# TOWARDS A BETTER UNDERSTANDING OF SOLUBLE ADSORBED WATER DISPLACING IONIC ADDITIVES

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**ABSTRACT**

The use of SAWDIA (Soluble Adsorbed Water Displacing Ionic Additives) has not been as extensive in South Africa as the products really merit. These liquid stabilizers have been on the market in South Africa for over 30 years but even today many road engineers are not in favour of their use. This paper is an attempt to clarify some of the misunderstandings regarding the use of these products and to note where they do or do not give acceptable results.

## 1. INTRODUCTION

Some 30 years ago a product known as RRP (Reynold's Road Packer) appeared in South Africa as a liquid additive which when added to a clayey soil would cause the clay within the soil to become hydrophobic instead of hydrophilic in nature. In other words a clay soil treated with RRP did not become muddy and lose strength when it rained. The product was reported at times to be unreliable and it's importation was discontinued.

The principle ingredient of this product was a sulphonated petroleum oil and a study of this product resulted in a few local products which the producers claimed resulted in the drying out of clay soils thus making them yielding a ridable surface which soils if untreated would be unacceptably bad in wet weather.

The marketing strategy extolling the use of these materials laid stress on:

- The ease of application which only required the placing of the liquid product in the water normally applied to reach a moisture content suitable for compaction.
- The logistics of one drum of liquid stabilizer compared to the placing of some 80 tons of cement or lime.
- The ability to open the road to traffic immediately after completion of the layer's treatment.

Although none of these claims were untrue they unfortunately did not include any of the shortcomings when these products are applied which resulted in a decline in their use. It is the sincere wish of the writer to attempt to clarify misunderstandings regarding the use of these products in road works and to underline where and when not these liquid stabilizers can be used to the best advantage.

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## 2. A SIMPLE STUDY OF CLAY AND ADSORBED WATER

These ionic stabilizers work on the surfaces of the clay particles in a soil by producing an ion exchange. It is thus worth getting to know a little more about the difference between a very small particle, say of silt and that of clay.

Although a very fine silt or rock flour particle may be less than 0.002mm in diameter it is still very different from a clay particle of the same size. This fundamental difference lies in the surface area of the particles. The silt particle may be likened to a flat block such as a book with a surface area of the top and the bottom. (Discounting the areas of the sides of the book). Clay on the other hand may still resemble the book block but it's surface area is not only that of the top and bottom but also that of each of the pages. (See figure 1).

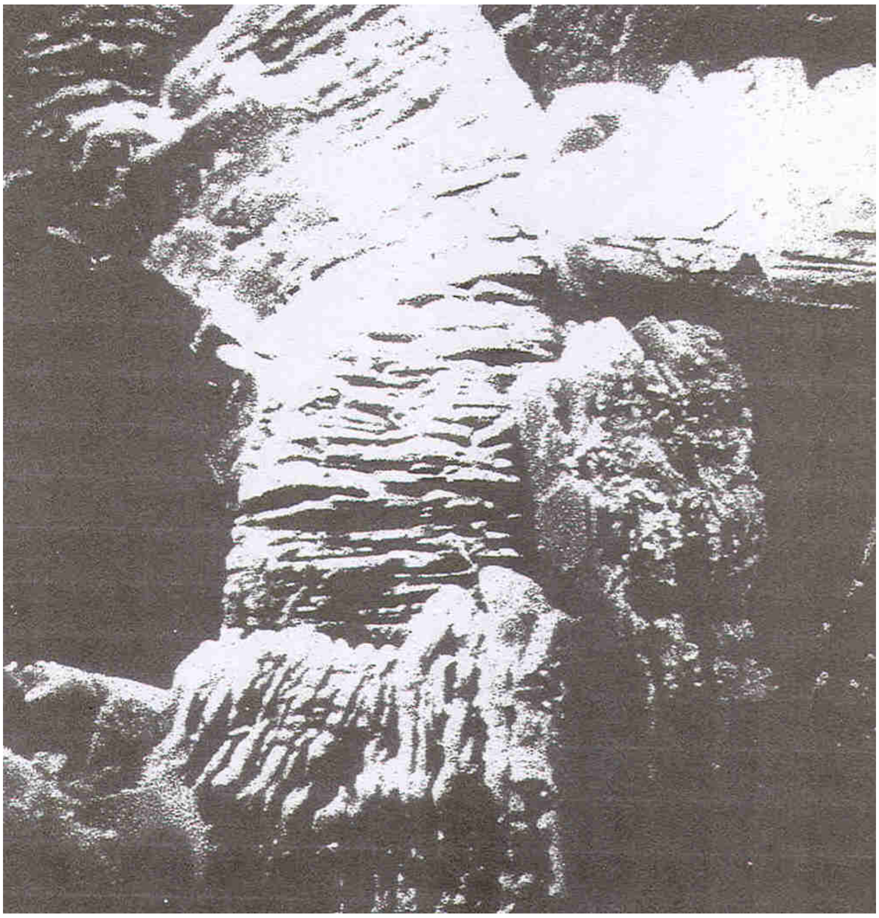


**Figure 1. Kaolinite Mineral.**

Electron photomicrograph of kaolinite showing overlapping plates forming a stack, magnified 7 400 diameter. (Courtesy: Electron Microscope Laboratory, Engineering Experiment Station, Georgia Institute of Technology).

Where the specific surface of the silt particle may be $2m^2$ per gram an equivalent clay particle may have a specific surface area of 80 to 800 $m^2/g$ depending on the type of clay (Kaolin and Montmorillonite in these two cases).

The significance of the surface area of a clay in a soil is thus very important. Putting the matter into a different perspective:

If a cubic meter of soil contained 3% of montmorillonite, the surface area of the clay particles would be equal to an area 7 x 7 $km^2$ i.e. 50 square km. The surface area of the remaining 97% of the soil particles would be less than 1$km^2$ and is thus virtually negligible compared to that of the clay.

When a soil gets wet water adheres to the particle surfaces and as this acts as a lubricant the soil often shows a drop in strength. The clay presents an entirely different picture however.

The surface area of a clay particle which includes that of all the “pages” has a negative charge which attracts metallic ions of a positive charge. These ions also attract water as part of their claim and this forms a thin film of water on the surface of the clay. This water is known as adsorbed water, ionic water, hard water or first layer water. This adsorbed water is so firmly attached to the clay surface that ordinary sun drying or oven drying does not remove it. It may in fact be assumed as part and parcel of the clay itself. (It is the presence of this adsorbed water which normally is not taken as part of the moisture content of a soil but it is measured as water by the nuclear gauge contributing thus to the known high moisture readings of the nuclear gauge compared to that of an oven dried sample).

It can be understood that this adsorbed moisture is not generally removed by oven drying when it is appreciated that a pressure of some 550 MPa is needed to press out this adsorbed water. In other words a water head of 55km could be equated to this pressure.

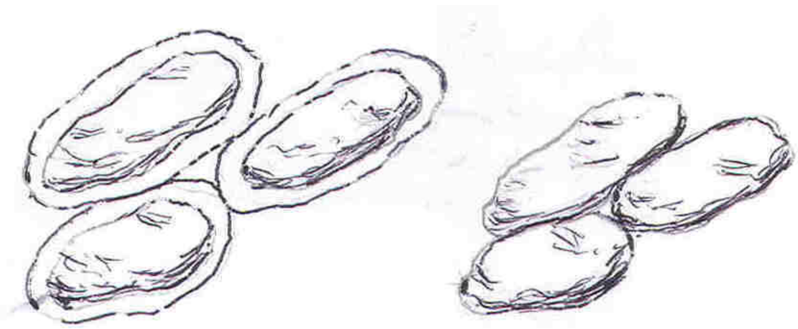
This adsorbed water makes a clay hydrophilic which when free water (rain) is available causes the clay to absorb more water and to hold it even under pressure. Clays are thus termed non-self draining as is the case of a clean sand for example. This water holding propensity of the clay is indicated by the so-called Plasticity Index of the soil.

Soils with a high plasticity index particularly on the fine side such as G7 to G10 are considered to be unsuitable for use in road foundation layers and are generally confined to fills. These are the very soils which when treated by a SAWDIA may give excellent service as a rural road surface.

## 2.1 How do they Work?

It is not intended to go into complicated chemical detail in order to explain the action of a SAWDIA on a clayey soil; a simplified description of the reaction is quite sufficient to enable the process to be basically understood.

The SAWDIA contains ions which have a very strong affinity for the surface of a clay particle. These ions when coming into contact with a clay particle displace any existing ions (which attract water and form the adsorbed water layer). The ion exchange results in the adsorbed water being largely removed as the corresponding ions are replaced by SAWDIA ions. These latter ions attach themselves firmly to the clay surfaces and are not displaced, thus resulting in a virtually permanent clay surface that does not attract water as normal ions do. The clay thus becomes hydrophobic. The removal of the adsorbed water layer allows the clay surfaces themselves to get closer together causing densification of the soil matrix. The bonding effect of the clay particles free of the adsorbed water surround is strong and a firm soil structure develops in time. It must however be clearly understood that this firming up of the soil is not as a result of any cementing action but purely surface attraction and an increased soil suction. (A clay brick if only sun-dried can give a good strength even when the adsorbed water is still present. It is thus evident that without or with reduced adsorbed water the strength can be even greater as the interface bonding becomes greater). See Figure 2.



Particles separated by Adsorbed water          Water removed: particles in contact

**Figure 2. Removal of adsorbed water brings particles into closer contact.**

In practice a relatively small amount of SAWDIA is added depending on the quantity of clay and exchangeable ions present in the treated soil. Two important factors must now be clearly understood:

- The relatively small quantity of SAWDIA added needs water to enable the ions in the additive to reach all the clay. The SAWDIA quantity is thus diluted with water prior to application. A moisture regime is necessary during the initial stages after treatment, which may be termed the maturation period.
- Because of the relatively large surface area of the clay within the soil, the migration of the SAWDIA ions to all the clay must take time which may be from a week or two to even 6 months or more depending on the clay quantity and type within the soil and the prevailing moisture regime. A dry condition can bring the maturation to a dead stop which will only continue when a proper moisture regime is restored.
- An excessive application of stabilizer can inhibit or even destroy the effect of the displacing ions (almost similar to an excess of moisture in a soil, which causes it to become quick and pump under load).

<u>2.2 To Sum Up:</u>
Water within the soil is needed during maturation.

The full benefit of treatment is only obtained after a time lapse.

Excessive applications of stabilizer inhibits successful treatment.

## 3. A GRAPHICAL ILLUSTRATION

When a soil is compacted say during a moisture density test the co-ordinates of the density and M/C represent a strength contour for the soil at the effort applied. I.e. The dry leg of a Moisture/Density test is in fact a line of equal strength for the soil (CBR values, unsoaked would all be the same along the dry leg). The area of low density and high M/C would show low strength lines while a high density low M/C area would yield high strength contours (see Figure 3).

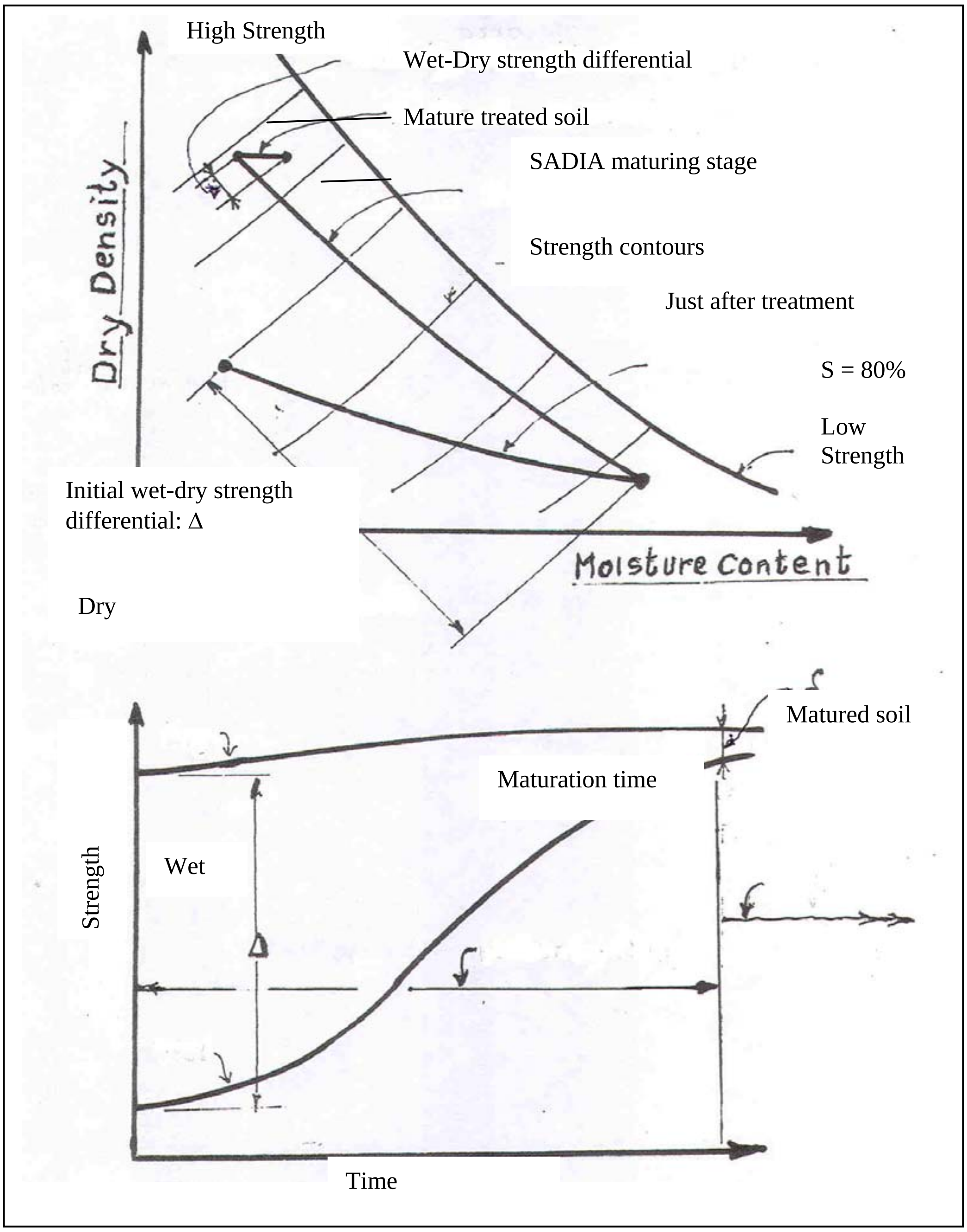



**Figure 3. Illustrating strength build-up during maturation.**

All soils have two extreme strengths at any given density (a dry strength and a wet strength). An untreated soil or/and a freshly treated soil would show a large dry-wet strength differential Δ (see Figure 3). A soil relatively dry at a given density (point A in the upper part of Figure 3) may show a fairly high strength but when soaked or wetted up will drop in density due to swelling and also drop severely in strength (Δ) (Point B on the upper chart). During maturation the soil becomes less and less sensitive to water (hydrophobic) and at the same time densifies until at the end of the maturation period the soil shows a high density but also a very small wet-dry strength differential δ (point C on the upper chart).

It is unfortunate that marketing strategy has often failed to make this point clear; that the strength build up is a slow process. Statements such as "After compaction the road may immediately be opened to traffic" give the impression that an immediate increase in strength has occurred. Whereas, the soil is still virtually unchanged. It might even appear worse when wet as the SAWDIA products have a soapy content to aid the spreading of the applied ions. It must be clearly understood that "the opening to traffic" after compaction is perfectly valid as the compacted layer at this stage is dry enough to take traffic (even if it were not treated) after all it did not fail under the construction traffic! However if too high a moisture content is present (e.g. after rains) the surface may become muddy and rutted during early maturation.

The period of maturation is dependent on several factors namely:

- The moisture regime within the treated soil (a moist condition shortens the period).
- The amount of clay present within the soil (a high clay content will need a longer period).
- The type of clay present (smectites need a longer period than kaolinites)
- The exchangeable ions present (the more ions the longer the period)
- The amount and type of traffic (much traffic enhances compaction)

In general terms this maturation period may extend from about two weeks to 2 – 3 months or more.

## 4. TESTING FOR SUITABILITY

The manufacturers of SAWDIA products have each developed a means of testing a clayey soil for success or otherwise if treated. Some tests even indicate the rate of application of the SAWDIA. These tests all show that a treatment will or will not be successful or beneficial but they do not indicate what strength can be expected in time after treatment.

Road Engineers want to know the expected performance improvement when a soil is treated. The CBR test or an unconfined compression test will often give them the answer they expect. The writer is unfortunately unaware of any laboratory "quick term" test that will indicate what strength (unsoaked CBR for example) can be expected in time. Tests on treated soils such as soaked CBR, Atterberg limits are quite unsatisfactory as they all relate to a value at a virtually saturated moisture condition. A treated soil with all adsorbed water removed can still show a PI or a low CBR when soaked. Tests over time appear to be the best approach at this stage. Research in this field is still very much underway. Visser and Erasmus, (2005) developed a test which clearly relates the moisture conditions in a treated and untreated soil after a lapse of time. The results clearly demonstrate the strong hydrophobic nature of the treated soil after maturation.

## 5. THE BEHAVIOUR OF SOILS AFTER TREATMENT

Materials which give the best results after treatment are soils that are fine grained with say a maximum particle size of 2mm and which have a relatively high PI and show the worst conditions under traffic when wet. (Remember: A SAWDIA is quite useless when applied to a sand or very low PI soil as there is no clay on which it can act!) The fine soils will produce a surface that is virtually free of any raveling or dust formation. As the soil increases in particle size i.e. the $D_{85}$ value becomes larger, the more raveling can be expected under traffic. The drying out clay will bond the finer particles into a strong matrix but larger particles are not held strongly and will become dislodged in time forming potholes and/or a loose un-bonded surface. Soils that are likely to ravel such as gravels will need a top layer or surfacing if the full benefit of a SAWDIA treatment is to be retained.

It is the writer's strong opinion that unsurfaced SAWDIA treatments be confined to rural roads where the natural soil is fine and the importation of a gravel is not an option. Although a gravel road un-surfaced after treatment will demand less maintenance and show less dust under traffic, the surface will ravel in time and unless surfaced the benefit of any treatment will be lost.

Figures 4 and 5 are photographs of soils treated with a SAWDIA some 6 to 10 years ago. Figure 4 clearly shows the honeycomb form of block cracking giving the effect of a cobbled surface. This road has never been surfaced and exhibits virtually no raveling. Figure 5 illustrates the resistance to erosion exhibited by a treated soil. This road was surfaced some 3 years after treatment but after 10 years the treated shoulder layer which is un-surfaced, clearly appears as if it is a cemented layer.

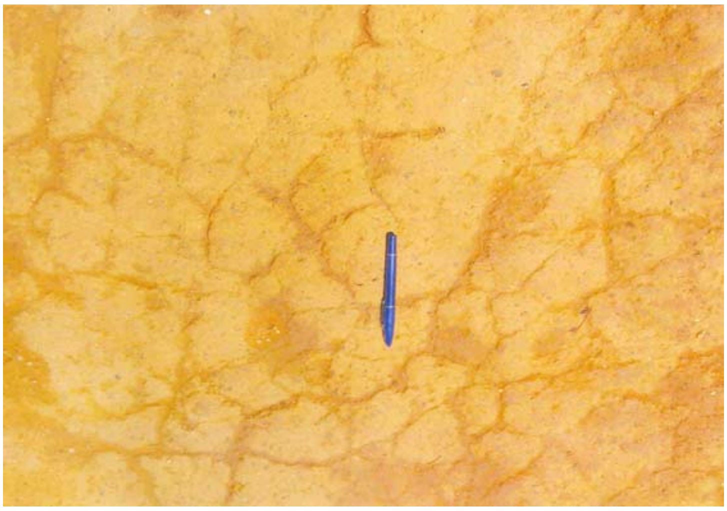


**Figure 4. Typical Honeycomb cracks due to shrinkage of soil after treatment with a SAWDIA.**

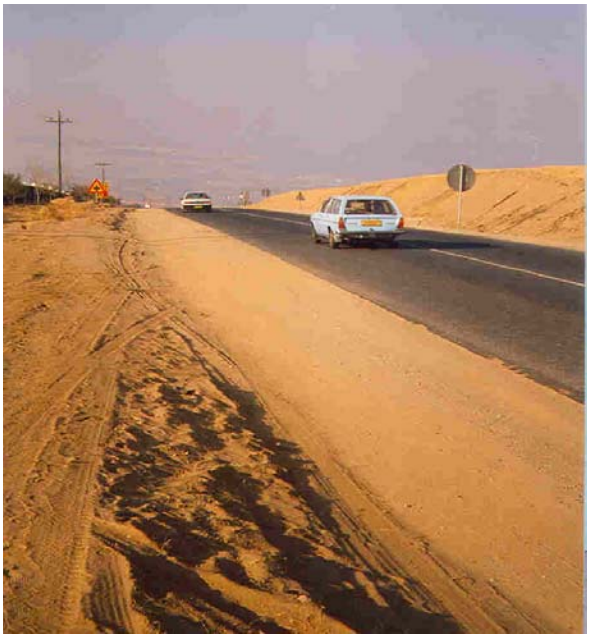


**Figure 5. Example of a SAWDIA treated layer after 10 years. Surfacing applied directly onto the treated soil layer. Note condition of treated unsurfaced shoulders.**

## 6. PREPARATION PRIOR TO TREATMENT AND MAINTENANCE

As the treatment of a soil by means of a SAWDIA ensures that the surface dries out quickly and does not absorb undue moisture it is essential that the surface be given the opportunity to exercise this properly. Bad drainage of the surface or a waterlogged condition will negate any treatment of the soil. It is thus essential that any road proposed for treatment should be of good cross-section which allows the road surface to drain off properly. Depressions in the road surface where puddles can form are fatal to a treated surface as the passage of traffic results in a pore pressure and suction action. It is thus essential that proper maintenance such as reshaping of the road surface if necessary during the maturation period be sustained.

A rough and rutted surface, if allowed to remain until the end of the maturation may be difficult to remedy as the bonding process often results in an extremely hard surface. (An untreated dried out heavy clay if rough and rutted will not easily be smoothed).

Treatment of a road surface with a SAWDIA does not in any way eliminate the need for proper drainage maintenance nor the general requirements of appropriate maintenance of a treated surface. Very often only hand labour is sufficient to ensure a proper drainage, the lack of which can seriously jeopardize a successful performance.

## 7. APPLICATION

It is not intended to detail the operation of SAWDIA applications. As the providers of the product, generally give clear guidance in this respect.

In general, the liquid additive is added to water which is then sprayed onto the prepared road surface until the required application rate has been met. Untreated water may then be added to bring the moisture content to that required for compaction of the soil layer.

During the maturation period, a proper moisture regime ensures a short period. Rain may be sufficient to ensure this but if a dry spell is anticipated applying water from time to time will hasten the end result. A dry condition within the soil after treatment will delay the final effect of treatment but will not need further application of additive.

If the road surface is properly shaped and is acceptably smooth, ripping up and re-compaction after treatment may not be necessary and a spray on technique can be applied. This is done by spreading treated water onto the road surface at about one tenth full application rate following within 24 hours with a spray of untreated water to aid the penetration of additive. This operation is then repeated (treated then un-treated water) until the full application rate has been applied. A maturation period will still be needed before full benefit can be expected and treatment such as reshaping watering if required during this period still applies.

## 8. CONCLUSION

It is worth concluding with a summary of "for and against" relating to SAWDIA treatments:

- SAWDIA products drive off adsorbed water and cause clay in the soil to become hydrophobic.
- SAWDIA products do not provide a cementitious bonding like cement or lime.
- The bonding is solely done to the drying out of clay as it loses it's adsorbed water.
- SAWDIA work only on clayey soils and have no effect on soils with no or low clay contents.
- In time the treated soil exhibits a small dry-wet strength differential.
- During maturation a moisture condition within the soil is essential (A dry condition stops all reaction).
- Testing of soil samples determines the suitability of the soil for treatment.
- Tests for the effectiveness of treatment all take time, there is no known rapid test for effectiveness as yet.
- Fine soils containing clay are best for treatment. Gravels will ravel and need early surfacing.
- Surfacing if done must not be applied until the end of the maturation period.

Finally:

> SAWDIA are not the wonder products that will make silk purses out of sow's ears but may be considered as an extra tool in the road engineer's box to enable him to treat poor soils and thereby make them yield a sound rideable surface.

## 9. REFERENCE

[1] Visser, AT. & Erasmus, F. (2005) "Practical Evaluation of additives used for soil stabilization".