1.1 Introduction

In most developing countries, the shortfall in resources being provided to road network development is shrinking. This is due to other facilities such as electricity, water, housing, schools and hospitals gaining higher needs and priorities. At the same time obtaining good road construction materials is becoming scarce and more expensive as borrow pits are depleted and haul distances become extended. This is forcing a “re-think” or re-excavation of conventional design, material standards and construction methods. Thus engineers have to reevaluate the standard specifications by reducing the requirements to more appropriate limits by considering lower traffic loads and the service required. However, this leads to additional problems particularly on un-surfaced gravel roads.

- Maintenance problems of the road surface under wet and dry conditions.
- Deterioration of the surface as the traffic increases on heavier axle loads (rutting and potholes) caused by using interior materials.
- Experienced operators can improve the surface problems, but this maintenance is costly and disruptive to the traffic flow.

The material requirements for low volume roads can be substantially lowered compared to those for high volume roads, and as much use as possible should be made to use local and in-situ materials. These materials may need to be blended or modified to produce appropriate pavement materials. This has the assed advantage of reducing the environmental impact of road construction.

The main factor influencing the strength of soils is the presence of water. And one of the main reasons for moisture related road failure is the presence of clay minerals either in the soil or from partly weathered aggregates. Using local or insitu soil materials increases of clay minerals and this in turn increases the moisture sensitivity of the material, thus reducing the strength of the pavement layer.

With this in mind, **CON-AID/CBR PLUS** was developed to stabilize the material through increasing the shear strength of the soil and decreasing the influence of moisture susceptibility of the clay materials. The main advantage of the liquid chemical stabilization, such as **CON-AID/CBR PLUS**, is that only a small volume of stabilizing agent is generally require and most soils can be stabilize with it.

2.1 Nature and Characteristics of CON-AID/CBR PLUS Liquid Chemical Stabilizer

CON-AID/CBR PLUS is a stabilizer for anionic soils that improves the load bearing performance of a variety of clays and silty soils. It has been used worldwide for over twenty years to control dust and improve compaction.

CON-AID/CBR PLUS is a synthetic thio compound which forms protective, oily layers on the surfaces of soil and clay particles. It reduces ion mobility and ion exchange and simultaneously makes the material hydrophobic by eliminating the adsorption of water. The result is a soil material that is much less sensitive to moisture, more workable and can be compacted to a better particle-interlock state by equipment and traffic forces. Better particle-interlock means higher internal friction and improved bearing capacity.

CON-AID/CBR PLUS will treat materials ranging from clays to silty sands and some gravel. Non-cohesive materials such as sand can be treated only after they have been modified by mixing them with a suitable clayey material.

CON-AID/CBR PLUS has the following physic-chemical properties:

- Totally water soluble with no solid residue
- Non-flammable
- Non-corrosive
- Non-Toxic and Safe
- Environment and user friendly

2.2 Clay Water Interaction and Ion Exchange Capacity of Clay Mineral

Clay minerals are highly reactive due to their large surface area and because they commonly carry a charge forming is the basis for their exchange capacity and their swelling properties, which are both extremely important to the civil engineer. The ion exchange capacity of the clays is the property to clay minerals in adsorbing ions (due to the interlayer charge deficiencies) and retaining them in an exchangeable state, i.e., these ions are exchangeable for other cations and anions by treatment with such ions in a water solution. These ion exchange reactions generally do not affect the structure of the clay mineral.

Ion exchange is of very great importance because the physical properties (e.g., plasticity) of clay materials are frequently dependent on the exchangeable ions carried by the clay. The plastic properties of clays, for instance, are highly dependent on whether Na+ or Ca+2 are the exchangeable cation. It is, therefore, possible to alter the plastic characteristics of many soils to meet their specific needs by carrying out specific ion exchange reactions.

The interaction of clays with water depends only on the water which can be held by clays at relatively low temperatures (less than 100 - 1500C). An understanding of the nature of this low temperature water is of great importance, since it largely determines the plastic, bonding, suspension, compaction and other properties of clay minerals. The water, which is lost from clays at low temperatures, may be classified into three (3) categories (Figure 1):

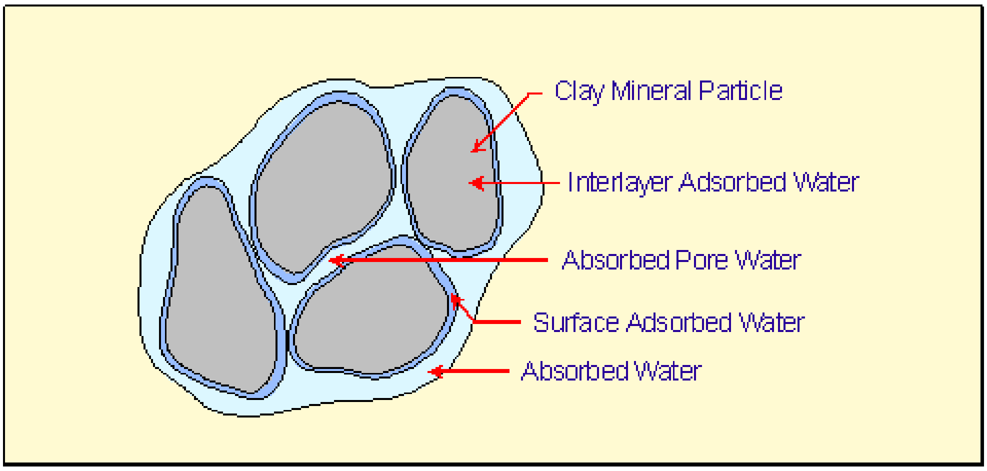

Figure 1 Absorbed and Adsorbed Water in Clay-Water Systems

- The water in the volume of pores and capillaries (absorbed water). **Pore water** requires very little energy for its removal (e.g., drying at only a little above room temperature).
- The water on the surfaces around the edges of the discreet clay minerals particles as well as on the surfaces of pores (adsorbed water).
- The interlayer water (adsorbed water) which controls the swelling of clay. **Adsorbed water** requires definite energy for its complete removal.

Clay particles when suspended in water, therefore, can be considered to be surrounded by a hydrosphere of adsorbed water within which is contained soluble ions of different charges. Around the ultimate clay particle are layers of negatively charged ions (due to the fact that oxygen makes up the bulk of the composition of the silicates), and these are balanced by a swarm of exchangeable cations which are diffused throughout the hydrosphere. These *"counter"* cations provide links between the clay particles with the result that plasticity develops. Plasticity is associated with the formation of adsorbed water films of a certain order of thickness around each particle, and is thus a function of the water content. The maximum plasticity of clays is developed at a specific water content which corresponds with a film around each particle of approximately 2,000+ thick. For most clay, this would be in the water content range of 15 - 25 % by weight. An attempt to compact such material will cause an overall reduction in grading which will result in a further increase in plasticity. This is due to the development of hydrostatic pressure within the material during compaction.

2.3 Reaction of CON-AID/CBR PLUS on Clays

CON-AID/CBR PLUS was developed to assist the engineer with:

- The removal of adsorbed water in order to achieve maximum density with less mechanical effort. (**CON-AID/CBR PLUS** as a compaction aid).
- To prevent the re-adsorption of water. This results in a permanently stabilized construction material. (**CON-AID/CBR PLUS** as a stabilizing aid).

Compaction per se can easily and much more economically be achieved by the use of a variety of the relatively cheap compaction aids such as a diluted sulphuric acid or even caustic soda. The problem is that the materials thus treated will not be stabilized permanently, and will re-adsorb water (after the first rains), thereby causing road failures.

CON-AID/CBR PLUS however, is a complex chemical formulation of which one of the active ingredients is sulphonated oil. The permanent action of this sulphonated oil depends on the presence of other active compounds, which enhance the effect of water dispersal in clay materials and produce a permanent association between **CON-AID/CBR PLUS** and the clay particle. This formulation of active compounds makes **CON-AID/CBR PLUS** unique in chemical constituency, behavior and end results when applied as a compaction aid in road construction.

Sulphonated oils (Figure 2) are surfactants (surface active reagent) and have this character due to the duality of their chemical constituency and behavior. A sulphuric acid moiety (referred to as the hydrophilic "head") is completely soluble in, or miscible with, water and insoluble in most non-polar organic solvents. This part of the molecule dissociates when the oils dispersed in water and produces an anionic SO3- group which is linked via the sulphur atom to the so called "tail" of the molecule. This "tail" consist of an assembly of carbon and hydrogen atoms and is completely insoluble in, (immiscible with) water, therefore, referred to as the hydrophobic "tail". It is lyophilic in nature - miscible with oil and non-polar solvent - strictly due to its hydrocarbon character. Despite the difference in nature of the two parts of the molecule, it is soluble in water as well as in organic solvents. This dual behaviour of the sulphonated oil is utilized as a means if dispersing water from minerals.

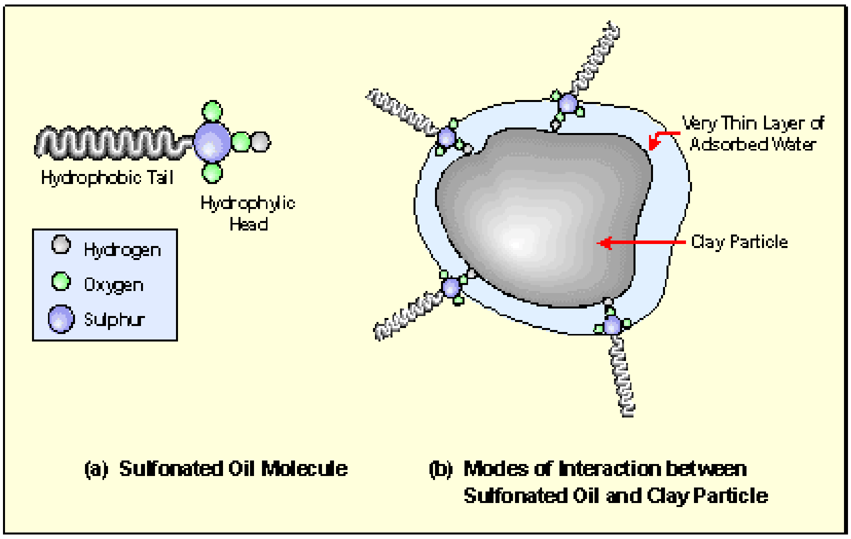

Figure 2 Reaction of Clay Particle with Sulfonated Oil

As discussed earlier in this document clay minerals consist of layers with a variety of loosely associated ions adsorbed on their surfaces. In an aqueous environment, these ions move freely in the hydrosphere surrounding the clay particles and exchange positions at random. Most ions are solvated (surrounded) by a number of water molecules in such an environment and therefore enhance the hydrophylicity of clays. The large quantities of water and the mobility of cations and anions in a clay water system will produce the undesired plasticity. In order to reduce the plasticity, it is necessary to reduce the mobility of ions in solution and secondly to liberate as much water as possible from the system. **CON-AID/CBR PLUS** provides a simple, inexpensive chemical solution to this problem.

Treatment of material with **CON-AID/CBR PLUS** provides the chemicals required to reduce ion mobility and to repel water from the clay minerals. The hydrophilic head of the sulphonated oil forms chemical bonds with the surfaces of clay particles, both on the external surfaces and on the planar surface (Figure 2). These bonds may be of a different nature:

- Direct chemical bond formation between the SO3- Anionic head of the oil and a metal cation on the surface. These bonds are relatively strong.
- Inductive bond formation between an uncharged oxygen atom of the SO3 group and a metal cation.
- Occupation of a vacant ionic site on the clay surface by the sulphonated oil.
- The hydrophilic head of the oil dissolves in a very thin layer of water adsorbed on the clay mineral surface.

These interactions between the sulphonated oil and the clay minerals have the following results:

- Cations, which otherwise would have been highly mobile are now fixed in their position and are *"sealed off"* by the sulphonated oil molecules. This also prevents the ions from forming solvation complexes with water.
- Once the oil molecules have formed their associations (of whatever nature) with the clay particle, the hydrophobic tail is directed away form the planar surfaces to form an oily; protective layer around the clay particle and also on it's under layer surfaces. Naturally, water would be repelled by the hydrophobic tails to such an extent that virtually no mechanical pressure is required to liberate the water. In the absence of the chemical, up to 420 kg/cm^2 mechanical pressure is required to force interlayer water out of clays.

Compaction can now be achieved with a minimum of mechanical effort and clay particles are brought into a very close association with each other. The natural density acquired, as well as the hydrophobic layers surrounding the clay particles, prevents water, in small quantities, from re-entering the system.

2.4 Summarized End Result of the CON-AID/CBR PLUS Application:

Compaction and permanent stabilization can be achieved with minimum mechanical effort producing a base in which particles are bonded simply by direct contact. Clay particles having their inner walls coated with a hydrophobic layer, allow for the free movement of water. This means that water in the soil of a road can move freely in the **CON-AID/CBR PLUS** treated material. With natural evaporation, this free water evaporates from the system more easily and hence increasing the stability of the material.

2.5 Environmental Concerns

Test using **CON-AID/CBR PLUS** has been conduced by Robertson Technologies Corporation 580 Homby Street, Vancouver, B. C., and Canada. The test that were conducted incorporated hazardous ingredients, physical data, fire and explosion data, reactivity data, toxicological effects, preventative measures, first aid measures, and environmental effects. The CAS numbers of all components of this compound does not appear on the USEPA Toxic Substances list, implying that the product is considered to be non-toxic and non-hazardous.

The use of **CON-AID/CBR PLUS** means that a wider range of materials than previously considered can now be used. This gives the engineers more scope to use the in-situ material in signal or multi-layer pavement by reducing the importation of materials from unsightly and environmentally degrading borrow pits thus, minimizing the environmental degradation. From the past experience, it has been observed that dust on a **CON-AID/CBR PLUS** treated road is substantially less than the untreated surface. Quite often up to 80% reduction.

3.0 CON-AID/CBR PLUS Application Procedure

3.1 Soil Analysis and anticipated Traffic Loading

The local soil from the proposed project has to classify in terms of either AASHTO or the Unified Classification System. This is done by means of sieve analysis and the Atterberg Limits test.

The proposed traffic loading for the road has to be determined.

CON-AID/CBR PLUS will further analyze the soil for reactivity with the **CON-AID/CBR PLUS** product, to ensure compatibility and determine the correct application or dosage rate for the particular soil to be treated.

All soils are different and react differently with the **CON-AID/CBR PLUS**. This test ensures the optimum application rate for each soil type and also ensures highest performance possible.

3.2 Designs the Road

The information from Step 1 is used to design the proposed road and the appropriate construction method is prescribed. This would include the construction sequence, number of layers required in the road, equipment to be used, and additional material such as clay or gravel that has to be added to modify the soil and post construction monitoring and treatment. All recommendations are based on road layers 150 mm or 6 inches thick.

3.3 Equipment Required:

For most methods of construction, the machinery equipment required is listed as follows:

List of Machinery needed for Construction

Machinery	Minimum Size	Average Production	Remarks on Average Production
Grader with scarifying teeth OR TILLER	CAT 14 G	6-8 hrs per day	Hard / heavy ripping by grader scarified may reduce production. Spreading from dumped stockpiles will improve production
Water Tanker with pressure pump to provide even spraying	6,000-8,000 li	1/2 day	Must have pump to fill / discharge water quickly from the tanker. If water source is far from site, water supply to layer will be slow. If material is very dry or clay much water loads will be required. Moisture content of layer or dumped material will affect number of tanker loads required.
Pneumatic tired roller	10 - 12 T	1/2 day	This is a good roller to compact around stone particles and so give even compaction of layer. Use immediately shaping starts compacting from the bottom of layer to top.
4. Vibratory / flat 3 wheel roller	10 - 12 T	1/2 day	Rollers required to get required specified density compaction to start early from bottom to top of layer
5. Tamping / pad foot roller	10 - 12 T	1/2 day, if required	If clay material is being used for lower layer this roller should be used compacting from bottom to top of layer
6. Rotovator or Tractor with disc harrow		1/2 day, if required	This plant can be used to break up clods of soil and to provide good mixing

Assuming that the specified layer (15 cm) material is either in place on the road (therefore requiring ripping or scarifying for mixing to take place) or sufficient material brought from borrow pits and dumped alongside road edge for 15 cm layer to be cut in from dumped piles by grader when mixing.

Average daily production is about 300 to 750 meter length x 7-9 meter width x 15 cm thickness or about 1.2 km - 1.5 km / week. (i.e., 2,000 - 5,000m2 / day or 10,000 - 25,000 m^2/week).

3.4 Construction Procedure

1. Clearing the road of any vegetation and organic topsoil to ensure construction is possible within the boundaries.
2. Sides have to be excavated for new roads and cleared for existing roads.
3. Shape the road to ensure at least 4-6% side slope for drainage.
4. Layer thickness must be in multiples of 15cm, and where more than one layer is to be treated, windrow the top layer to expose the lower layer.
5. Imported material, where recommended, must be placed and spread.
6. The layer material must be scarified with a grader to loosen and break down lumps or clods as much as possible. Where necessary a Rotovator or disc harrow must be used to help loosen and break down lumps.
7. Determine the required quantity of **CON-AID/CBR PLUS** needed to treat the area of road open and also determine the quantity of water required to raise the moisture content of the soil to 1% above OMC.
8. Equally distribute the quantity of **CON-AID/CBR PLUS** into the water tankers before the mixture is sprayed evenly over the open area. The **CON-AID/CBR PLUS** is fully soluble in water and must be added to tanker only after (not before) the tanker has the full or required quantity of water in it.
9. Mixing of the water and **CON-AID/CBR PLUS** in the tanker can be facilitated by circulating the water with the pump, or where no pump is fitted, to drive the tanker backwards and forwards over a short distance.
10. The diluted mixture is sprayed onto the layer while being processed by grader, disc harrow, or Rotovator until the layer of soil has been well mixed.
11. After re-shaping the road, compaction can begin with a roller. Where heavy clays are present, compaction must be by pad foot and in layers of 5-7cm, from the bottom up.
12. Final shaping with the grader is followed by final rolling, usually with a pneumatic roller.

3.5 Opening to Traffic

During construction and immediately after final compaction, the roadway can be opened to traffic. Any deformation should be corrected by grading and compaction before the material dries out fully.

3.6 Curing

After the stabilized layer has been compacted to the required density and brought to the required lines and grades in accordance with the typical cross section, the completed section should be cured. This curing is accomplished by the daily application of water with the water tanker, depending upon the climate and the depth of treatment, usually for seven to ten days after completion date. During this period traffic may use the stabilized road.

Please note that during this period small quantities of **CON-AID/CBR PLUS** remain on the surface which may create a slippery face in some instances during rainfall and depending upon the type of soil stabilized. This slipperiness is normal and usually disappears after the curing period or a few rainstorms.

3.7 Maintenance

One of the major advantages of CON-AID/CBR PLUS over other soil stabilizers is the fact that CON-AID/CBR PLUS can be repaired.

CON-AID/CBR PLUS is not cementing agent. Normal wear of the gravel road surface i.e., gravel loss, rutting and dust can be expected. To repair the road to its original state, wet the road surface thoroughly and follow normal grader blade maintenance procedures. Provided no untreated material is brought into the road from the sides during grading, the traffic will compact the road again without re-treatment with **CON-AID/CBR PLUS**. If untreated material from the road side is brought onto the road during maintenance grading, the surface should be treated with a very small dosage of **CON-AID/CBR PLUS**.

3.8 Surfacing

If surfacing of the treated road surface is required, the field moisture content of the stabilized layer must be allowed to stabilize between 50 to 60 % of optimum moisture content. Depending on the soil type, climate and temperature (including rainfall during this curing period), this may take between 6 to 12 weeks or longer.

4.0 Life Span of CON-AID/CBR PLUS Stabilized Layer

The change in the treated clay is permanent and will not reverse itself due to leaching. In theory therefore, the **CON-AID/CBR PLUS** treated road should last forever if the construction procedure and instructions are followed properly, but in reality special variability of subsoil and drainage is expected. Normal wear and tear prevails and the roads built with **CON-AID/CBR PLUS** stabilized soil will require some maintenance.

The resultant road should however present a significantly improved ridability, particularly in wet weather, and substantial reductions in maintenance. There are some **CON-AID/CBR PLUS** stabilized roads in existence, which have been used continuously for over twenty years.

5.0 Key Benefits

- Cost saving
  - Use local soils.
  - Reduces gravel loss
  - Does not require re-treatment of surface
  - Increased workability saves time, machine effort and fuel during construction.
- Increase performance of in-situ soils.
  - Increase bearing capacity
  - Reduces Surface Tension
  - Reduces Capillary Rise
  - It reduces swelling
  - It helps to increase density with less compaction effort.
  - Improved traffic ability and better driving conditions in wet weather.
- Dust reductions up to 90% and create safer driving conditions
- Long term stabilization
  - Treatment is permanent

6.0 Primary Uses

- Economical road construction
- Upgrading of roads
- Maintenance on unpaved roads
- Rehabilitation of failed roads
- Construction of roads
- Parking areas
- Air strips
- Mass fills

7.0 An Analysis of Cost Benefits Obtainable With the Use of CON-AID/CBR PLUS as a Soil Stabilizing Agent:

Since **CON-AID/CBR PLUS** operate in the East, Africa, the Americas and Canada cost implications would differ largely. The factors that would affect such differences are:

- The state of development of the country and its traffic requirements.
- The ability of natural roads building materials due to its geological diversity or lack thereof.
- The harshness of climate conditions such as dry, wet, ice, hot or cold.
- The size and population density of the country. The cost of plant and labour.
- The replacement and maintenance cost analysis made is mostly for construction whether new or reconstruction.

In the case of developing countries it is often case that donors readily make money available for construction, but seldom for maintenance. The effect of this is very noticeable in Sub-Saharan countries. Sadly very often there is a total degradation of roads whether bitumen or gravel. **CON-AID/CBR PLUS** receives a fair amount of feed backs regarding cost savings against conventional construction. Sadly, what is considered to be the greater advantage of **CON-AID/CBR PLUS**, namely the cost saving on maintenance of a gravel road, is seldom evaluated.

Reports do came through with terms such as *long life maintenance free, good possibility when wet* etc. but not expressed in monetary terms. This may possibly due to the fact that little or no maintenance in carried out and therefore no costs are available.

The highway Design and Maintenance Standards Study (HDM) has done some excellent studies on the effect of Road Roughness and its prediction by Paterson and others. Likewise Rodrogis S. Archondo-Callao and Asif Faiz (*World Bank Technical paper number 234*). Show significantly the effect roughness has on vehicle operating cost. Similarly Cavelle D. Creightney stresses the importance of good roads infrastructure in Transport and Economic Performance (*World Bank Technical paper number 232*).

When one travels on many of the Sub-Saharan roads one wonders if these excellent works do get through to grass roots. **CON-AID/CBR PLUS**, in spite of its technical experience, has opted for simplistic hands on approach with emphasis on training, assistance and labour intensive operations. John F Kennedy said: *Wealth does not bring roads, but roads bring wealth.*

The following is an attempt to illustrate financial benefits, which could be expected when **CON-AID/CBR PLUS** is used in the construction and maintenance of rural roads.

The benefits are shown to fall within the following categories:
(a) The design and construction stage – this analysis illustrates immediate cost saving.
(b) Post construction maintenance – long term benefits.
(c) The environment and community – long term benefits

7.1 Construction Stage Cost Analysis:

The cost analysis illustrated here is presented firstly as a theoretical comparison of costs followed then by some available case studies.

(a) Design and construction savings:

The overall cost of construction of a road to whatever standard cannot be used for illustrating cost saving that the use of **CON-AID/CBR PLUS** could produce. Constructions costs remote from the areas where:

CON-AID/CBR PLUS may be related must perforce be excluded from the analysis. The overall costs of design, surveys, major earthworms, crushed stone layers and bituminous surfacing for example are thus excluded in this analysis.

Costs saving falling within two facets of road construction are considered here:-

- Gravel roads or unpaved roads.
- Conventional bituminous roads.

7.1.1 Gravel Roads

These roads are generally constructed as a single layer of gravel on a formation of natural in situ soil graded and shaped to require line and level.

CON-AID/CBR PLUS may be applied here as an alternative to the gravel layer by treating the in situ soil or remnant of the existing depleted gravel mixed with the underlying soil. The importation of a gravel layer is thus obviated. Cost comparison is made in the table below.

Treatment	Gravel Treatment	CON-AID/CBR PLUS Treatment
CON-AID/CBR PLUS replaces gravel Importation	Opening of a borrow pit. Hauling, spreading, grading And compaction of gravel (hauling fee haul distance only)	Supply **CON-AID/CBR PLUS**, add to compaction water; apply to scarified layer mix and compact. No gravel imported.
Unit Cost percent: (%)	100.00	60.00
CON-AID/CBR PLUS replaces treatment with cement or lime.	Supply lime or OPC apply, spread and mix into layer.	Supply CON-AID; add to compaction water and mix into layer.
Unit Cost percent: (%)	100.00	40.00

7.1.2 Surfaced Roads:

Where conventional road design involves the importation of gravels, **CON-AID/CBR PLUS** may be applied as an alternative to the treatment of these layers with lime or to permit a selected layer to be formed by treating the in situ soil in lieu of importing a more suitable material. The table below gives a comparison of cost:

Treatment	**Conventional Gravel layer**	**CON-AID/CBR PLUS treated layer**
CON-AID/CBR PLUS replaces lime in gravel	Supply gravel and treat with lime	Supply gravel and treat with CON-AID
Unit Cost percent: (%)	100.00	50.00
CON-AID/CBR PLUS replaces importation of selected layer.	Import, spread selected layer	Supply **CON-AID/CBR PLUS** and treat in situ soil to form compacted selected *Layer*.
Unit Cost percent: (%)	100.00	60.00

Case studies summary of case studies where cost comparisons have been made:

Site	**Description**	**Conventional**	**CON-AID**
Sunningdale	**CON-AID/CBR PLUS** as alternative: Lime	100	31
	Gravel	100	18
Ladybrand	**CON-AID/CBR PLUS** treated soil in lieu of gravel importation	100	36
Paradise Beach	**CON-AID/CBR PLUS** in lieu of shale gravel	100	66
Renosterhoek	**CON-AID/CBR PLUS** replacing importation of extra gravel	100	39
Bethsab	**CON-AID/CBR PLUS** in lieu of excavation and Rock fill	100	12
Township roads	**CON-AID/CBR PLUS** rehabilitation in lieu of reconstruction	100	33
Umlazi	Reconstructed storm drainage **CON-AID/CBR PLUS** in lieu of lime	100	42
Urban roads	**CON-AID/CBR PLUS** replacing gravel	100	56
Savannakhet	**CON-AID/CBR PLUS** in lieu of Portland Cement	100	70

Although difficult to quantify the cost benefit by using **CON-AID/CBR PLUS** as an alternative to lime and cement treatment the following two cases would exhibit considerable benefits:

- Where very high clay content soils are encountered lime and cement treatment may not be possible or financially prohibitive.
- In areas where lime and cement would have to be imported as very high cost.

7.2 POST CONSTRUCTION AND MAINTENANCE:

The maintenance of roads irrespective of sealed or unsealed may be divided into two broad categories:

(a) Surface or carriageway maintenance; and
(b) Drainage or wayside maintenance

As **CON-AID/CBR PLUS** treatment is basically within the carriageway area, maintenance as discussed here is confined to the above category (a) only.

Initially, as **CON-AID/CBR PLUS** treated soil do not show immediate improvement as it needs time for the full benefit to be affected it is obvious that very little, if any cost saving in maintenance will be experienced just after construction, but after a period of one to two months marked reduction in grading maintenance will become evident. The degree of conventional maintenance of the soil and gravel roads depends on climate, soil type and traffic. While climate and soil type are constants, traffic will tend to generate when a road is improved. This is in turn requires additional maintenance if the road is not surfaced. This fact should not be overlooked if the **CON-AID/CBR PLUS** treatment of an in situ soil is an alternative to untreated gravel. The latter will by nature present a dustier as well as a rougher riding surface (e.g. corrugations, loose stones etc). Nevertheless reports have shown a marked reduction in routine maintenance when **CON-AID/CBR PLUS** treated surfaces are compared with untreated soil of gravel surfacing.

Assuming the mature stage after treatment with **CON-AID/CBR PLUS** has been reached by a soil or gravel road one or two regrading per month is reduced to about two to three per year.

The re-importation of gravel is virtually eliminated in most cases.

The table below illustrates a cost saving in surface maintenance when CON-AID/CBR PLUS was used:

Description	No treatments of in situ soil or gravel un-surfaced Unit cost percent (%)	**CON-AID/CBR PLUS** treated soil Unit cost percent (%)
Grading and reshaping of carriageway after rains and traffic distortion of in situ soil	100	20
Grading and reshape of gravel riding surface	100	20
Regravelling by importation From borrow areas (free haul distance only)	100	Only to reduce slipperiness at early stage 5 - 6

The table below summarizes some case studies, which involved maintenance of road surfaces:

Description and site	**No treatment**	**Treatment CON-AID/CBR PLUS**
Ubombo Ranches	Grading 100 Regravelling 100	Grading 20 Regravelling 0
Simunye	Grading 100 Regravelling 100	Grading 8 Regravelling 0

7.3. The Environment and Community:

The principle benefits which the community and environment may enjoy when CON-AID/CBR PLUS treatment of soils and gravels is applied are:

(a) Less dust pollution (although **CON-AID/CBR PLUS** is not a dust palliative, dust is reduced by treatment with **CON-AID/CBR PLUS**, but not necessary eliminated).

(b) Negotiable roads in all weather with comfort.

(c) More comfortable riding on road surfaces which receive insufficient or no maintenance (fewer potholes etc).

(d) Less wear and tear on vehicles and tires.

"While the infrastructure costs borne by road agencies are substantial, the costs borne by road users are even greater" From World Bank Technical Paper Number 234. (See Appendix: Bibliography).

(e) Less unsightly and hazardous borrow areas.

These items although reflecting benefits are difficult to relate to a relative cost. Reports from road users do however; record marked improvements to the local environment after roads in their areas were successfully treated with **CON-AID/CBR PLUS**.

8.0 Road Rehabilitation by COLD IN-PLACE RECYCLING Of Asphalt Roads on Clay.

Cold in place recycling or Full Depth Rehabilitation, is the most cost effective method available today for the rehabilitation of existing paved roads.

The top layer of asphalt or seal is milled with a Road Re-claimer or road milling machine to various depths (usually 15 to 30 cm.) depending on the thickness of the asphalt layer, so that the existing asphalt is broken down into small pieces. This milled asphalt is then mixed with the base material during this milling process.

Gravel (course grained materials) bases or sub bases are then stabilized by the injection of hot foamed asphalt during the milling process to compact and bind the gravel particles. This treatment binds the gravel particles together during their placement and also reduces the future effects of moisture in the treated layer. This foamed asphalt process however cannot be used where the base contains fine-grained or clay soil with a plastic index higher than 6. **CLAYS**, or fine-grained soils, can likewise be treated by injecting a **CON-AID/CBR PLUS** to water mixture instead of the foamed asphalt into the milled layer during milling.

The effects of the **CON-AID/CBR PLUS** is to release the adsorbed or bound water from the clay particles and facilitate better compaction for higher resulting densities, while at the same time stabilizing the clay to reduce the effects that moisture will have on the treated layer. It is no longer necessary to remove and replace the clay in the base with gravel or similar fine-grained material, since the treatment with **CON-AID/CBR PLUS** will strengthen the in situ clay material.

The milled asphalt layer is finely ground into a gravel-like material. During this milling process, the ground asphalt is mixed evenly into the base layer to mechanically strengthen the base material. At the same time the **CON-AID/CBR PLUS** to water mixture is sprayed into this finely ground soil/asphalt mixture to stabilize the clay. The milled asphalt, together with the effectively stabilized clay components in the modified soil mixture, provides a strong base layer that resists the effects of moisture.

8.1 Cost Savings

- Obviates the need to haul away existing old asphalt/base soil - Work is done in place.
- New gravel to replace the existing clay base is no longer required.
- Provides a simpler and more cost effective stabilization than lime or cement.
- Requires only one pass with the Road Re-claimer - The work is fast.
- Treated layer is resistant to the effects of moisture - Lasts longer.

8.2 Project References

Residential Street - City of Edmonton - Alberta
200mm asphalt milled with 175mm heavy clay. CON-AID/CBR PLUS stabilized the full layer. 80mm Asphalt layer was placed onto the treated layer.

Tera Parking Lot - Atlanta Georgia USA
100 mm Gravel milled with 100 mm clay base CON-AID/CBR PLUS stabilized the full layer. 80 mm Asphalt layer was placed directly onto treated layer

Street in Nisku Industrial Area - Leduc Alberta
80mm asphalt milled with 250mm heavy clay CON-AID/CBR PLUS stabilized layer. The picture shows the unsealed surface of the treated road after twelve months.