RURAL ROAD BETTERMENT: CONSIDERATION WHEN USING CBR PLUS AND/OR CON-AID MATERIALS

by

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ABSTRACT

Poverty among the rural population can be immediately relieved by improving the rural road structure by making such roads negotiable at all times. The importation of gravel from a logistics aspect alone cannot compete with a liquid stabiliser such as CON-AID / CBR PLUS as it treats the existing in-situ soil.

The need to improve culverting and drainage prior to treatment of the road surface is stressed together with the need for proper soil testing and foundation design.

Construction requirements are listed as well as post compaction treatments and maintenance during the maturation period.

The importance of proper monitoring during this period is also stressed.

1. INTRODUCTION

The well being and prosperity of most Africa countries is hampered by the ongoing poverty of its rural population. One of the major contributing factors is the all too often lack of proper communication between the rural and urban areas. Rural roads in general are of unacceptably low standards, which prohibited any form of transport during wet rainy conditions. This matter was strongly stressed by W Lyatuu et al. (2000).

However desirable it may be to improve the rural road, lack of financing funds limits the extent to which roads authorities can address this problem. Unsurfaced roads, particularly those which do not have any gravel wearing course are extremely vulnerable to wet conditions, but the placing of gravel on all roads is quite prohibitive even if sufficient gravel was universally available. Logistics alone make the task of gravelling quite out of the question apart from the regular maintenance, which such surfacings demand.

The use of materials such as CON-AID and CBR PLUS now becomes a matter, which deserves serious consideration. These products which are soluble adsorbed water displacing ionic additives (SAWDIA) can and do make a poor quality in-situ soil resist the effects of rain so as to enable the road to be used at all times by light traffic without the hauling in and placing of a gravel layer. The term CON-AID as used here may constructed as including the alternative product CBR PLUS.

The quantity of CON-AID generally needed per square meter of road pavement is so small that a single drum of 200 litres is sufficient to treat at least 1 to 2 km of roadway 7 m in width. The transport costs are miniscule compared with the importation of gravel.

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CON-AID acts on the clay within a soil mass and is therefore unsuitable for the treatment of a sand, which contains no clay. However, by importing a clayey soil from a nearby source, which is then mechanically mixed with the in-situ sand a product, is produced which when treated with CON-AID yields excellent road surface qualities.

The product CON-AID although in used for over 20 years, is still unfortunately not easily accepted by many road authorities, but because of its relatively inexpensive application particularly in the treatment of in-situ soil it is slowly being accepted as an extra road building material. (Bunnet 2000).

Many attempts to use CON-AID have been made throughout Africa and elsewhere but it is the author's experience that unfortunately all too often incorrect methods and treatments both during the pre-construction as well as post construction phases have resulted in apparently poor results CON-AID which acts on in-situ soils cannot be expected to compete with lime or OPC which is used on imported gravels and the purpose of this paper is an attempt to present a form of guideline document detailing the necessary actions that should be undertaken when CON-AID is used. Although it may appear to the experienced engineer that these details are "o*ld hat*" it is nevertheless the author's somewhat facetious opinion that the use of CON-AID in many cases appears to give the impression that a "*freeway*" is produced within 24 hours of construction. Although a useful product CON-AID is not a miracle worker.

2. PRE-CONSTRUCTION CONSIDERATIONS

If the riding surface of any rural or minor road is been improved it is a sound practice to carefully examine the present structure with respect to its adequacy. Treating the existing surface without regard to its width, drainage, foundation etc is unsound practice and this is therefore essential to weigh carefully the possible need and feasibility of first improving these conditions if funds can merit it.

2.1. Roadway Width

The road under consideration may be a rural road with very little, light traffic. In which case the actual width treated with CON-AID need not be more that say 3 to 3,5 metres, but if the traffic intensity and type demands it, it may be wise to upgrade the existing road width to a wider treated carriageway.

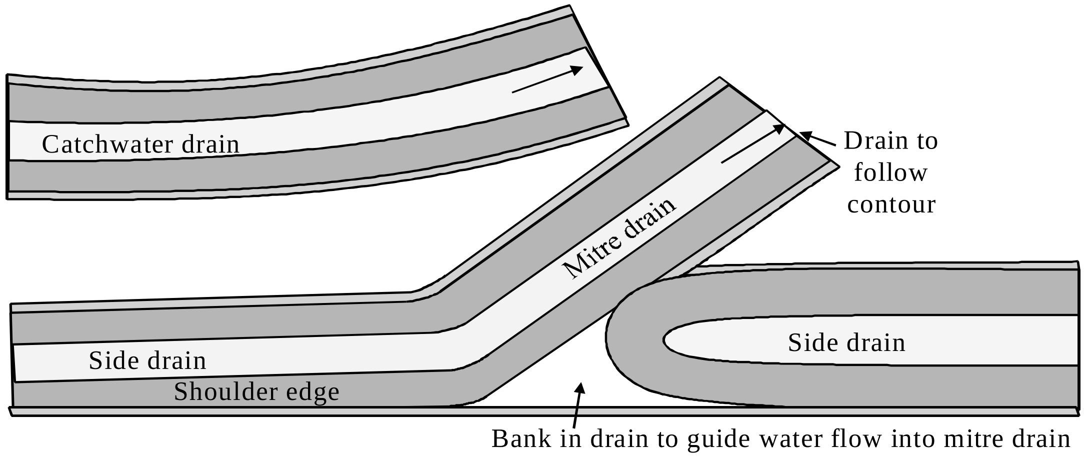
2.2. Drainage

Most rural roads evolve gradually and often tend to follow high ground, but inevitably they have to cross gulleys and low-lying areas; culverts are often missing or inadequate.

Disregarding the culvert shortfalls is courting disaster, as any surface pavement within these areas will be ruined by erosion or permanent wet conditions.

In relatively flat areas existing culverts are often silted up, this is a clear indication that the road surface is too low, and the whole roadway and culverts should be raised so that the culvert invert is at ground level. Long discharge channels are often not properly maintained and eventually just dam up.

Side drains tend to form gulleys if the soil is of an erodable nature particularly, if the road is on grade. Lead off drains (See Figure 1a and b) following the natural ground contours should be formed at proper intervals to ensure that storm water is carried off before it accumulates to too large a volume.



Note: Side drain to take road way water only. Catchwater drain to cut off all floodwater flowing onto road reserve.

Figure 1: Catchwater and discharge or mitre drains and banks

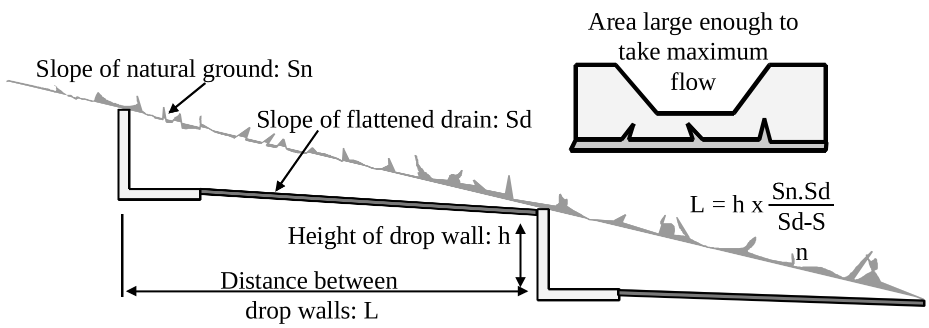


Figure 2: Spaced drop walls to reduce erosion in side drains

Where the road is cut in a cross fall of natural slope a long side drain within this cut area may require cladding at some later stage or the provision of check drains or drop walls and culverts as well as subsurface drains (See Figure 2 and 2a)

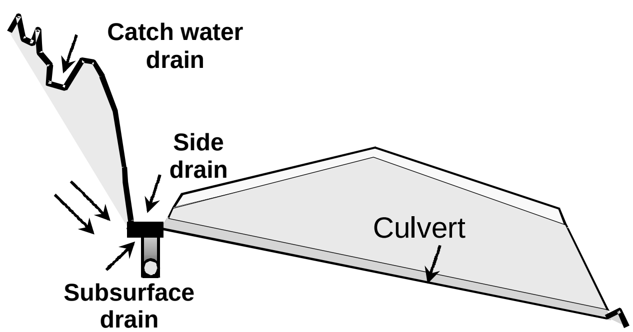


Figure 2a: Cross section showing typical drainage including subsurface drain

A side drain should carry only such storm water as falls onto the road and storm water which may discharge from outside onto the roadway, should be collected by a properly maintained catch water drain above the cut face.

It should be noted here that a comprehensive drainage system might not be necessary initially for very lightly trafficked rural roads as occasional flooding could be dealt with by routine maintenance. Good road management however cultivates a drainage awareness, which ensures that in time the roadway will achieve a good drainage system (see later under maintenance).

2.3. Soil Survey

The nature of the soil, which will make up the foundation layer(s) of the road surface, must be tested in order to ensure that the following condition may be adequately met.

2.3.1. The suitability of CON-AID as a proper additive.
2.3.2. The necessity of adding a clay binder if the soil to be treated is poor in clay content.
2.3.3. The cover above the untreated soil in the carriageway must be of sufficient depth to be able to carry the anticipated traffic.

Full scale soil testing is not required in all cases. It is obvious that a major road would demand far more extensive soil testing than that needed for a lightly trafficked rural road. A minimum number of tests is however essential and may be considered as listed below:

- Atterberg Limits (Cone or Casegrande method) [BSS; ASTM; AASHTO]
- Grading analysis (excluding hydrometer)
- Moisture / Density relationships
- DCP / CBR tests on in-situ soil which forms the surface on which the treated layer(s) is / are to rest.

DCP tests can be converted to CBR values by means of graph or formula (Kleyn 1984) (see Figure 3)

The extent of the tests need not be excessive and a representative sample of each soil type along the road is in most cases quite adequate.

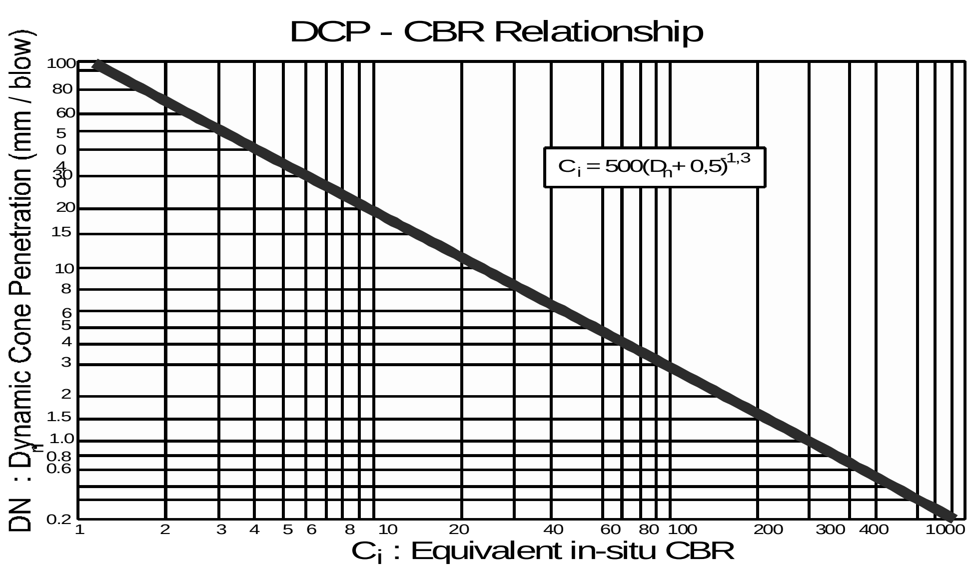


Figure 3: Graph showing the conversion of DCP values to in-situ CBR

A dry sample of each soil type of 200 to 250 gram of the portion passing the 0,425 mm sieve size should be forwarded timely to CON-AID in Johannesburg for reactivity testing and to obtain a proper CON-AID application rate. Notwithstanding charts or tables which may indicate the application rates for CON-AID for various classes of soil it should be noted that these values are for guidance or estimating purposes only and that it is unwise to assume an application rate for any soil without prior testing for reactivity. The field application rate may be obtained by the use of the chart in Figure 4.

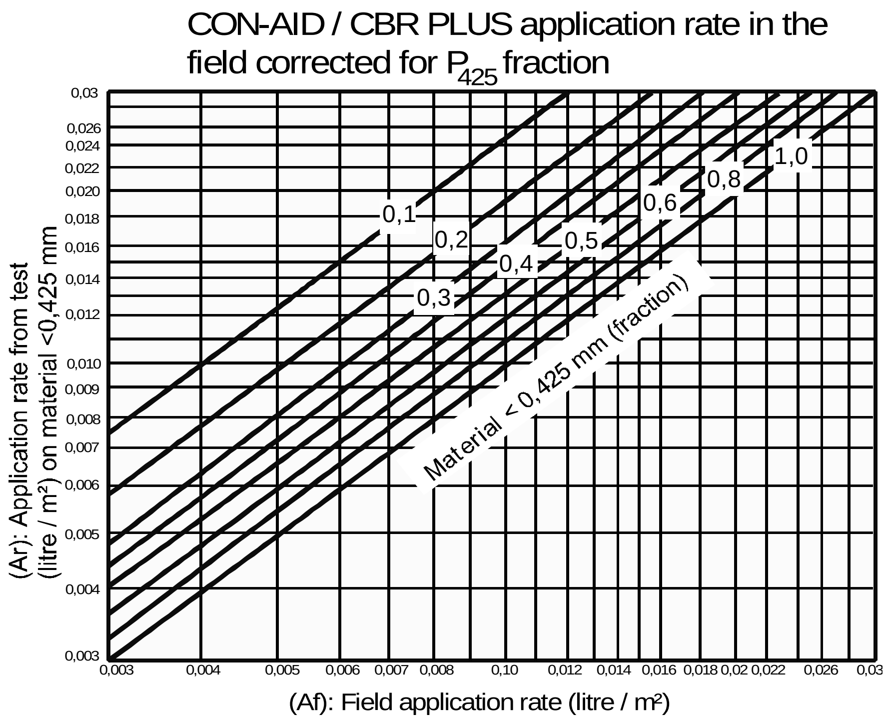


Figure 4: Adjustment of recommended Application Rate (Ar) to Field rate (Ar) according to value of P_{425}, material less than 0,425 mm.

It is always an advantage to know the type of clay and its quantity present in a soil and this is made possible by the results of the Atterberg and grading analysis tests.

From data presented by Lamb and Whitman (1963) and Skempton (1953) the author has derived the following useful data:

- To asses the type of clay present the ratio of Liquid Limit to Plasticity Index is a very good indicator as the table below illustrates:

Ratio of LL / PI	**2.6**	**1.9**	**1.2**
Type of clay	Kaolinite	Illite	Montmorillonite
Swell potential	Low	Medium	High

- The clay fraction (P_{002}) can be estimated from the following formula presented in graph form in Figure 5.

$P_{002} = 0{,}28 \times LL^{2.35} \times PI^{-1.35} \times P_{425}$

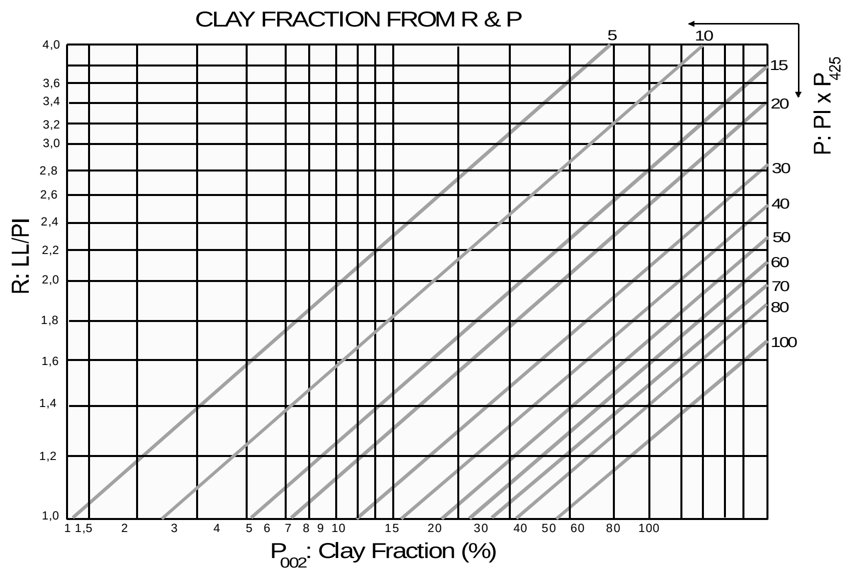


Figure 5: Estimation of the Clay Fraction (P_{002}) from LL/PI and P_{425}

2.4. Traffic Analysis

Although most rural roads would probably be perfectly safe with only one 150 mm layer of treated soil as the foundation it is always advisable to study the traffic at present using the road as well as that likely to be generated should the road be made more serviceable.

An assessment of the nature of the traffic, light to heavy, likely to use the road together with the assessed DCP / CBR value of the untreated in-situ soil will enable the road foundation cover to be reasonably evaluated. The CBR Method of cover design (1951) is suggested here and the original CBR design chart amended by the author is given in Figure 6 which relates the required cover in mm for various vehicle types and the adjusted DCP / CBR value of the in-situ soil. The equilibrium moisture content for the climate area in which the road exists should be used to estimate the CBR values in the design chart.

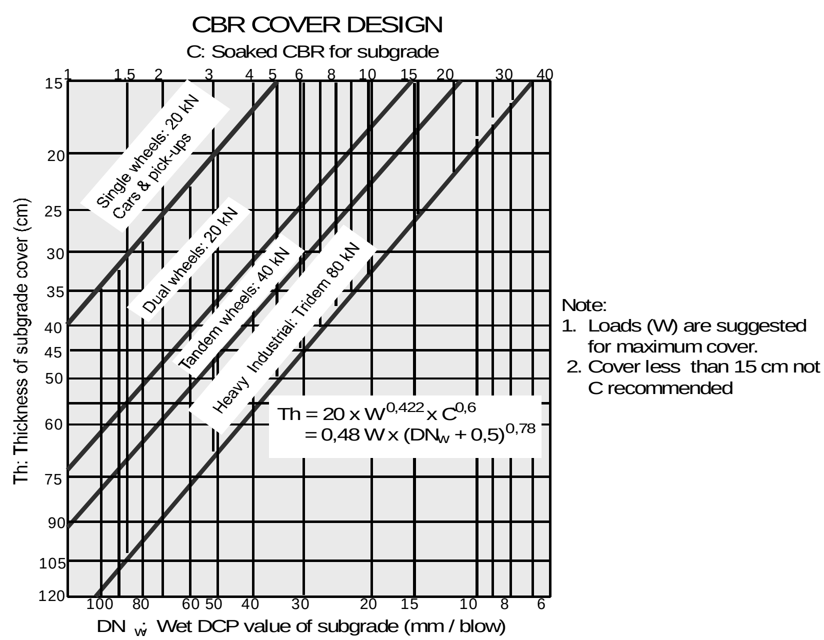


Figure 6: Estimation of cover thickness for in-situ soil wet CBR and DN values for various traffic types

The author recommends the following degrees of saturation for different climates:

Climatic Type	**Dry**	**Medium**	**Wet**	**Very wet**
Degree of saturation	25%	40%	50%	60%
Aprox. Moisture Content	5%	7%	9%	11%

The degree of saturation is recommended by the author in place of moisture content, as it is independent of particle density. However, if moisture content is desired in place of degree of saturation this can be done by using the graph in Figure 7. If the particle relative density is not known a safe value of 2,7 may be taken in which case Figure 8 may be used to relate degree of saturation and Moisture Content with soil density with reasonable accuracy.

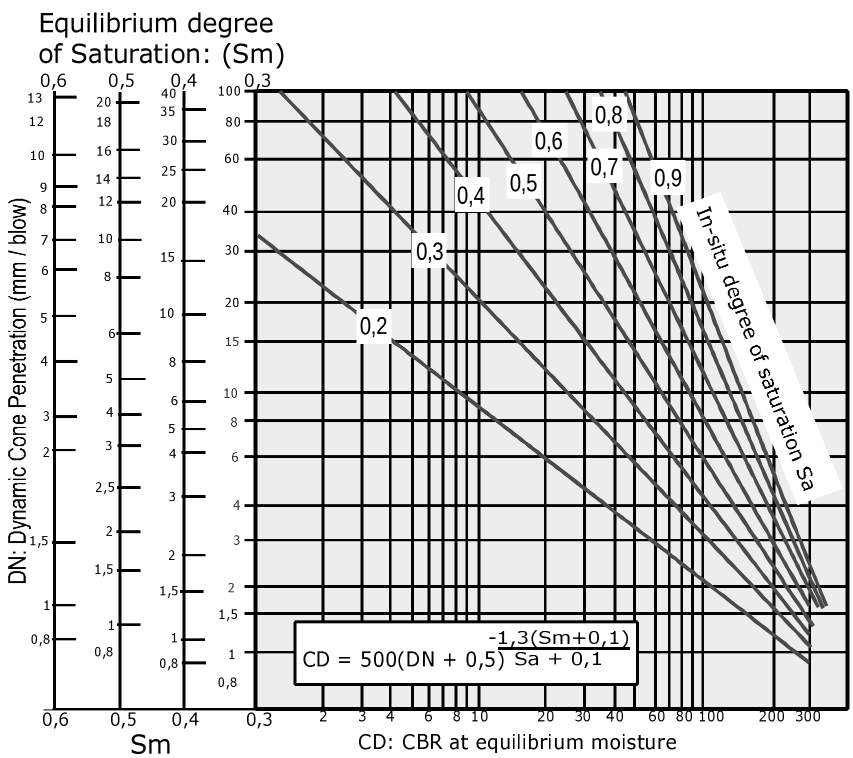


Figure 7: Conversion of DCP: (DN) to CBR (CD) for in-situ moisture (Sa) and selected equilibrium moistures (Sm)

The mathematical relationship on which Figure 8 is based, is:

$$M = S_a \text{ x} \left(\frac{1}{D_c} \Gamma \frac{1}{G_b} \right)$$

Where: M = Moisture Content (%)
S_a = Degree of saturation (%)
D_c = Dry Density of soil (tonnes / m^3)
G_b = Bulk density of soil particles

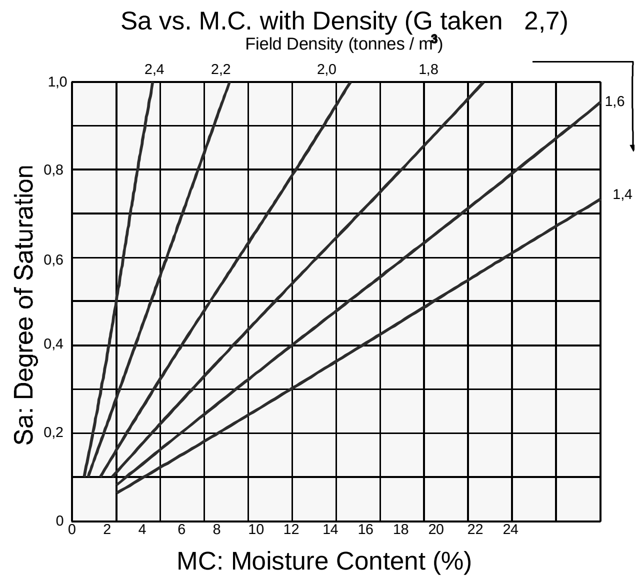


Figure 8: Moisture Content and Degree of Saturation Conversion based on G = 2,7

Alternatively Figure 9 may be used which used which replaces Figure 7 in that Moisture Contents in Percent are given in lieu of degree of Saturation, but the specific gravity for particles in assumed to be 2,7.

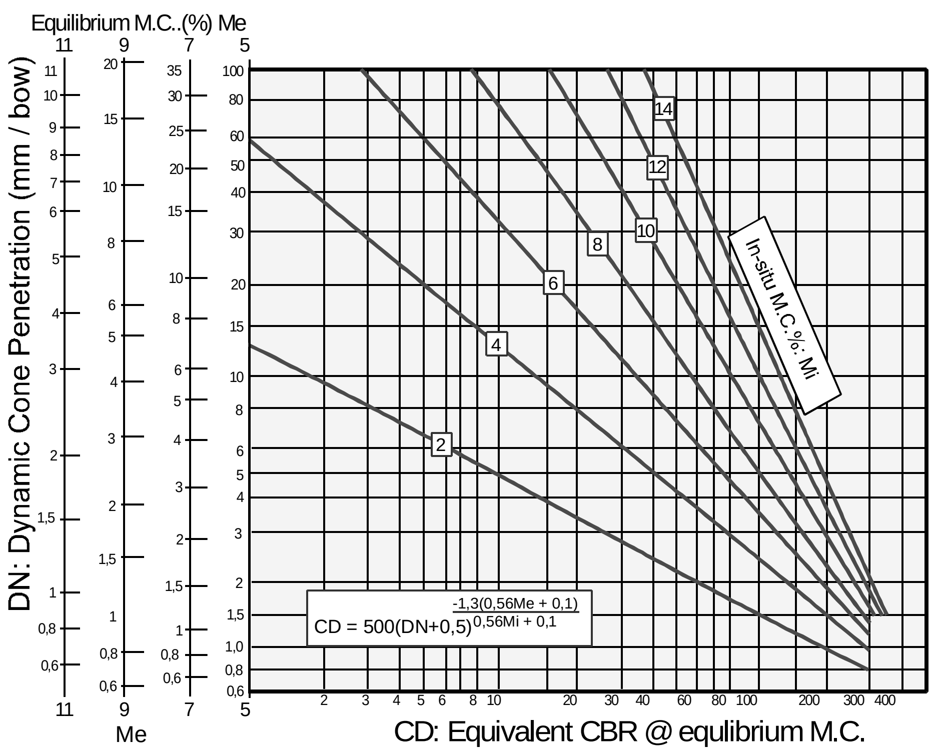


Figure 9: Conversion of DCP: (DN) to CBR (CD) for various in-situ and equilibrium moistures (%)

2.5. Application Options

The condition of the existing road and the nature of the traffic may dictate the type of any application of the CON-AID of which there are two alternatives. One is the one most commonly used when the road is new or has very little traffic. The surface to be treated is scarified; the CON-AID applied by bowser mixed in by discing and subsequently compacted.

The alternative method is the spray-on technique where the CON-AID treated water is applied piece-meal by successive applications onto the existing surface, which is not scarified. This method is generally used when the road surface is reasonable good and traffic cannot readily be diverted.

2.6. Quantities for CON-AID

The recommended rate of application of CON-AID made by the Head Office in Johannesburg after soil testing is based on the P_{425} material and the actual field application rate per square metre for a 150 mm compacted layer must be obtained by a reduction of the recommended rate as the percent of soil less than 0,425 mm in diameter necessitates this reduction. The relationship between the recommended rate and the field application rate is given in Figure 4, which incorporates the P_{425} fraction of the soil.

When the width and length of any section of the road has been decided the actual quantity of the CON-AID to be spread is then calculated. Because the quantity is relatively small for a large area the additive is diluted with water at a ratio of 1 litre of CON-AID to 250 to 500 litre of water depending on the existing moisture content of the soil. Alternatively a dilution of 1 : 250 may be adhered to throughout and untreated water applied if necessary for dry conditions.

3. CONSTRUCTION CONSIDERATIONS

It is not intended to detail here the methods employed in the normal construction of road works and the compaction of soils which is what is expected to be done to a lesser or greater extent when a CON-AID treated layer or layers are incorporated, but a few remarks are made here which the author feels are pertinent. His experiences where rural roads have been treated with CON-AID are that in many cases conventional methods of contractual work have not been properly applied. At the risk of "*teaching grandmother to suck eggs*" a few points are raised here which may be applied as and where the "*cap fits*".

3.1. Proper Documentation

Any Contractor required to upgrade a road vis-à-vis drainage layer work etc must have clarity in respect of the following:

3.1.1. Design drawings approved by the Roads Authority.
3.1.2. Clear instructions (specifications) as to what and where work is required.
3.1.3. A priced Schedule of Quantities.

The design may be done by the Contractor himself on a Design and Construct basis, but it is essential that such design be approved by all parties before the work commences. A Contractor must not be expected to work in the dark (as a result of insufficient documentation) and then be blamed or held liable for correcting work that is found to be unacceptable.

3.2. Compaction Moisture

Instructions to compact a soil layer at a certain moisture content related to Optimum Moisture content are quite unacceptable. The OMC is a moisture content obtained in the laboratory to produce a maximum density for a given effort (Modified or Proctor say). This moisture content being the extent of lubrication required for the method used in the laboratory has no connection with the field density and plant used by the Contractor. A heavy vibrating roller requires far less moisture for lubrication than a static roller and the Field Compaction Moisture Content (FCMC) should be left to the Contractor to suit his machines and the density required.

When CON-AID treatment is applied an over application of water by spraying or rain is desirable before compaction, but the moisture content will then in general be far too high for compaction. A super saturated condition is beneficial for the CON-AID to become active but should be allowed to dry out to Field Compaction Moisture Content before attempting to compact.

3.3. Density Requirements

The compacted density of layers treated with CON-AID need not be compacted to unnecessarily high requirements and the following general values may apply when laying down specified densities:

Material	% Modified AASHTO	% Proctor AASHTO
Base Quality gravel	95	100
Sub base quality gravel	93	97
In-situ Loam	90	94

It should be borne in mind that further densification will take place for treated soils or gravels under traffic action.

3.4. Supervision

Supervision should be performed by suitably qualified personnel who are made fully aware of the type of work required. It must be clearly understood by all parties that the rural road with very little traffic does not demand the same standards of finish or tolerance that would apply to a freeway for example. Proper drainage is however, essential and the following quotation must never be overlooked:

"A road can only be as good as its drainage will allow it to be".

The author is strongly apposed to the practise of nit-picking and condemning work that is unacceptable due to conditions outside the Contractor's control. If funds are short do not expect the Contractor to pay for work at his expense. Reduce the extent of the road length if need be. However, do not reduce standards accepted for the road concerned.

4. POST CONSTRCUTION CONSIDERATION

It must be clearly understood that immediately after a treated layer is compacted it will behave exactly as if no CON-AID had been added. At this stage the CON-AID has hardly reached any of the clay present. If the treated layer should get wet at this stage due to rain or any other cause it will exhibit only a wet strength, which is very much less than its dry strength particularly if it is an in-situ soil and not gravel.

4.1. Maturation Stage

When a road foundation layer is kept dry as a result of an overlying layer of surfacing it will exhibit a "*dry*" strength, which under the action of traffic will gradually improve due to further densification. If however, the layer is not covered and forms a surface layer it may become wetted up during rainy conditions and a drop in strength will occur i.e. the layer will now have a "*wet*" strength. This Dry-Wet strength differential will be reasonably large just after compaction of the layer, particularly so if it is an in-situ clayey soil. This stage is the start of the maturation phase during which the CON-AID travels to the clay within the soil, which gradually becomes more and more hydrophobic in nature. Towards the end of the maturation phase, when most of the clay has been reached by the CON-AID the Dry-Wet strength differential is markedly reduced (See Figure 10).

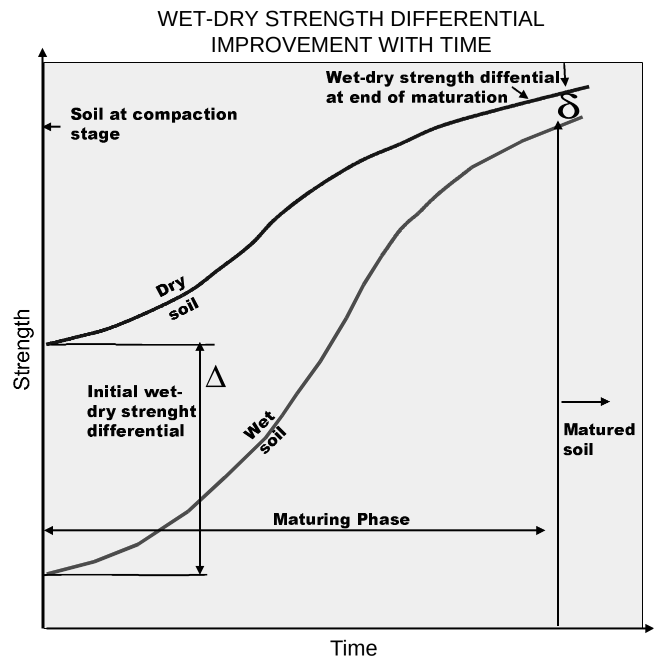


Figure 10: Example of the reduction of the Dry-wet strength differential during the Maturation period after CON-AID treatment.

4.2. Significance of the Dry-Wet Strength Differential

If the treated layer is to be covered up by a further layer, this may be done as soon as convenient. Just as one would place an extra layer on top of a compacted one like building up a fill for example. The covering of the layer will ensure that a reasonable dry strength is maintained and maturation will proceed unhindered.

A surface, which is not covered, requires special treatment, especially if it is not a gravel, but a soil with a large Dry-Wet strength differential. Let us not forget that at the early stages of the maturation phase all treated materials behave as if untreated. When dry even a clayey soil may be opened to traffic without distortion, but should it get wet, it will distort badly, become slippery and need reshaping or even covering up in order to present a negotiable surface.

A gravel layer will not distort so severely when wet, but will ravel and corrugate when dry. Thus regular reshaping, certainly at the early stage will be required. Failure to restore the surface to a smooth finish may result in corrugations, ruts and gullies in the hardened surface when maturation is virtually complete. Reshaping by grading at this stage is often not possible without scarifying and re-compacting.

4.3. How Long for Maturation?

The length of the maturation period depends on several factors:

4.3.1. The type of clay present. Kaolinite clays mature faster than Montmorillonitic or Smectitic clays.

4.3.2. The quantity of clay present. Two soils of the same clay type will show different maturation ageing. The higher the clay contents the longer the maturation phase.

4.3.3. The extent of the traffic. Further densification occurs under traffic, therefore the more traffic the shorter the maturation.

4.3.4. The Climate. Alternate wetting and drying is the ideal condition. As CON-AID removes the adsorbed or ionic water surrounding the clay particles the soil must dry out. However, if the drying out is too rapid the maturation stops as water is needed to carry the CON-AID to the clay particles. Thus a reasonable moist condition not too wet and not too dry is ideal. This would be the case where a layer is covered by another but sealing a top layer at an early stage with a seal coat or surfacings is not recommended, as distortion correction can now no longer be applied.

In general regular DCP tests properly performed will indicate when the maturation phase is ending as the wet strength will begin to show a strong approach to the that of the dry condition.

If surfacing of the layer is considered it should only be applied when the stability at in-situ Moisture Content has reached an acceptable value.

4.4. Monitoring

Post construction testing of a treated layer is all too often sadly neglected, but it is only as a result of regular monitoring of such layers that any form of data bank and records can be prepared. It is thus strongly recommended that tests on treated layers be done at reasonable intervals over a period of at least one or two years. A suggested time of testing may be at 1; 2; 4; 7; 12; 18 and 24 months after compaction. The tests to be conducted at each test position should be:

4.4.1. DCP to a depth of at least 600 mm.

4.4.2. Moisture Contents of upper and lower layers.

4.4.3. Density tests if possible.

If the DCP results are related to moisture content the graph in Figure 9 may be used to estimate a CBR value at specified common or equilibrium moisture content

4.5. Maintenance

Maintenance may be divided into two portions:

4.5.1. The road surface

4.5.2. The drainage

The author is strongly in favour of maintenance by contract. This ensures that it will generally not be neglected, which unfortunately is all too often the case.

Surface maintenance generally requires heavy plant and transport, but drainage maintenance can be achieved readily by hand labour and local villages may be recruited to participate in work of this nature. Local villagers are best placed to notice where existing drainage may fall short and could constantly improve the system by being "*on site*". By encouraging an interest in their own rural road the local population will begin to realise that this medium will move greatly towards relieving their poverty by opening up new markets and improving communication.

5. CONCLUSION

It is the authors sincere wish that when a road network betterment is envisaged particularly the rural road that careful consideration be given to such matters as are described above, to thereby ensure that even if all items are not necessarily fulfilled work that is undertaken will be a future asset which is not placed in jeopardy because some important item was overlooked, neglected or not done properly.

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