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A DETAILED STUDY ON THE IMPROVEMENT OF DURABILITY OF SOIL AND REDUCING THE PAVEMENT THICKNESS BY ADDITION OF CERTAIN ADDITIVES

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ABSTRACT

As we know the road development is one of the major parts of growing infrastructure & Nepal, which is expanding at a very fast rate, the construction of roads is of major concern. As per IRC recommendation, California Bearing Ratio (CBR) value of subgrade is used for design of flexible pavements. The CBR test may be done either in Soaked Specimen or in Unsoaked Specimen. But the standard test requires soaked test, hence in this experiment Soaked Specimens are prepared and tested for CBR values. Also as fly Ash is one of the abundant forms of Solid Waste produced at thermal power plants. Its disposal is a big problem. keeping both these concerns in mind it was tried to come out with a project which will integrate Road development and Fly ash disposal. Thus, in this project we intend to calculate and compare CBR values of natural soil with soil mixed of Lime and fly ash in the ratio 1:3 and then calculated their respective pavement thickness.

KEYWORDS: Analysis, Investigation, Research, California Bearing Ratio, Correlation, Soaked, Unsoaked,

I. INTRODUCTION

1.1 About Kathmandu (Study Region) :

Five major climatic regions are found in Nepal. Of these, Kathmandu Valley is in the Warm Temperate Zone (elevation ranging from 1,200 to 2,300 metres (3,900 to 7,500 ft)), where the climate is fairly temperate, atypical for the region. The location and terrain of Kathmandu have played a significant role in the development of a stable economy which spans millennia. The city is in an ancient lake basin, with fertile soil and flat terrain.

In this region soils have high shrinkage and swelling characteristics. The shearing strength of the soils is extremely low. The soils are highly compressible and have very low bearing capacity. It is extremely difficult to work with such soils

II. EXPERIMENTAL PROGRAM

For checking the properties of the soil, reported different properties like Grain Size Analysis, maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), etc.

2.1 Collection of Materials :

The materials were obtained from the nearby borrow areas in Kathmandu, where plenty amount of material is available for the construction purpose.

Grain Size Analysis (IS: 2720 - Part 4)

Grain size analysis is carried out to determine the relative percentages of different sizes of particles in the sample. These sizes control the mechanical behavior of coarse grained soil. Dry method of sieving is used for coarser fractions (retained on 4.75 mm sieve) and wet method is used for finer fractions (retained on 75micron sieve) and pipette method is used for fractions passing 75 micron sieve.

Case-I : Soil Type 1

Dry Sieving

Weight of Soil sample taken 2000gm

I.S. Sieve Designation (mm)	Weight of sample retained in (g)	Percentage of wt. retained	Cumulative percent of wt. retained (%)	Percentage of wt. passing
100	-	-	0	100
75	-	-	0	100
19	-	-	0	100
4.75	120	6	6	94
Pan	1880			

Table–1 : Sieve Analysis of Soil

Result : Percentage of Gravel in Soil Sample = 6% (<10%)

Case-I : Soil Type 2

Dry sieving

Weight of Soil sample taken 2000gm

I.S Sieve Designation (mm)	Weight of sample retained in (g)	Percentage of wt. retained	Cumulative percent of wt. retained (%)	Percentage of wt. passing
100	-	-	0	100
75	-	-	0	100
19	-	-	0	100
4.75	94	4.7	4.7	95.3
Pan	1906			

Table–1 : Sieve Analysis of Soil

Result : Percentage of Gravel in Soil Sample = 4.7% (<10%)

Liquid Limit, Plastic Limit and Plasticity Index:

If a large quantity of water is mixed in a fine grained soil, the soil will be in a liquid state. The soil will not be able to offer any resistance to deformation i.e. the shear strength of a soil will be equal to zero. On gradual reduction of water content and through kneading of the soil, the soil starts offering some resistance to and deformation and becomes plastic. The limit at which the suspension passes from zero strength to infinitesimal strength is the true liquid limit. At moisture content lower then the liquid limit, the soil will be in a plastic state. At plastic state, the soil can be put into desired shape. On further reduction of water content, Soil loses its plasticity. The limiting water content above which the soil will be in plastic state is called the plastic limit. The range of water content over which the soil is in plastic state is called Plasticity index,

Mathematically,

$$\text{PI} = W_L - W_P$$

Case I – Black Cotton Soil

Atterberg Limits Test Determination of Liquid Limit (LL)

S.No.	Determination No	1	2	3	4	Remarks
1	Container Number	11	12	13	14	
2	Weight of container + wet soil (gm)	42.83	45.87	42.54	44.17	
3	Weight of container + dry soil (gm)	32.54	34.51	32.17	32.89	
4	Loss of Moisture (gm)	10.29	11.36	10.37	11.28	
5	Wt. of container (gm)	13.87	14.21	14.05	13.95	
6	Wt. of dry soil (gm)	18.67	20.3	18.12	18.94	
7	Moisture content %	55.13	56.73	57.21	59.58	
8	Number of blows	38	30	28	20	

Result : Moisture Content at 25 blows from the graph

From graph or by interpolation of above obtained data,

Liquid Limit (LL) = 58 %

Determination of Plastic Limit (PL)

S.No.	Determination No.	1	2
1	Container Number	11	12
2	Weight of container + wet soil (gm)	41.33	40.28
3	Weight of container + dry soil (gm)	32.71	32.16
4	Loss of Moisture (gm)	8.62	8.12
5	Wt. of container (gm)	13.87	14.21
6	Wt. of dry soil (gm)	18.84	17.95
7	Moisture content %	45.77	45.23

Plastic Limit $= \frac{45.77+45.23}{2} = 45.5\%$

Plasticity Index $= (58 - 12.5)\% = 45.5\%$

Case-I : 85% Black Cotton Soil + 15% (Lime + Fly ash)

Atterberg Limits Test Determination of Liquid Limit (LL)

S.No.	Determination No	1	2	3	4	Remarks
1	Container Number	11	12	13	14	
2	Weight of container + wet soil (gm)	39.72	40.53	40.78	41.25	
3	Weight of container + dry soil (gm)	31.52	32.09	32.21	32.15	
4	Loss of Moisture (gm)	8.20	8.44	8.57	9.10	
5	Wt. of container (gm)	13.76	14.02	14.31	13.83	
6	Wt. of dry soil (gm)	17.76	18.07	17.90	18.32	
7	Moisture content %	46.21	46.75	47.90	49.67	
8	Number of blows	35	33	27	20	

Result : Moisture Content at 25 blows from the graph;

From graph or by interpolation of above obtained data,

Liquid Limit (LL) = 48.35 %

Determination of Plastic Limit (PL)

S.No	Determination No.	1	2
1	Container Number	11	12
2	Weight of container + wet soil (gm)	37.09	38.27
3	Weight of container + dry soil (gm)	30.51	31.39
4	Loss of Moisture (gm)	6.58	6.88
5	Wt. of container (gm)	13.76	14.02
6	Wt. of dry soil (gm)	16.75	17.37
7	Moisture content %	39.34	39.63

Plastic limit $= \frac{39.34+39.63}{2} = 39.485\%$

Plasticity Index $= (48.35 - 39.485)\% = 8.865\%$

Proctor Density :

Compaction is the process by which the soil particles are artificially rearranged and packed together into a closer state of contact by mechanical means so that dry density of soil is increased. The process of compaction is accompanied by explusion of air and the volume of water in the soil remains unchanged. In the laboratory different values of moisture contents and the resulting dry densities, obtained after compaction are plotted both to arithmetic scale, the former as abscissa and the latter as ordinate. The points thus obtained are joined together as a curve. The maximum dry density and the corresponding OMC are read from the curve.

Case-I : Black Cotton Soil

Water content %	24	27	29	30.95	35
Dry density (gm/cc)	1.57	1.61	1.64	1.67	1.63

Hence, Max dry density = 1.67 gm/cc at a moisture content of 30.95% .

Case-II : 85% Black Cotton Soil + 15%(Lime + Flyash)

Water content %	19.43	20.85	26.45	29.57	31.46
Dry density (gm/cc)	1.64	1.59	1.76	1.71	1.63

Hence, Max dry density = 1.76 gm/cc at a moisture content of 26.45% .

The California Bearing Ratio Test :

California Bearing Ratio (CBR) Test is developed by California Division of Highway for evaluating the strength of subgrade soil and base course materials for flexible pavements. After II world war, the U.S. Crop of Engineers adopted CBR test for use in the design of base course for the airfield pavements. The test is empirical and the results of this test can't be related accurately with the fundamental properties of the material but useful in the design of flexible pavements. Unless the test procedure is strictly followed, dependable results can't be obtained.

Based on the extensive CBR test data collected, empirical design charts were developed by the California State Highway Department, correlating the CBR value and flexible pavement thickness required. Indian Road Congress (IRC) also use this type of chart.

As per IS:2720 (Part XIV) – 1979, the CBR is define as the ratio of force per unit area required to penetrate a soil mass with a circular plunger of 50 mm diameter at a rate of 1.25 mm/min to force per unit area required for corresponding penetration of a standard material.

Mathematically,

$$\text{CBR}(\%) = \frac{Load\ sustained\ by\ the\ specimen\ at\ 2.5\ or\ 5.0\ mm\ penetration}{Load\ sustained\ by\ standard\ aggregate\ at\ the\ corresponding\ penetration\ level} * 100$$

Case-I : Black Cotton Soil

Table for CBR values of Black Cotton Soil

Penetration	Proving Ring Dial Gauge Reading (R)	Load on Plunger p = R*1.282 kgf
0.0	0	0
0.5	7	8.974
1.0	11	14.102
2.0	21	26.922
2.5	25	32.05
3.0	30	38.46
4.0	47	60.254
5.0	65	83.33
7.5	115	147.43
10.0	165	211.53
12.5	211	270.502

Calculation for CBR value,

Standard load for 2.5 mm penetration = 1370kgf

Value of load from table at 2.5 mm penetration = 32.05 kgf

Therefore, CBR = $\frac{32.05}{1370} * 100 = 2.34\%$

Standard load at 5 mm penetration = 2055 kgf

Value of load from table at 5 mm penetration = 83.33 kgf

Therefore, CBR = $\frac{83.33}{2055} * 100 = 4.055\%$

Case-II : Black Cotton Soil +15% (Lime + Fly ash)

Table for CBR values of Black Cotton Soil + 15%(Lime + Fly ash)

Penetration	Proving Ring Dial Gauge Reading (R)	Load on Plunger p = R*1.282 kgf
0.0	0	0
0.5	12	15.384
1.0	17	21.794
2.0	29	37.178
2.5	34	43.588
3.0	40	51.28
4.0	60	76.92
5.0	76	97.432
7.5	127	162.814
10.0	184	235.888
12.5	228	292.296

Calculation for CBR value,

Standard load for 2.5 mm penetration = 1370kgf

Value of load from table at 2.5 mm penetration = 43.588 kgf

Therefore, CBR = $\frac{43.588}{1370} * 100 = 3.182\%$

Standard load at 5 mm penetration = 2055 kgf

Value of load from table at 5 mm penetration = 97.432 kgf

Therefore, CBR = $\frac{97.432}{2055} * 100 = 4.74\%$

Flexible Pavement design as per CBR method;

Present traffic of ADT = 1200

Annual growth rate = 8 %

Therefore, if design period is of 20 yrs then,

ADT at the end of design period = 1200*$(1 + 0.08)^{20+3}$ = 7045.76 vehicle/day

Therefore design curve G is used for the design :

Case I – Black Cotton Soil

Subgrade CBR = 4.055 %

Similarly if CBR value are 95%, 20%, and 7% for well graded gravel, fairly graded gravel, and compacted soil respectively, then

Using design chart, following thickness of various pavement layers is obtained :

Asphalt surfacing 8 cm thick

Well graded gravel base 15 cm thick

Fairly graded gravel 19.5 cm thick

Compacted soil of 15.5 cm thick

Total pavement thickness = 580 mm

Case-II : Black Cotton Soil + 15 % (Lime + flyash)

Subgrade CBR = 4.74 %

Similarly if CBR value are 95%, 20%, and 7% for well graded gravel, fairly graded gravel, and compacted soil respectively, then

Using design chart, following thickness of various pavement layers is obtained :

Asphalt surfacing 8 cm thick

Well graded gravel base 15 cm thick

Fairly graded gravel 19.5 cm thick

Compacted soil of 9.5 cm thick

Total pavement thickness = 520 mm

III. CONCLUSION & RECOMMENDATIONS

The major conclusions found out after the successful completion of this experiments are be summarized into following points :

- The thickness of crust varies with the change in the value of C.B.R. Higher the value of CBR, smaller will be the crust thickness and vice versa.
- From the experimental analysis it can be concluded that the soil after mixing with lime and fly ash can considerably reduce the pavement thickness required for construction.
- Due to higher value of CBR of soil mixed with fly ash and lime it will have comparatively more lifespan than that of natural soil.

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