CHEMICAL STABILISATION FOR LOW COST ROADS IN BOTSWANA

by

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ABSTRACT

During road construction, particularly on unsurfaced earth and gravel roads, many problems usually arise like deterioration of the surface (rutting and potholes), dust on the road, maintenance problems of road surface (under wet and dry conditions), etc.

As road maintenance is costly and disruptive to the traffic flow, stabilization of some local road materials during construction is necessary.

The paper is based on the experimental work carried out on the use of chemical soil stabilizer Con-Aid for stabilization of low cost roads and rehabilitation of existing roads. Conventionally lime and cement can be used, however this is very costly.

Con-Aid is a water-soluble anionic compound with surface-active properties. It was developed in South Africa from a blend of locally produced synthetic chemical products. The product is non-toxic and environmentally friendly.

For stabilization with Con-Aid two types of Botswana soils were used and laboratory tests on treated and untreated soil samples were carried out to establish the engineering properties of the soil.

It was suggested that Con-Aid chemical stabilizer can be recommended for use on low cost roads, as it will reduce construction and maintenance costs, ensure that the roads remain passable in rainy season and dust-free in dry season.

Keywords: **Soil stabilization, liquid chemical stabilizer Con-Aid, earth and gravel roads, black cotton soil, calcrete.**

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1. INTRODUCTION

For low volume and low cost unsurfaced earth and gravel roads the use of local materials should be made as much as possible. However, these materials are not always suitable and many problems usually arise like deterioration of the surface (rutting and potholes), dust on the road, maintenance problems of road surface (under wet and dry conditions), etc. Due to the semi-arid climate of Botswana, the performance of these types of roads is not very good. According to the Technical report "Roads in Botswana", published by Roads Department [5], the available naturally occurring gravel very seldom meets the required properties and tends to abrade very quickly under traffic. In order to produce suitable pavement materials in most cases, modification of the engineering properties of available materials is needed.

Soil stabilization is the process by which a stabilizing agent is added to natural soil deposit to improve the engineering properties of soils by mechanical or chemical means or both. There are numerous stabilization methods and techniques currently in practice. According to K.N. Derucher at al (1998) [3] the type of techniques to be chosen for a particular site depends on the type of soil to be stabilized, the extend of required stabilization, the type of structure to be built, the availability of materials, and the environmental effects. Soil stabilization improves shearing resistance of the soil, stiffness, resistance to wear, decreases the amount of dust and water penetration of unsealed roads. G.H.McNally (1998) [4] summarizes the most common stabilization methods used in highway construction as:

(a) blending of coarse-grained materials with fine-grained soils;
(b) use of granular additive – gravel, coarse crushed aggregate, grid and loam;
(c) use of stabilizing additives:
    - Portland cement and cement-slag blends
    - Lime (quick-lime, hydrated lime) and gypsum
    - Lime-pozzolan (lime plus fly ash or ground slag) mixtures
    - Hot bitumen and cold bitumen emulsion
(d) use of chemicals - the most frequently used chemicals are calcium chloride, sodium hydroxide, silicates, etc. used in traced quantities.

The aim of this paper is to study the effect of chemical stabilizer Con-Aid on the strength characteristics and performance of two common soil types in Botswana - black cotton soil and calcrete as road building material in order to investigate the possibilities of the application of the chemical for new low-cost roads and for economical rehabilitation of existing gravel roads.

2. CHEMICAL STABILIZER CON-AID

The liquid chemical stabilizer Con-Aid is one of the numerous chemical products on the market, developed in SA by Con-Aid (International) (Pty) Ltd [1, 2] from a blend of locally produced synthetic chemical products. It was designed for stabilizing poor quality soils containing clayey material in order to improve their properties as road construction materials and for rehabilitation purposes. Con-Aid anionic soil stabilizer, originated from petrolcum, is

viscous, deep red colour liquid with no smell or taste. The active agent is weak organic acid. The manufacturers claim that the chemical is totally water soluble, non-hazardous, non-flammable, non-corrosive, non-toxic, environmentally safe and user friendly. The product is synthetic compound with surface-active properties, which has been devised to change the hydrophilic (water adsorption) properties of clay materials to those of hydrophobic nature (water repellent).

Con-Aid can be used to stabilize various types of soils, i.e. silty sand, clay material, gravel, etc. under the condition that the above-mentioned materials have Plastic Index PI > 11 and clay content of 15 % or more in order facilitate densification and to provide the desired properties -permanent stability and increased workability of the soil.

One of the main advantages of liquid chemical stabilization is that only a small volume of stabilizing agent is generally required and the cost of stabilization is lower than that of other methods of stabilization. Application rate of Con-Aid according to the manufacturers [1] is varied between 0.01 to 0.03 litre/m^2 per 15 cm thickness, the higher value being for higher clay content.

The action of the Con-Aid with clay minerals can be explained as follows. Chemically clay minerals are crystalline hydrous aluminosilicates, characterized by the small size of their crystals. The bonds between individual units, stacked one above the others, are comparatively weak, so water can enter between the sheets, causing them to expand with consequent high swelling and shrinkage characteristics. Applying Con-Aid, an extremely thin hydrophobic oily layer is formed on the surface of soil particles, which allows for free movement of water [2]. This means that water will not be absorbed by the Con-Aid treated material and will evaporate naturally without affecting the stability of the material. Thus, Con-Aid changes the hydrophilic nature of clay materials to hydrophobic, rendering the material stable in wet conditions. In addition to this, Con-Aid lubricates the particles, facilitating compaction of soil to a higher density and increasing the bearing capacity of the soil.

Chemical stabilization with Con-Aid has been successfully used in many countries – South Africa, Zimbabwe, Canada, Argentina, Australia, Vietnam, Cambodia, etc. [1,2] to overcome the problems of using marginal quality construction material for road pavement layers.

3. SOIL CHARACTERISTICS

3.1 Black cotton soils

Soils, having PI > 12 and clay content > 12 %, should be considered to be potentially expansive. Black cotton soils are typical expansive soils with potential for shrinking and swelling under the changing moisture conditions. In Botswana, expansive clays are fairly common in the Northern and Eastern regions, while in the Kalahari region they are less common. Expansive soil is one of the problematic soils, causing damages to structures, pipelines and pavements. The foundation and pavement problems relate primarily to volume change as a result of increased moisture content after construction.

This research pays attention to the expansive soil (black cotton soil) found around Francistown city. Deposits of black cotton soil in the field show a general pattern of cracks during the dry season of the year. When saturated during the rainy season they loose strength and become very wet and muddy. In both cases volume changes will occur, which will affect the pavement.

3.2 Calcrete

In the Kalahari region, which covers about 80 % of the area of Botswana, the predominant road building material is calcrete [5]. This is a pedogenic material, of which laterite and ferricrete are other family members. Calcretes may differ from most road building materials in that they have an unusual composition and may exhibit unusual properties. In the experiments calcrete from Tsabong area was used.

4. TEST METHODS

The amount of Con-Aid stabilizer was as prescribed by the manufacturers. Samples of untreated and treated with Con-Aid soil were prepared and the following tests were carried out according to the required standards: Specific gravity using pycnometer, sieve analysis, Hydrometer test, Compaction test for Optimum Moisture Content, Maximum Dry Density, Atterberg limits (Liquid limit, Plastic Limit, Plastic Index) and CBR test.

5. EXPERIMENTAL RESULTS

Table 1 presents test results from untreated and treated with Con-Aid soil samples [6,7].

Table 1: Summary of Laboratory Test Results

No	Test	Results			
		Black cotton soil		Calcrete	
		Untreated	Treated	Untreated	Treated
1	Specific gravity	2.58 - 2.69	2.58 - 2.69	2.57	2.57
2	Clay content, %	47 - 58	47 - 58	22	22
3	Liquid limit, %	53 - 55	55 -57	26	28
4	Plastic limit, %	24 - 28	30 - 31	13	17
5	Plasticity Index, %	27 - 29	25 - 26	13	11
7	Maximum dry density, kg/m^3	1236	1276	1530	1540
8	Optimum moisture content, %	22	24	21	22
9	CBR	3	5	10 –12	14 – 20

For both types of soils Liquid Limit and Plastic Limit increase after treatment with the chemical stabilizer, making the soil less plastic and more trafficable. The addition of the chemical reduces Plasticity index of the soil. The clay will thus become drier and less susceptible to water changes. The changes in plasticity are governed mainly be the proportion of the clay contained within the soil. The compaction tests show a small improvement in maximum dry density and a small increase in Optimum Moisture Content. However, although there is a tendency for better results after treatment, the laboratory tests have not

shown immediate and convincing improvement in materials properties due to addition of Con-Aid. Obviously, time will be needed for the beneficial effects to be fully shown. Investigations were carried out to estimate the influence of the curing time on CBR. The increase of curing period of Con-Aid treated samples increases the values of the CBR. (Table 2).

Table 2: CBR values of the calcrete samples tested with different compacting efforts and on different curing times [7]

Compacting effort	Untreated sample	Treated sample after curing for		
		10 days	20 days	30 days
5 layers, 55 blows	13.5	14.6	24.7	29
5 layers, 25 blows	12	13.5	14.2	18

Unlike conventional road pavement design, in which strength gradually decreases with time, the Con-Aid treated samples increase in strength over time. Fig. 1 illustrates phases of strength build-up in Con-Aid treated layers as per manufacturers [1].

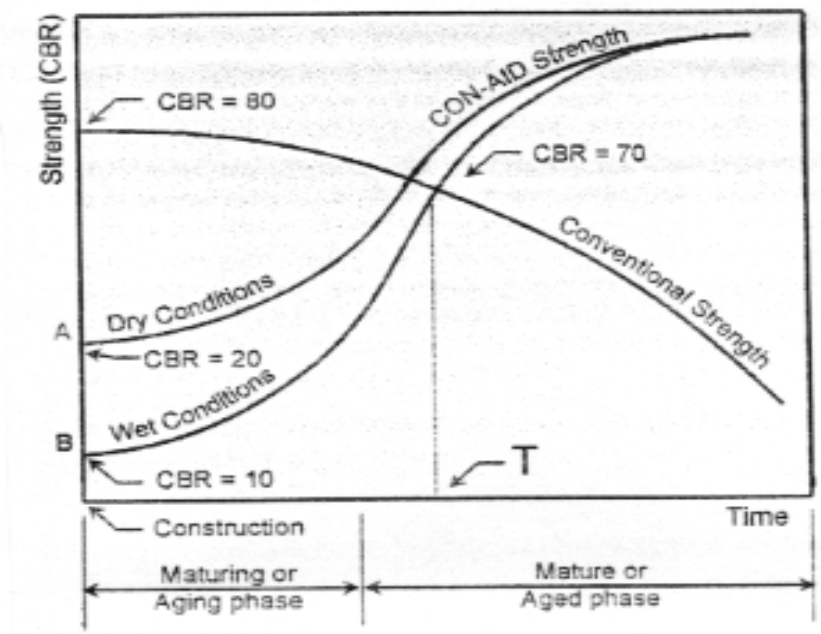

Fig. 1: Phases of strength build-up in Con-Aid treated layers

A small trial test section of unsealed earthen road, exposed to light traffic was used to assess the influence of stabilizer Con-Aid. The trial section and control section were monitored for one year at 3 months intervals. Visual inspection showed that stabilized section stayed harder, smoother and dust free during hot weather, was less muddy and not so slippery during rains, remained stable and did not develop potholes and gullies. To obtain quick field CBR a Dynamic Cone Penetrometer (DCP) was used. In general, the CBR values of the treated section were higher than those of the untreated section.

6. CONCLUSION

The laboratory results have shown that Con-Aid chemical stabilizer has considerable potentials in modifying properties of black cotton soil and calcrete. The rates of application vary from 100 ml/m^3 for gravelly materials to 200 ml/m^3 for fine clays such as black cotton soils. The addition of Con-Aid causes permanent changes to clay minerals, assists in the exclusion of water from soils, facilitates compaction and increases substantially bearing capacity. Looking at the rate of how often the maintenance of gravel roads is required in Botswana in order to keep them trafficable, Con-Aid could be the solution to the problem, as it will lower the construction and maintenance cost. From the trial section of the road, it has been observed that performance characteristics of treated with Con-Aid parts are better than the untreated surface.

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