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Abstract. The stabilization products often used to improve the support of granular layers in the construction of road surfaces may be expensive and difficult to get. Therefore, it is necessary to test different materials, which are cheap and easy to obtain, and which will enhance the physical and mechanical properties of pavement layers. This document evaluates the use of coal tar, as a stabilizer for granular subbase. Initially, with a description of tar properties, determining the optimal conditions for the granular subbase material compaction, by means of modified proctor tests and the calculation of the resistance of the unaltered material by using CBR lab tests (California Bearing Ratio). Afterwards, with the design and development of granular material mixes with different percentages of coal tar and determining its CBR as comparative parameter with that of the unaltered material. Finally, by calculating the optimal coal tar percentage in order to stabilize the subbase granular, the results showed an improvement in the resistance of the granular material and a decrease in its expansion due to the use of coal tar.

1. Introduction

When suitable granular materials are not available for pavement construction [1], it becomes necessary to decide the most convenient stabilization treatment for the soil, in order to make them useful for the construction of the layers forming such structure [2]. Tar is often used in asphalt layers to embed them with higher resistance, imperviousness to water and to prolong their lifetime [3]. Nevertheless, granular soil stabilization using tar has not been applied so far.

This research aims to determine the feasibility of coal tar as a granular subbase stabilizer, by means of characterizing such materials, making granular soil mixes with tar, and the analysis of such mix with the determination of its resistance method (CBR) [4].

2. Materials and methodology

The applied methodology involves obtaining the materials, the characterization of such materials by lab tests according to INVIAS-2007 norms [5], the resistance determination (CBR) for the unaltered material, design and making of mixes with different coal tar percentages and its resistance determination (CBR) and choosing the optimal coal tar percentage. The subbase material corresponds to SBG-2, coming from a quarry belonging to the company CSS constructors in Tunja. The coal tar was obtained from enterprise Acerías Paz de Río, as a sub-product of coke [6]. The research was performed at laboratory floors and pavements of the Universidad Pedagógica y Tecnológica de Colombia, known as Uptc, in Tunja (Boyacá).

3. Experimental design and results

It was decided to use four test percentages in weight for coal tar: 3%, 5%, 7% and 9%, in order to check any variation of soil resistance with the increasing content of coal tar and to find an optimal percentage of it [7]. The characterization of coal tar coming from Siderúrgica Paz de Río was performed according to the parameters given by INVIAS for bituminal materials, with the aim of simulating the use of this stabilizer as asphalt, according to results shown in Table 1. In the same way, the physical characterization of the granular material modified with clay fine material, based on the test norms for subbase materials given by Instituto Nacional de Vías–2007, article 300-07.

Table 1. Coal tar characterization.

Trial	Test Standard	Obtained Value
Ignition point and flame point using Cleveland's open coup (°C)	E-709-07	90 – 138
Specific gravity (g/cm3)	E-707-07	1.20 – a 25°
Viscocity Saybolt Furol (SSF)	E-714-07	245
		392 a 60°C
		170 a 70°C
Viscosity using rotational viscosimeter (mPa)	E-717-07	92 a 80°C
		60 a 90°C
		43 a 100°C

Later on, different tar percentage mixes were designed (3%, 5%, 7% and 9% tar) in order to calculate its resistance using submerged and not submerged CBR tests, according to proceedings of norm INV E-148-07. The mixes were elaborated outside during sunny days and were compacted in open air, this due to the type of solvents coming out of tar, in moulds for CBR tests, with compression energies of 10, 25 and 56hits/layer, subject to a tanning period of 72 hours, with the results given in Table 2.

Table 2. CBR test results.

Unaltered subbase CBR			Unaltered modified subbase CBR		
CBR (%)		45.0	CBR (%)		17.0
Submerged tar mix CBR					
% TAR	3%	5%	6.7%	7%	9%
CBR (%)	14.0	17.2	20.3	20.2	10.2
Non-submerged tar mix CBR					
% TAR	3%	5%	6.5%	7%	9%
CBR (%)	16.5	19.7	21.0	20.8	15.5

The expansion of the material was also evaluated. Samples were immersed with overload and its respective perforated disc stem in a water tank and then expansion initial readings were taken with the dial gauge and tripod. The immersion process lasted about four days, which the dissipation of pressure and saturation was achieved compacted soil. At the end of the period of immersion readings they were taken final expansion, to calculate the percentage of soil expansion subbase and determine the susceptibility of the material to volumetric change in saturated condition.

4. Analysis of results

The results of experiments show that the resistance of the mixes increase with the percentage variation up to a certain point, after which, resistance starts decreasing with higher amounts of binder. According to this behaviour, the inflection point at which the subbase hits the maximum resistance with the addition of tar was calculated to be 6.5% in weight, as the optimal amount of coal tar to stabilize the granular subbase material.

Mixes with 6.5% tar presented a remarkable increase in resistance, compared to the unaltered material, showing CBR values higher than 20%, which represents a profit of more than 3 CBR units. It was also evident that low tar percentages in the subbase do not improve its resistance; on the contrary, the CBR value decreased in mixes with 3% tar; in the same fashion mixes with 9% got CBR values of 10.2% and 15.5%. This loss in resistance could be the case because the binding substance in the mix does not cover all the components; therefore the mix is not compact in a uniform fashion. On the other hand, a high amount of tar corresponds to more tar in the interspaces between particles, thus, losing consistency and becoming highly deformable.

Another factor to be taken into account is material expansion. The tearless material gave an expansion percentage close to 0.2%, whereas the mixes with tar showed negative expansions, meaning, they compressed their volume. This could be explained due to the bonding character of the tar, that will not allow water to separate the material particles, thus inducing a settlement. Taking this into account, we can conclude that tar reduces totally the volume expansion.

5. Conclusions and recommendations

It was proven the possibility of stabilize a subbase granular material for road construction using coal tar coming from steel industry Acerías Paz del Río, since mixing the right amount of it with the subbase granular increased the resistance, showing CBR values beyond 3% of those for the unaltered material.

With the analysis of the CBR values for subbase-tar mixes, the optimal value for coal tar was found, with which it was obtained the higher resistance increase, being 6.5% in weight for the stabilization of granular subbases.

Since the CBR increase for the granular subbases produced by the coal tar stabilization is not too big, it can be considered as a stabilization method for materials with a CBR that does not behave as specified by INVIAS, but nevertheless, close to the acceptance limit.

With the stabilization of subbases with coal tar there is a profit in terms of volume expansion, since the mixes did not show any expansion, and on the contrary, they contracted slightly, which means a decrease in this factor as a whole.

Coal tar was characterized and manipulated as liquid asphalt; nonetheless, it was observed that the material is viscous and its volume changes drastically as temperature increases, behaving in a different way than asphalt and thus, there is a necessity to get a technical norm for lab tests with coal tar as well as for its use as a stabilization agent, since there is nothing of that sort as of now. It is recommended to use personal protection gear in order to manipulate the coal tar (gloves, anti-gas mask, eyeglasses, among others), and to do it in places well ventilated or outside if possible, since it is a bituminous substance that emits toxic gases, potentially harmful for people.

It is recommended also for the granular subbase stabilization with coal tar to be performed in a sunny day, mixing the compound with the bituminous binder and letting it rest for about a week period for its proper sealing before open it for traffic use or building the superior layer. Also, during the sealing period, the layer should be protected from rain, and preferably during nice weather conditions, so that all the tar solvents can be evaporated.

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