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Design of Reinforced Flexible Pavements on Clayey Sub Grade

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ABSTRACT:

The life period and performance of flexible pavements is greatly influenced by subgrade soil. Among various subgrades, clays are the problematic subgrades as they possess low wet strength and poor drainage. Due to the characteristics of clay and the heavy wheel loads acting on the pavement, the failures causing damage are noticeable in pavement section though the pavements are constructed as per the standard methods of design. So there is need for evaluating the present CBR method of design of flexible pavements more rigorously. A clay of intermediate. High, low compressibility has been used in the study, As CBR method of design does not deal the aspect of shear failure of soil. It is proposed to develop a design methodology that enables distribution of load over a large area and avoids shear failure in subgrade. In the present work, the various failures occurring in clay subgrades are explained. The existing practices of unreinforced and reinforced pavement design and their limitations are reviewed. After evaluating the pavement thickness design from 'CBR' and 'SBR' methods. Reinforced flexible pavement design has been developed based on the concept of reinforced foundation mattress. The sub base reinforced by geo grids has been considered to stiffen the layer and to spread wheel load over the subgrade over a large area. Detailed discussions are made on the work carried out and conclusions have been drawn.

INTRODUCTION:

India has one of the largest road networks in the world, aggregating to about 33 lakh km at present. However many of the existing roads are becoming structurally inadequate because of the rapid growth in traffic volume and axle loading.

At locations with adequate sub grade bearing capacity/CBR value, a layer of suitable granular material can improve the bearing capacity to carry the expected traffic load. But at sites with CBR less than 2% problems of shear failure and excessive rutting are often encountered. The ground improvement alternatives such as excavation and replacement of unsuitable material, deep compaction, chemical stabilization, pre loading and polymeric geosynthetics etc are often used at such sites. The cost of these processes as well as virgin material involved is usually high and as such they are yet to be commonly used in developing nations like India. In this context natural fiber products hold promise for rural road construction over soft clay.

India is the first largest country, producing coir fibber from the husk of coconut fruit. The coir fibber (50 to 150 mm long and 0.2 to 0.6 mm diameter) till recently were spun into coir yarn and then woven to obtain woven nettings. The fibers are now a day's being needle punched or adhesive bonded to obtain non woven products or blankets. Geotextiles are proving to be cost effective alternative to traditional road construction method. Studies have indicated that the biodegradability of coir can be used to advantage and the coir based geotextile have the potential of being used for rural road construction over soft clay. In paved and unpaved road construction, geosynthetic reinforcement has been applied to improve their overall strength and service life. The stabilization of pavements on soft Ground with geotextiles is primarily attributed to the basic functions of separation of base course layer from sub grade soil, reinforcement of composite system etc.

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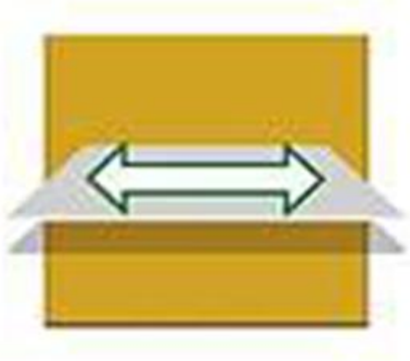
But these synthetic products are biodegradable and cause environment problems, whereas natural geotextile like coir is biodegradable. In paved and unpaved road construction, geosynthetic reinforcement has been applied to improve their overall strength and service life. The stabilization of pavements on soft ground with geotextiles or geogrid is primarily attributed to basic functions of separation of base course layer from sub grade soil, reinforcement of composite system etc. The report presents the results of CBR and plate load test carried in a model test tank simulating rural roads with coir geotextiles. The results of the test in the laboratory and the construction of road stretches at 3 locations, with each 100m length are encouraging for use in developing countries (like India) in rural roads that are yet to be developed to connect as many as 0.2 million villages as most of these roads happen to be on soft clay. The main objective of the project is to construct 100m stretches of Coir geotextile reinforced road and evaluate the performance. These details of the test stretches and the results of tests conducted in the laboratory are described in this report.

FUNCTIONS OF GEO TEXTILES:

SEPERATION:

The non-woven geo textiles are used in the construction of roads, retaining walls and embankments where the ground is soft and unstable. Using a layer of geo textile to separate the soft ground from the fill material will reduce the amount of fill required, increase the life span of the retaining structure and cut long-term maintenance costs.

REINFORCEMENT:

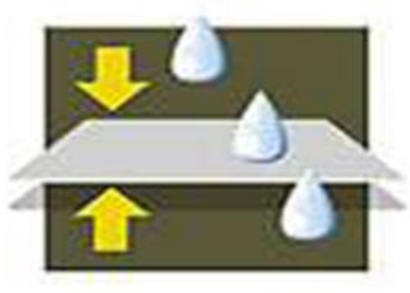


DRAINAGE:

The non-woven geo textiles have a three-dimensional structure designed to improve performance. Ideal for use in subsoil draining systems will assist in the removal of water from water road and railway works, and behind retaining walls.

FILTERATION:

The non-woven geo textiles are highly porous, allowing water to pass through while preventing soil migration. When used in revetment and subsoil drainage projects, geo textiles are more effective than natural fibers.



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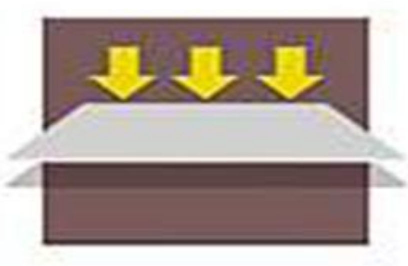
PROTECTION:

Using heavyweight non-woven geo textiles in landfills extends the life of the lining system by protecting it from punctures and excessive deformation. The geo textile acts as a cushioning and stress relieving layer, minimizing the chance of leakage in the long-term.



SBC METHOD:

Considerations:

1. The safe bearing capacity of subgrade soil is reduced by 20 percent to account for action of repetitive wheel loads, which may produce some impact due to uneven pavement surface and breakers.

2. Pavement thickness design based on considerations of 80 percent safe bearing capacity of subgrade soil is critical over the case of increasing static wheel loads by 15 percent.

3. The loading due to moving vehicles in saturated clayey subgrades is taken equivalent to strip load since in saturated condition the excess pore water pressures do not get dissipated quickly. This will be more appropriate in case of heavy traffic pavements.

4. The load bearing mechanism of pavement component layers is due to passive resistance offered by material of the layers under applied wheel loads and so 2:1 load dispersion ($\tan \alpha = 0.5$, where α is dispersion angle with vertical) is valid for dispersion of wheel load through the flexible pavement layers.

5. The shape of contact area of tyre with pavement is considered as rectangular with two semi-circular areas at the ends.

6. The pavement width equivalent to dispersed width of wheel at subgrade level acts as a surface strip footing over weak subgrade soils, particularly saturated clays.

7. Vesic's bearing capacity theory is valid for clayey sub grades.

The pavement thickness (h) required for transmission of wheel loads without any risk of shear failure in subgrade can be calculated by equation vertical stress due to wheel load and overburden pressure to safe bearing of soil using the expression given below.

$$\frac{p}{(B+2h\tan\alpha)(le+2h\tan\alpha)} + \gamma_{av}h = q_s \quad \ldots\ldots\ldots\ldots(1)$$

Where,

P is equivalent single wheel load in KN.

B is width of load contact area = b + S

B is width of contact area of single tyre and S is centre to centre spacing of tyres.

L is length of contact area of equivalent rectangular section.

q is safe bearing capacity of sub grade.

By using standard axle load with tyre contact pressure, the values of B and L can be calculated. The required pavement thickness is to be calculated for the following criteria;

i. Reducing safe bearing capacity by 20 % keeping wheel load unchanged.
ii. Increasing wheel load up to 15%keeping safe bearing capacity unchanged.

The design thickness which is greater to be taken from the above criteria. To evaluate risk of shear failure in subgrade, it is preferable to consider reduction in safe bearing capacity of soil rather than considering increase in wheel load.

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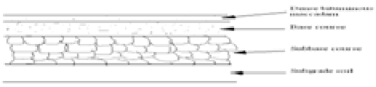
CBR METHOD:

In this method of design the total thickness of the pavement required is determined using the design chart, with the value of Ns in million standard axles (msa). The value of Ns will be coming from the traffic survey data and the CBR value of sub grade soil determined in the laboratory. The IRC 37 has also suggested the base course and surfacing and the combinations for various ranges of cumulative standard axles.

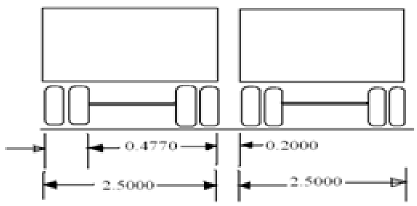


The typical cross section of the road is shown this fig.

MATTRESS METHOD OF REINFORCED FLEXIBLE PAVEMENT DESIGN:

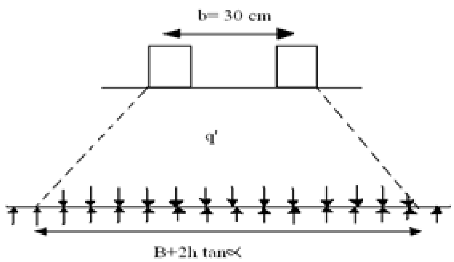
The concept of reinforced soil mattress or foundation mattress is given by Jones C.J.F.P (1985) for supporting embankments on soft soils. The foundation mattress consists of stone material reinforced by two layers of high tensile strength stiffer fabric/grid. The use of foundation mattress at the base of embankment increases load dispersion width and thereby reduces the applied load intensity on subsoil and increases the factor of safety against bearing capacity failure. The concept of reinforced soil mattress is extended to stiffen the sub base layer of pavement to spread the load uniformly onto subgrade over a larger area. By extending the granular sub base layer into shoulder portion, it can be designed as foundation mattress to support the traffic loads and to avoid bearing capacity failures in subgrades. The design of sub base layer to serve as foundation mattress is presented below. The design of sub base foundation mattress is done by considering single lane pavement and taking l.2m wide shoulders. It is proposed to use granular sub base as per MORTH specifications (2001) and extend it into shoulder portion also.

For critical loading, two trucks have been taken side by side with a minimum clearance of 0.2m. The width of each truck has been taken as 2.5m as shown in the Figure.



All dimensions are in mm

The load dispersion causing due to the wheel load on surface of the flexible pavement may be as shown in Figure.



Load Dispersion of the wheel

P is the reaction pressure from the soil

q' is the intensity of Load from the equivalent wheel load on sub base layer

q' value will be obtained from the formulae as follows:

$$q' = \frac{5.1}{(B+2htan\alpha)(lg+2htan\alpha)} \text{.........................} (2)$$

$$P = \frac{\text{total load coming from the two trucks}}{\text{Width of the pavement}} \times (Le + 2htan\alpha) + \gamma avh \text{...........}(3)$$

The contact pressure at subgrade is determined by considering the stiffening action of sub base.The reinforcement is designed in sub base for maximum bending moment by taking Cover to geo grid reinforcement as 50mm on either side. The required tensile strength (T) of reinforcement is calculated using the relation.

$$T = \frac{Max.B.M}{d} \text{.......................}(4)$$

Where, d is effective depth of sub base layer.

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CONCLUSION:

Based on the work carried out the following conclusions have been drawn

1. Clay subgrade, under study has low strength in wet condition due to its high Plasticity and poor drainage.

2. The flexible pavement design based on CBR method over clayey subgrade under study indicated risk against shear failure as CBR method yield 76cm of thickness where as SBC method yield 100cm.

3. Pavement thickness can be reduced over clayey subgrade using reinforcement techniques at subgrade level up to 50%.

4. Adoption of reinforcing material at interface clay subgrade and subbase avoids risk of shear failure.

5. In reinforced mattress method, there is no reduction in thickness of the pavement. However it improves performance of the pavement and reduces maintenance cost.

6. The required tensile strength of the geotextile fabric for the contact pressure of 7kglcm^2 is 10% higher than in the design of pavement by considering contact pressure of 5.62 kg/cm^2 by SBC method.

7. The percentage of required tensile strength of the reinforcement for the tyre Contact pressure of 7 kg/cm^2 is 36% higher than the required tensile strength of the reinforcement for the contact pressure of 5.62 kg/cm^2 in reinforced mattress approach.

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