Pavement failures like potholes, rutting, waviness and corrugation in flexible pavement.
- Reduction in strength of many pavement materials like stabilized soil, WBM and BT surfacing.
- Damages to shoulder and pavement edges from surface water.
- Considerable erosion of soil from sub strata, slopes, cut and hill side due to surface water.

Water enters the pavement structure in one or a combination of the following ways:

- Ingress of water through berms and porous BT surfacing
- Seepage water flowing across the pavement structure
- High water table conditions
- Capillary rise of water through embankment and sub grade soils
- Absorption of water during curing of subsequent layers

2.3 Use of Gravelly Soil in Base and Sub-Base

The biggest contributor of road damages in the southern states is the use of highly adhesive and plastic gravelly soil in sub base and base layers. Even today, many highway engineers strongly believe that adhesive quality is very much required for sub base and blind age materials. A look into the definitions and specifications prove that this belief is totally wrong. Definition of sand and gravel as per Code IS: 1490 – 1987: Sand and gravel are defined as Cohesion less aggregates of angular, sub angular, sub-rounded, rounded, flaky or flat fragments of more or less unaltered rocks or minerals.

2.4 Water Stagnation, A Perennial Problem

Water stagnation on city roads and in residential areas due to showers continues to trouble pedestrians and motorists. The problem has becomes perennial without a solution.

Residents of Mittapudur said that the recent patch work carried out by the Corporation has failed to withstand the showers as potholes have emerged once again making it difficult for pedestrians and vehicles. “There is no end to the slushy and waterlogged roads,” said motorist P. Madhan.

Residents said that the road was earlier dug for laying water pipelines and now again dug for laying of optic fibre cables. “Soon, it would be dug for underground drainage work or for some other work. It is almost a year that various road works were carried out and it would take another one year for tar-topping,” added a shopkeeper in the area. Since the roads were dug in the centre and water stagnates on it, pedestrians are left with no space to walk as vehicles on both the directions keep moving.

“Getting splashed with rain water mixed with stagnated water is common,” said residents in Balaji Nagar. They said that the stagnated water did not drain easily due to the presence of potholes and also the road was low-lying. Residents also said that the uncleared garbage dumped on roads also mix with the water and cause bad odour and cause sanitation concern in their area.

III. METHODOLOGY

3.1 Field Boring and Sampling

One number of Rotary Calyx drilling machine rig was mobilized and drilling operation work was done. Standard 150 mm diameter boreholes were made at locations. These boreholes were sunk to the required depth of hard strata. SPT tests were conducting at 1.0m and 1.5m regular intervals and at all type of soil stratum and disturbed samples were collected.

3.2 Standard Penetration Test

SPT split spoon sampler of standard dimensions was driven into the soil from the borehole bottom using 63.5 kg hammer with a fall of 75 cm height. The SPT weight was lifted to the specified height and allowed to fall freely on the anvil with the use of cat-head winch with one to one and half turn of the drum. Blow counts for the penetration of every 15 cm were recorded and the ‘N’ value is reported as the blow counts for 30 cm penetration of the sampler excluding the first 15 cm penetration as seating drive. When the number of blows exceeded 50 to penetrate the first or second 15 cm length of the sampler, the SPT 'N' is regarded as more than 100 as described in IS 2131 - 1981. The test is terminated in such case and a record of the penetration of the sampler under 50 blows is made. These tests were conducted at close intervals of 1.0m so that a continuous SPT 'N' profile is available. Disturbed soil collected in the SPT sampler was preserved in polythene covers and transported to the laboratory.

3.3 Excavation of Trial Pits/ Test Pits

Trail Pits or merely Tests Pits of depth varying from 1.70m to 2.10m were excavated at required locations. Disturbed samples were collected from the Trial Pits for determining Laboratory California Bearing Ratio (CBR), the representative sample of nearly 25.00kg – 30.00 kg was collected from each Trial Pit. And also other tests like NMC, Dry Density Bulk Density, gradation properties, attreberg limits and finally laboratory CBR – both soaked and un-soaked of the Trial Pit samples are interpreted

3.4 Collection of Barrow Area Samples (Excavated Samples Reservoir Area)

Barrow area samples were collected at site in Three (03) different locations viz., Reservoir-I, Reservoir-II and Reservoir-III. These samples were tested for various engineering properties which are applicable to the formation of roads from earthen material.

3.5 Collection of Fly Ash Samples

Fly Ash samples were collected from plant and tested for various Chemical and gradation parameters.

3.6 Details of the Geotechnical investigations Carried Out / Exploration Program

The scope of work completed at this site is summarized below:

- Making of Four (04) numbers of Standard Soil Investigation Borehole upto the depth below 15.00m or upto 1.50m Hard Strata, whichever is earlier on the existing Ground Level and as directed by the Engineer-in-Charge. The details of the Boreholes are given below:

Table3.1: Details of Boreholes:

S. No.	Borehole No.	Elevation, RL Details with respect to Bridge, m	Location (Chainage) from Bridge m	Total Depth of Drilling, m
1	BH-01	375.520	105.50	7.80
2	BH-02	376.295	195.00	5.40
3	BH-03	377.745	394.00	4.00
4	BH-04	377.325	527.50	8.00

These boreholes (BHs) were advanced by shell and auger method using Rotary Calyx Rig as per IS: 1892 and during the boring operations, necessary in-situ strength tests like Standard Penetration Tests (SPT) were conducted within the bores as per IS: 2131 at the required depth intervals and also a number of soil and rock samples were taken and from the bores and the relevant standard laboratory tests were carried out by this testing agency as per IS: 2720, IS: 1498 etc.

Table3.2: Details of Trail Pits:

S. No	Trial Pit No.	Location, Chainage (m) from Bridge	Elevation (RL)- with reference to Bridge, m	Depth of excavation of the Pit (in m)
1	TP-01	378.745	452.50	1.70
2	TP-02	377.675	390.00	1.80
3	TP-03	376.765	285.00	2.10
4	TP-04	376.475	157.50	1.90

The soil samples, taken from these Trail Pits (TPs) are used in conducting the relevant standard laboratory tests. These were carried out by this testing agency as per IS: 2720, IS: 1498. On a four (04) numbers of samples, California Bearing Ratio (CBR) tests were also conducted to establish the design parameters in the design of pavements for roads.

IV. RESULTS AND DISCUSSION

4.1 SOIL PROFILE OF OPEN TEST PITS/ TRAIL PITS

As the soil characteristics of the top layers significantly influence the design and stability of the road parameters. An effort was made to excavate four (04) numbers of Test Pits upto a depth of about 2.0m below the EGL. The soil samples taken out of these pits, at depths of 1.70m, 2.10m indicate that they are predominantly of Silty Clay type (with finer fractions constituents 62% to 88%) and this top surface influences the design and stability of the road parameters

4.2 ANALYSIS OF LABORATORY TEST RESULTS

4.2.1 INDEX PROPERTIES

The Liquid Limit (IS: 2720) values of the top strata are in the range of 56% to 64% indicating the clay of CH type and they are likely to exhibit moderate swell pressure.

Bore Hole No	Depth (m)	Liquid Limit W_L %	Plastic Limit W_P %	Plasticity Index I_P %
1	3.4	64	42	22
	4.4	54	32	22
	4.5	42	26	16
2	2.4	48	28	20
3	1.00	36	20	16
4	1.00	42	20	22
	2.00	39	21	18
	3.00	44	23	21
	4.00	41	21	19

Trail Pit No	Depth (m)	Liquid Limit W_L %	Plastic Limit W_P %	Plasticity Index I_P %
1	1.7	64	42	22
2	1.8	62	38	24
3	2.1	56	31	25
4	1.9	58	36	22

Reservoir No	Depth (m)	Liquid Limit W_L %	Plastic Limit W_P %	Plasticity Index I_P %
1	0	64	44	20
2	0	58	36	22
3	0	62	36	26

4.2.2 PARTICLE SIZE ANALYSIS

Bore Hole No	Depth (m)	IS	Gravel %	Sand %	Silt %	Clay %
1	4.50	GC	6	46	48	
	5.50	SM	18	64	18	
2	3.40	SM	16	72	12	
3	1.00	SC-CL	0	62	38	
	2.00	SM	8	68	24	
	2.50	GP	18	78	4	
4	1.00	SC-CL	0	54	46	
	2.00	SC	0	62	38	
	3.00	SC	0	64	36	
	4.00	SC	0	63	37	
	5.00	GP	14	69	17	
	5.00	GP	18	73	9	

4.2.3 CHEMICAL ANALYSIS OF SOIL SAMPLES

	Depth (m)	Parameters				
		p^H	Sulphite (as SO_3)	Chloride (as Cl)	Carbonate (as CO_3)	Organic matter (%)
BH: 01	3.40	7.96	0.064	0.68	0.026	2.2
BH: 02	2.40	8.04	0.078	0.64	0.032	2.4
BH: 03	1.00	8.12	0.076	0.72	0.036	2.8
BH: 04	2.00	8.08	0.068	0.66	0.033	2.6

4.4.6 CALIFORNIA BEARING RATIO (CBR) TESTS (IS: 2720, Part-31)

On these samples (Refer the results), CBR tests were carried out as per IS: 2720, Part-31. These test results indicate CBR values (under soaked condition) of 3.9% to 5.2%. This indicates that as per IRC: 37, the minimum pavement thickness under Flexible Pavement Condition, is about 700mm. However, considering the nature of traffic (Axle loading, number of repetitions of this axle loading) conditions and the Weather Conditions, it is not advisable to adopt Flexible Pavements along this road.

It has been advised to adopt the following design condition for the Road Pavement:

Design Life of the Road Pavement : 30 years
Road Width : 4.5m to 7.0m
Concrete Grade for the Road Pavement: M-40
Traffic Intensity : 300 commercial vehicles per day.

4.2.4 ROCK TEST RESULTS

Bore Hole No.	Sample Reference @ Depth	Water Absoption Ratio (%)	Specific Gravity	Density Kg/cm³	Crushing Strength (Kg/cm²)
BH - 01	6.30-7.30	0.32	2.63	1.96	326.78
	7.30-7.80	0.33	2.67	1.94	346.25
BH - 02	3.40-4.40	0.41	2.69	1.78	331.58
	4.40-5.40	0.39	2.66	1.91	379.84
BH - 03	2.50-3.00	0.38	2.68	1.92	332.42
	3.00-4.00	0.42	2.71	1.98	365.96
BH - 02	6.50-7.50	0.38	2.69	1.86	364.32
	7.50-8.00	0.43	2.73	1.94	386.28

V. CONCLUSION

The following conclusions are made based on the laboratory experiments carried out in this investigation.

- From the laboratory studies, it is observed that the Expansive Soil chosen was a problematic soil having high swelling, and high plasticity characteristics.
- It was observed that the treatment as individually with 25% VTS has moderately improved the expansive soil.
- There is a gradual increase in maximum dry density with an increment in the % replacement of VTS up to 25% with an improvement of about 2% and it was about 25% for strength characteristics.
- There is an improvement in maximum dry density and also corresponding strength characteristics with an increase in the WTR content from 0% to 1.5% with an improvement of 126% for cohesion, 8 times for friction angle and about 3 times for soaked CBR respectively.
- It is evident that the addition of Vitrified Tile sludge (VTS) to the virgin Expansive soil showed an improvement in compaction, strength and penetration characteristics to some extent and on further blending it with WTR, the strength mobilization was more pronounced.

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REFERENCES

[1] P. R. Modak, P. B. Nangare, S. D. Nagrale, R. D. Nalawade, V. S. Chavhan "Stabilization of Black Cotton Soil Using Admixtures". International Journal of Engineering and Innovative Technology (IJEIT), Volume 1, Issue 5, pp.1-3, (May 2012).

[2] Seda, J.H., Lee, J.C and Carraro, J.A.H. (2007) "Beneficial use of Waste Tire Rubber for Swelling Potential Mitigation in Expansive Soils," Proceedings of Geo-Denver 2007, Geotechnical Special Publication No.172,1-9.

[3] Patil, U., Valdes, J.R. and Evans, T.M. (2011) "Swell Mitigation with Granulated Tire Rubber," Journal of Materials in Civil Engineering, 23 (5), 721-727.

[4] Palaniappan, K.A. and Stalin, V.K. (2009) "Utility Effect of Solid Wastes in Problematic Soils," International Journal of Engineering, Research and Industrial Applications,2(1), 313-321.

[5] Sabat, A.K. and Nanda, R.P. (2011) "Effect of Marble Dust on Strength and Durability of Rice Husk Ash Stabilised Expansive Soil," International Journal of Civil and Structural Engineering, 1(4), 939-948.

[6] Koyuncu, H., Guney, Y., Yilmaz, G., Koyuncu, S., and Bakis, R. (2004) "Utilization of Ceramic Wastes in the Construction Sector," Key Engineering Materials, 264-268, 2509-2512.

[7] Sabat, A.K. (2012) "Stabilization of Expansive Soil using Waste Ceramic Dust," Electronic Journal of Geotechnical Engineering, 17(Z), 3915-3926.

[8] Sabat, A.K. and Bose, B. (2014) "Strength, Swelling and Durability Characteristics of Fly Ash-Lime Stabilized Expansive Soil-Ceramic Dust Mixes," Paper Accepted for publication in International Journal of Earth Sciences and Engineering