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Pavements on Black Cotton Soil its Challenges & Solutions

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Abstract - *Black Cotton soil is a moderate to high compressibility, inorganic clay soil in India. They have notable shrinking and swelling characteristics. In India's middle and western sections, these Black Cotton soils cover around 20% of the entire area. Because of their significant swelling and shrinkage properties, Black Cotton soils have been a difficulty for roadway engineers. In addition, black Cotton soils are firm dry but weaken entirely when wet. The paper's objective is to discuss the Black Cotton soil challenges and solution during the pavement laying.*

Keywords: Pavement; Flexible Pavement; Rigid pavement; Black Cotton Soil; Construction; Challenges.

1. Introduction

The black, or lava-covered, soil stands out among the situ Indian soils [1]. Black cotton soils are often referred to as regur soils. Chernozems, primarily found in interior Gujarat, Madhya Pradesh, Karnataka and Maharashtra, are trap-basalt derivatives and are found with moderate rainfall. Black soils create enormous cracks in the dry season because of their iron-rich granular composition. [2]. The reaction well to irrigation but deficient in humus. These soils are found in several river-affected locations outside of the city. Sifting has increased the concentration of sediments. Drying causes different-depth fissures to appear in the Black Cotton soil. Fig. 1 illustrates typical cracks in Black Cotton soils as they are dried up.

Figure 1: Black Cotton Soil Cracks || Source *[3]*

In addition, vertical movement occurs as a consequence of the wetting and drying process. All the motions contribute to pavement failure, including settling, significant depression, cracking, and unevenness [3]. The paper covers pavement building challenges in Black Cotton soils. First, the sections of the papers cover an extensive background and later the challenges and the recommended solutions for the challenges faced during the pavement building on Black Cotton Soil.

2. Background

Black Cotton soil is fairly clayey. For treatment in road building, it is so complicated that clods cannot be readily crushed. These flaws will affect the road's future performance. Moreover, softened subgrade tends to float upward into the pavement surface when the sub-base consists of stone slugs with many voids. Every rainy season Black Cotton soil infiltration causes the road to collapse. Black Cotton soil base roads produce undulations at the road surface due to the subgrade's softening owing to monsoon rains. Black Cotton soil contains titanium oxide in low concentrations. The soil is primarily clay-rich with a high proportion of montmorillonite clay, dark blackish-grey in colour. Black cotton soil may be found in numerous areas. Black Cotton soil, 80% has a size less than 0.001 mm. between liquid limits, the volume change is around 200% to 300% and results in substantial pressure swelling of 8 to 10 kg/cm2 [4]. Black cotton soil has bearing capacity issues with significant swelling and shrinking. Roads that use it are very hard to construct using it. CBR values for wet Black Cotton soils range from 2% to 4% [5]. Black Cotton soil CBR values cause extra pavement thickness for flexible pavement. New R&D technology has been used to help with the strength properties of Black Cotton soil.

3. Black Soil Challenges

Water is a well-known adversary of road pavement, especially in vast soil regions. Capillary action leads to water seeping into the road from the top, side berms, and subgrade [6]. Because of this, road standards in vast soil regions must include these issues. For example, pave side berms and construct subgrade drains to eliminate the capillary rise in the pavement. Water has been identified while handling several road research project tasks for determining reasons for road breakdowns. It saturates the subgrade soil, lowering its bearing ability, resulting in massive depressions and settlement. A water-lubricated binding material creates an unstable mechanical interlock. Burr and pitting may occur in the bituminous surface layers because of water stagnation and seepage. Usually, road construction organizations neglect the construction and maintenance features of side berms. Instead, always see road construction, including carriageways and berms, as a unified entity [7]. The mushy soil around unpaved berms represents the most significant threat since they become unusable, demonstrate the dissemination over the Black Cotton soil regions [8].

3.1. Black Cotton Soil Design Problems

Most CBR method designs are in India. This methodology imposes a surcharge weight of 15 kg for laboratory and field-based CBR measurements when counterbalancing the swelling pressure of Black Cotton soils. Black Cotton soils create 20-80 tons/m2 of swelling pressure and 10-20% oedema. So, because CBR values are derived by mathematical manipulation, they cannot be considered reasonable or scientific [9]. In CBR 2% and commercial vehicle traffic of 4500 daily, paved roads have a total thickness of 830 millimetres, which is nearly impossible. To accommodate the larger soil area [10]. For flexibility, the rigid pavement has a crust thickness of 300-320 millimetres. One-third of the thickness is necessary for flexible pavement. [11]. Cement concrete pavement on Black Cotton soil areas seem suitable. The pavement of this sort might help reduce on-the-job repair work. Another solution is to use semi-rigid substructures. First, the proper technique should be given, and then the crust thickness should be worked out. It will lessen the amount of crust needed. Traffic stresses compact berm uncompacted berm (no treatment). Occasional, large trucks' front ends get trapped when overtaking, occasionally resulting in catastrophic crashes. Therefore, BMS must be developed as a different standard [12].

4. Solutions

Reduction of oedema and shrinkage in black cotton soil is best achieved through stabilization. Black cotton soil is what causes many research endeavours to take place. One of the methods used to stabilize black cotton soil over the previous several decades is lime stabilization. Black cotton becomes less plastic when you use lime. In addition, t lime-soil interaction increases the strength of the combination [13]. Recently, the price of lime has skyrocketed. Lime stability of soil increased due to this. In the current investigation, lime was used to stabilize the black cotton soil, which proved inadequate as a subbase. Thus, call for other and cheaper alternatives.

4.1. Soil Stabilization

Soil stabilization Use a lime-based, OPC-grade 43 moorum (with sand) for black cotton soil stabilization. IS:8112-OPC"s 43rd grade. The minimum granular moorum grading of 4 days with a CBR of 10% or above shall not be less than 17.5KN/m3. Is:383-1970. Dry soil quality requirements for CNS soil are 16 kg/m3 [14]. The use of lime or cement may improve black Cotton soil. Global, this technology has been relatively popular in the past. Black Cotton soil is made better with 3% cement or hydrated lime. [15].

Cement/lime-soil stabilization has proven effective and valuable for manual construction. [16]. This method is 20-30% cheaper than standard WBM building. In this treatment, the main emphasis is on using lesser strength than concrete but much more than natural Black Cotton soil. Additionally, integrate subgrades and foundation courses for the concrete pavement to tolerate volume fluctuations and displacement or erosion better. It will lead to improved shearing resistance and bearing capacity [17].

4.2. Mixing Method

Pulverized Black Cotton soil should be blended with cement, moorum, lime, and moorum. Black Cotton Soil is dug from the embankment where pickaxes reduce clods to 50mm [1]. Instead, tractor harrows may be used. A 4-tonne wheeled roller is used to smooth the excavation and to disseminate soil clods. Raking and smoothing are performed often as well. Between 8 passes of the roller and raking, the desired degree of pulverization should be obtainable. As long as 80% of the soil goes through the 475-micron screen, no lumps are more significant than 25 mm [18].

Black Cotton soil is evenly mixed with cement and moorum employing a rotavator machine or motor grader. Portland cement and Black Cotton soil were mixed in a wet state to provide a sturdy footing for motorways, expressways and airports. Nonetheless, Black Cotton soil may include less than 5% cement by volume [19].

It provides a semi-rigid framework, helps maintain soil structure, and minimizes soil expansion. Coupled with Black Cotton soil, OPC and lime raise the liquid limit, plasticity index, and volume change [20]. Increase the shrinkage limit and shear strength The Black Cotton soil-cement combination provides better subgrade bearing capacity and strength. It is cheap and effective. The water enhances the cement matrix's strength while enhancing the mix's strength [19].

4.3. Building A Barrier to Build a Road

It may be enhanced by implementing the procedure listed above. Remove all black cotton soil to a depth of 1,600 mm below natural ground level (NGL). It is discovering the density to be less than 95% of Max. Dry Density (MDD), 225 mm, should be loosened and recompacted using OMC to determine whether the density is 95% of MDD and CBR of 5%. [21]. Purified Black Cotton soil (60% by weight), cement (OPC 43 grade) or lime (3% by weight) should be evenly blended using a rotavator machine or other agricultural equipment to achieve a density of 95% MDD and 5% CBR. [18]. As depicted, a 225 mm thick sand filter layer should be applied on Black Cotton soil. Put down 1000 mm thick–compacted moorum over this. compacted sublayers should be protected from groundwater by compacted 3,000 mm-wide, 2,000 mm-deep soil layers. [22].

Additionally, excellent side drains on the embankment should be made accessible—subgrade modulus. Fly ash may be used wherever it is located on the building site. However, Flyash should meet IS:3812 Grade 1 requirements, and the quality and quantity of fly ash must be guaranteed [23].

It is often encountered in roadway engineering, especially in terrain with expansive soil. In the USA, it was first employed in the early 1970s, while in India, it is just beginning. Petroleum-derived polymers are used to create geotextiles. High tensile strength, burst and puncture strength, permeability and abrasion resistance. Geotextile cloth is used to separate subgrade and subbase courses [24]. The potential for Black Cotton soil application is vast. This layer functions as both a strengthening layer and helps avoid reflective cracking in the pavement structure. The thickness of the pavement is predicted to be reduced by around 10% to 25% using geotextile. But though geotextile prices have hampered its use in India [25]. Black Cotton soil geotextile provides highway engineering difficulties with a solution. The usage of the moorum layer has been motivated by the significance of cost-effectiveness. Several moorum with low plasticity indexes have shown favourable results, preventing dirt from penetrating aggregate and gap stones. On soft soils, 225 mm of sand is usually used to maintain infiltration resistance and prevent granular base/sub-base layer interstitial penetration [26].

4.4. Top Flexible-Pavement Wearing Course

Black cotton soil sites are significant in the bituminous surfacing of road crests. With a seal coat applied, macadam is the preferred surface over bituminous concrete because it provides superior impermeability and has less void content. When it rains, the open-graded bituminous surface shows unevenness, waviness, and depression. Therefore, it is essential to ensure surface installations are done before the rainy season begins. In addition, the surface course receives extra compaction due to traffic during the monsoon time slot, which is set to occur at least one month after construction is completed. The feature consolidates and compacts [27]. Bumpy shoulders on the road are critical for cars that are becoming trapped when passing. Therefore, special attention must pave the berms and establish distinct requirements [28].

5. Conclusions

- There is a need for giving the soil engineering features to Black Cotton Soil.
- To modify the flexible pavement design approach, the CBR approach should be used. In addition, rigid road building may be used to improve Black Cotton soil economies.
- In Black Cotton soil sites, the lime-soil stabilization technique has immense promise. Using a moorum layer to separate subgrade and sub-base layers have proved cost-effective. High-specificity PIM has shown to be effective, as it limits infiltration between aggregates and the groundwater exit.225 mm thick sand filter layer for soft soils to avoid intrusion of subgrade soil into interstices of granular base/sub-base layer and offer consistent support.
- A geotextile fabric incorporation is a relatively new technique. seepage and loss in thickness
- Water intrusion must be halted before the surface is waxed.
- Primer and stone grafting is needed on the roadside berms. A steep camber of 1:36 is recommended. Compacted moorum, as specified, shall be applied over the sand filter layer.

- There should be compacted sub-layers containing soil of a width of 3000 mm on the outside margins to prevent the groundwater from seeping into the sub-layers.

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