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Stabilization of Expansive Sub-Grade for Pavement using Foundry Sand

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Abstract - Clayey soils posses low shear strength and high compressibility which often pose problems in the construction of buildings, roads, bridges and other structures. There are different techniques to improve the strength and deformation characteristics of clayey soils. This experimental study on improving the load-deformation characteristics of soils has been conducted through the addition of waste materials obtained from industries and construction works. Compaction tests were performed on soil and combinations of soil with waste material and reinforcement. Optimum mixes obtained from compaction tests were tested for strength and drainage characteristics. The results indicate sufficient improvement in California bearing ratio and moderate improvement is observed in unconfined compressive and permeability. The economic analysis reveals that the additives can be effectively utilized in the construction of sub-grade for roads.

Key Words: Clayey soil, Compaction tests, Unconfined Compressive Strength, Optimum Mixes.

1. INTRODUCTION

Transportation is necessary for the proper functioning and development of economic activities for any country, which involves production and distribution of goods and services from one place to other. Performance and life of road network is generally depending upon the design and construction. Sub-grade is generally made up of locally available natural soils. The strength and performance of a pavement is dependent on the load-bearing capacity of the Sub-grade soil. In case of poor soil in construction site, the poor soil can be removed or replaced with the soil of high strength. Design of pavement is depend upon the strength of the sub-grade soil, which affects the thickness of pavement ultimately increase the cost of construction. Improvement in load bearing capacity of soil will improve the load-bearing capacity of pavement and thus, pavement strength and its performance.

Stabilization means the improvement of stability or bearing capacity of soil by the use of controlled compaction, proportioning and/ or addition of suitable admixtures or stabilizers. It is required, when the soil available for the construction is not suitable for the intended purpose. Soil stabilization is used to reduce the permeability and compressibility of the soil mass in earth structures and to increase its shear strength. It also increases the bearing capacity of foundation soils. However, the main use of soil stabilization is to improve the natural soils for the construction of highways and airfields. This project deals with the use of foundry sand to improve the geotechnical properties of clayey soil.

As per IRC recommendation, California Bearing Ratio (CBR) value of sub-grade is used for design of flexible pavements. California Bearing Ratio (CBR) value is an important soil parameter for design of flexible pavements and runway of air fields. It can also be used for determination of sub grade reaction of soil by using correlation. It is one of the most important engineering properties of soil for design of sub grade of roads. CBR value of soil may depends on many factors like maximum dry density (MDD), optimum moisture content (OMC), liquid limit (LL), plastic limit (PL), plasticity index (PI), type of soil, permeability of soil etc. Besides, soaked or unsoaked condition of soil also affects the value. These tests can easily be performed in the laboratory. The estimation of the CBR could be done on the basis of these tests which are quick to perform, less time consuming and cheap, then it will be easy to get the information about the strength of sub-grade over the length of roads. In this study, attempts have been made to seek the values of CBR of different soil samples and correlate their CBR values for the design purpose of flexible pavement as per guidelines of IRC: SP: 37-2001. Commonly used methods for soil stabilization are traditional mechanical methods and chemical methods. A wide variety of waste materials from agriculture and industry have been used for soil stabilization. To overcome the drawbacks of existing materials and methods for soil stabilization, there is a need for such a method and material which gives better performance in strength, has easier availability and is cheaper in cost.

1.1 OBJECTIVES

- To stabilize the marine clay.
- To improve properties by adding waste foundry sand and to improve the bearing capacity.
- Study the behavior of marine clay with Waste Foundry Sand
- Study the various proportion mix of marine clay and foundry sand for soil stabilization and to arrive at an optimum percentage.

- Investigate the use of waste materials like foundry sand effectively as soil stabilizer.
- To compare the road pavement thickness constructed on natural weak soil with the thickness calculated from CBR value of sub-grade stabilized with waste foundry sand

1.2 SCOPE

- Improve properties of marine clay.
- Reduce thickness of pavement
- Reduce the construction cost.

2. CBR METHOD OF FLEXIBLE PAVEMENT DESIGN

In India flexible pavement design method based on CBR value of sub-grade soil. In 1928 California division of highway in the USA developed California bearing ratio (CBR) method for pavement design. The design charts was developed correlating the CBR value and the pavement thickness. The basic principle of CBR method of flexible pavement design is based on the concept that the total thickness of flexible pavement required mainly depends upon two factors,

a) CBR value of the soil sub-grade over which the pavement is to be laid.

b) Design traffic in terms of cumulative number of standard axles.

This method is applicable on roads with sub-grade CBR values ranging from 2% to 10% and design traffic ranging from 1 msa to 150 msa for an average annual pavement temperature of 35^{o}C. So the design traffic and pavement thickness.

Calculation made according to IRC 37:2001 guidelines.

Design Traffic: The combined effects of the traffic factors are represented in terms of cumulative standard axles (CSA) in terms of million standard axles (msa).The design traffic in terms of the cumulative number of standard axles of the road should be computed using the following equation:

$$N=365[(1+r)^{n}-1] / r * A * D * F$$

N = the cumulative number of standard axles in the design life in terms of msa.

A = Initial traffic means traffic in the year of completion of construction in terms of the number of commercial vehicles per day (CVPD)

D = Lane distribution factor

F=vehicle damage factor (VDF) n = Design life in years

r = Annual growth rate of commercial vehicles.

The traffic in the year of completion is estimated using the following formula, $A = P (1+ r)^{x}$

P = Number of commercial vehicles as per last count

x = Number of years between the last count and the year of completion of Construction.

Design Life, n years

Flexible pavements are generally designed for a design life of 15 years for all important highways such as national highways. In all other roads, the design life of 10 to 15 years is generally adopted in India. However in the first stage the layers are designed and constructed for a design life of about five years only, pavement evaluation studies are carried out and the overlay thickness requirement is designed and constructed for a further design life of 5 to 10 years, as required in the second stage.

Vehicle Damage Factor, f

Table 1: Indicative VDF Values

Initial traffic volume in terms of commercial l vehicles per day	Terrain	
	Rolling/ Plain	Hilly
0 -150	1.5	0.5
150-1500	3.5	1.5
More than 1500	4.5	2.5

Growth Rate of Vehicle, r % per year

The average growth rate of each vehicle class is to be determined making use of the past data and analysis. If the actual growth rate could not be determined, an average growth rate of 10% may be assumed as a very rough approximation.

Lane Distribution Factor, D

Table 2: Guidelines on lanes distribution factors, D

Class of roads	Lane distribution factor, D (%)
Single-lane carriage way roads	50
Two-lane single carriageway roads	75
Four-lane single carriageway roads	40
Dual two- lane carriageway roads	75
Dual three- lane carriageway roads	60

3. FLEXIBLE PAVEMENT DESIGN USING CBR DESIGN CHARTS

Indian roads congress, IRC: 37-2001 'Guidelines for the design of flexible pavements' has presented two design charts for the determination of total thickness of the flexible pavements, considering use of sub-grade soils with CBR values in the range of 2 to 10%.The first design chart is useful to design flexible pavement of roads with low to moderate flow of heavy vehicles, for design CSA values of 1 to 10msa. The second design chart is made use of for the design of flexible pavements of roads with medium to very heavy volume of vehicles, with design CSA values between 10 and 150msa. In this chart the CSA values (in msa) are plotted on the X axis and the total pavement thickness (in mm)on the Y axis, both in arithmetic scale. Nine different design curves are given in each chart for different sub-grade CBR values in the range of 2 to 10%.

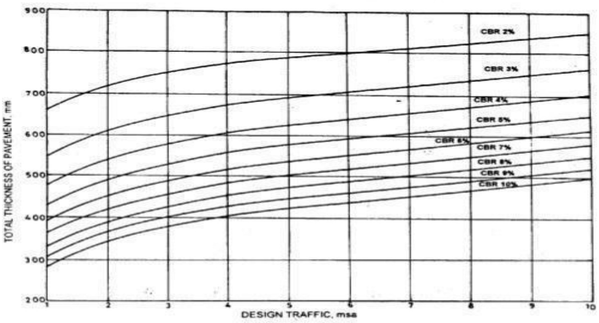

Fig 1: CBR design chart for traffic with CSA of 1.0 to 10msa

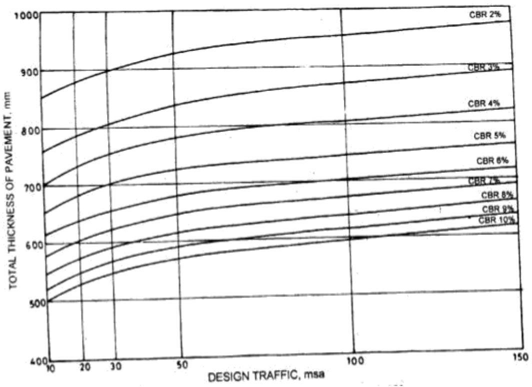

Fig 2: CBR design chart for traffic with CSA of 10 to 150msa

The design charts will give the total thickness of the pavement for the above inputs. The total thickness consists of granular sub-base, granular base and bituminous surfacing. The individual layers are designed based on the recommendations by the IRC 'Guidelines for the design of flexible pavements

4. THICKNESS REDUCTION AFTER STABILIZATION

The design traffic and pavement thickness calculation made according to IRC 37:2001 guidelines, according to that No of commercial vehicles taken per day=8800 $N=[365[(1+r)^n -1] / r]*A *D*F$

Where,N=number of cumulative standard axles according to design A=initial traffic in terms of CVPD

D=lane distribution factor=0.5 for single lane carriage way F=vehicle damage factor=4.5

r =annual growth rate =10%

The No: of years between the last count and the year of completion of construction is taken as one year and designed for a period of 5 years. $A= P*(1+r)^x$

$= 8800*(1+0.1)^1= 9680$

$N= [365[(1+0.1)^5−1]/0.1]*9680*0.5*4.5$

$= 48569400= 48.57msa \approx 50msa$

Now since the No: of years between the last count and the year of completion of construction is taken as two and half year and designed for a period of 10 years.

A = P*(1+r) x= 8800*(1+0.1)2.5= 11168.

$N = 365 [(1+0.1)^{10}−1]0.1*11168*0.5*4.5$

$= 146173596 = 146.17msa \approx 150msa$

CBR 2%				
Cumulative Traffic msa	**Total Pavement Thickness mm**	**Pavement Composition Bituminous Surfacing**		**Granular base & sub base(mm)**
		BC(mm)	**DBM(mm)**	
10	850	40	100	
20	880	40	130	Base =250
30	900	40	150	
50	925	40	175	Sub base= 460
100	955	50	195	
150	975	50	215	

Table 3: Pavement Thickness and Composition Detailing from IRC

The CBR value of untreated soil is found to be 2% and the design charts will give the total thickness of the pavement are found out to be 925 mm and 975 mm for 50 and 150 msa respectively. The total thickness consists of granular sub-base; granular base and bituminous surfacing are calculated from plate 2 of IRC 37. After the stabilization process with Foundry sand, the optimum admixture content is found to be 10% and at this optimum content of admixture, CBR value is found out to be10 %. For this CBR value, the thickness for pavement calculated from design curve for 50 and 150 msa is found out to be 585 mm and 625 mm respectively. The total thickness consists of granular sub-base; granular base and bituminous surfacing are calculated from plate 7 of IRC37-2012.

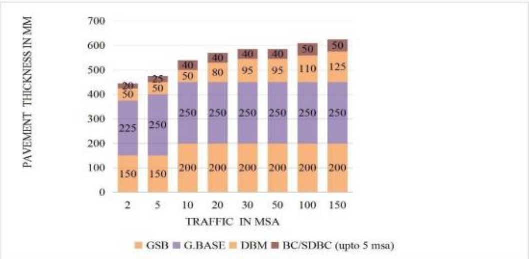

Fig 3: CBR 10% of IRC 37:2012 Design Standards for Flexible Pavements

CONCLUSIONS

In this experimental work, it has been found that the properties of marine clay get effectively modified by varying proportions (0% to 15%) of WFS. A series of laboratory tests were conducted to study the effects of WFS on the expansive soil. On the basis of present experimental investigation, the following conclusions are drawn. Expansive soils are very problematic as regards their nature and behavior of high swelling, and high plasticity characteristics.

- Optimum percentage of foundry sand was found to be 10% by dry weight of soil, within the framework of present investigation
- CBR value increased from 2% to 10% by the addition of 10% of foundry sand
- Maximum value of Unconfined Compressive Strength obtained on addition of foundry sand is 179.58kPa
- Hence from the results Foundry sand waste can effectively use for stabilization of weak soil like Marine Clay.
- The pavement have been designed according to CBR method recommended by IRC (Indian road congress) graph. Following are the results:
- The thickness of the pavement is reduced by 340 mm i.e., from 925 mm for untreated soil to 585mm for treated soil at a design traffic of 50 msa and the thickness of the pavement is reduced by 350 mm i.e., from 975 mm for untreated soil to 625 mm for treated soil at a design traffic of 150msa.

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