THE DEVELOPMENT OF A RESEARCH PROTOCOL AND FIT-FOR-PURPOSE CERTIFICATION FOR ROAD ADDITIVES

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ABSTRACT

Chemical stabilizers and dust palliatives are used in road construction and maintenance to improve the characteristics and performance of available materials in terms of lower dust levels, improved riding quality, reduced gravel loss and improved all-weather passability. Numerous products are currently available to the road industry. However, the level of research and usefulness of the findings differs from product category to product category. In many instances, no effort has been made to quantify the benefits and cost-effectiveness of additives over longer periods of time (eg five years) and little attempt has been made to compare the performance of treated roads with untreated roads in terms of reduced gravel loss and reduced maintenance - the two most important factors in unsealed road management. Only limited information on material requirements and application techniques is available, while there is minimal information on rejuvenation.

This lack of understanding has culminated in general scepticism in the roads industry regarding chemical dust control and stabilization with so called "alternative stabilizers". The situation is aggravated by poor marketing, with many sales representatives having no engineering background, little understanding of the roads industry and insufficient information to provide adequate technical backup.

Discussions with road authorities and consulting engineers indicated that a "fit-for-purpose" certificate for each product, issued by an independent certification body and justified by following a comprehensive research protocol, would contribute to confidence in the use of the products. A research protocol for the assessment of road additives, entailing a product description, categorisation, laboratory screening, laboratory environmental and performance testing, field-testing, data analysis and guideline preparation has since been developed. A certification body in South Africa has been approached with regard to developing a certification system, which is currently being finalised under the guidance of a steering committee with representation from road authorities, consulting engineers, product suppliers and academia.

In this paper, the development of a research protocol and fit-for-purpose certification for road additives is discussed.

INTRODUCTION

There are millions of kilometres of unsealed roads in the world, managed by numerous different road authorities. Unacceptable levels of dust and poor passability are experienced on many of these roads, especially those in and providing access to rural and urban communities.

Over the last 25 years, numerous chemical dust palliatives and stabilizers have been introduced to the road industry, which suppliers claim will reduce both dust and maintenance on unsealed roads. The level of research, protocols followed and usefulness of the findings differs from product category to product category, making it difficult to compare products. In all of these investigations, including those undertaken by road authorities, the methodology mostly entails an ad hoc laboratory investigation, usually on one material type using standard laboratory tests (which were not developed for treated materials), followed by a field trial. This is usually done on one road, which is subjectively monitored until dust suppression is no longer effective or the road becomes impassable, with rejuvenation and modified maintenance requirements and techniques not being considered. Reporting is based on the observations made, the recommendations and conclusions are usually applicable only to the road and environment on which the experiment was conducted, and very little, if any, scientific interpretation of the results is provided (ie what attribute caused failure or led to success). In many instances, failures that could have been related to incorrect application or construction techniques or to application on unsuitable materials were attributed to poor performance of the product.

No effort has been made to quantify the benefits and cost-effectiveness of additives over longer periods of time (eg five years) and little attempt has been made to compare the performance of treated roads with untreated roads in terms of reduced dust levels, gravel loss and maintenance and improved passability - the most important factors in unsealed road management. Only limited information on material requirements and application techniques is available, while there is minimal information on rejuvenation.

This lack of understanding has resulted in general scepticism in the roads industry regarding chemical dust control and stabilization. The situation is often aggravated by poor marketing, with many sales representatives having no engineering background, little understanding of the roads industry and insufficient information to provide adequate technical backup.

Research by many practitioners around the world has, however, shown that, if correctly used, many additives can provide a cost-effective road maintenance alternative. Discussions with road authorities and consulting engineers in southern Africa indicated that conformance to a testing protocol to facilitate product comparisons and a "fit-for-purpose" certificate for each product, issued by an independent certification body, would facilitate decision making and contribute to confidence in the use of the products. A certification system would also encourage suppliers to conduct appropriate product research. Agrément - South Africa, an independent internationally recognised certification organisation, was approached with regard to developing such a certification system for southern Africa.

RESEARCH PROTOCOL FOR ROAD ADDITIVES

Extensive research into chemical dust control and stabilization has been undertaken in numerous countries since the 1930's[1]. Despite the large number of resultant publications, there are still no comprehensive guidelines for selection of the most suitable additive or for undertaking economic analyses to determine whether the additive would be cost-effective. No standard protocol for testing road additives has been followed to present this information in a suitable format[2,3,4,5,6].

In order to overcome this, a standard protocol for conducting research into road additives has been formulated[1]. This protocol was developed during the course of research into the use of various dust palliatives (primarily calcium chloride). The research protocol is illustrated in **Figure 1** and is applied as follows:

i. An additive investigation begins with defining the chemistry of the palliative and hence the mode of binding.
ii. With this information, the additive should be classified into one of the following categories:

- Dust palliatives
  - Water and wetting agents
  - Hygroscopic salts (eg calcium, magnesium or sodium chloride)
  - Natural polymers (eg lignosulphonate, molasses, tannin extracts)
  - Synthetic polymer emulsions (eg acrylate, polyvinyl acetate, polyvinyl chlorate)
  - Modified waxes
  - Petroleum resins
  - Tars and bitumens (eg prime, bitumen emulsion, cutback bitumen)
  - Other

- Stabilizers
    - Synthetic polymer emulsions (eg acrylate, polyvinyl acetate, polyvinyl chlorate)
    - Sulphonated oils
    - Enzymes and biological agents
    - Tars and bitumens (eg prime, bitumen emulsion, cutback bitumen)

iii. The literature on this category should be reviewed to establish the status of research already carried out on that additive category in general and specifically on additives with the particular characteristics of the one being investigated. A report, in which the information is synthesised, should be prepared.

iv. Based on the information available, a decision is made as to whether sufficient information exists to prepare comprehensive guidelines on the use of the additive in line with the requirements of the road industry.

v. If sufficient information is available, a guideline consisting of information on the additive, economic analyses, material selection, climatic limitations, environmental limitations, best construction practice, application, maintenance, rejuvenation and road upgrading is prepared. A commercial development protocol will then replace the technology development protocol with introduction to industry. Technological assistance may be provided with implementation of programmes using the additive.

vi. If insufficient information is available to prepare the guidelines (see iv), an iterative process is implemented to acquire the required information. This begins with an assessment of the results of past laboratory testing. Results from a testing programme that has followed a formal experimental design should exist and be sufficiently comprehensive to form the basis of an experimental design for full-scale field-testing and an interim material selection guideline. If this information is already available, information on full-scale field-testing is assessed. If the review indicates that a monitoring programme on roads selected according to a factorial experimental design has provided sufficient information to prepare performance prediction models and guidelines for use, then the process can proceed in this direction (see xii). If insufficient data is available, then a field-testing programme will have to be initiated (see xi below). If no laboratory test results are available, then it would be obvious that minimal research had been undertaken on the additive and that a comprehensive study would need to be undertaken before it could be used with confidence. If there is any doubt about the effectiveness of the additive, a laboratory screening exercise, involving simple abrasion, erosion and/or strength tests using a single material is required. Different application rates can be used to determine the effectiveness of the additive. The durability and/or strength of the treated specimen is compared with that of an untreated control specimen. If the treated specimen does not withstand the abrasion or exhibit sufficiently increased strength, the research programme should be terminated and the additive subjected to further development. A summary report is completed at the end of this phase.

vii. If the treated specimen proves to be durable, a detailed laboratory study, assessing both performance and potential environmental impact, is carried out. In the performance assessment, materials with varying plasticity characteristics should be tested to determine the influence of the additive on particle size distribution (ability to agglomerate fine particles), plasticity (ability to reduce plasticity and hence slipperiness), maximum dry density and optimum moisture content (ability to act as a compaction aid), California Bearing Ratio or Unconfined Compressive Strength (ability to improve strength and hence passability) and durability (ability to resist abrasion and erosion). In the environmental compatibility assessment, the potential impact of treatment on water resources and vegetation is determined. If there is no improvement in any of the above parameters when compared with the results of tests on untreated material, or if potential environmental impacts are high, the research should be terminated and the additive returned for further development. A summary report is prepared on completion of testing with recommendations on proceeding with or terminating the study.

viii. If the results are acceptable, an experimental design for field testing should be developed with emphasis on experimental sections on roads with material characteristics in a range most suited to the additive, based on the laboratory test results. The application of the additive and thereafter its performance compared with that of an untreated control section constructed to the same specification should be monitored. Monitoring should include a visual assessment, using standardised criteria[8] and measurements of dust, riding quality, rate of gravel loss and in situ strength in wet and dry states. The additive should be rejuvenated and the road maintained as required. A detailed account of all costs incurred on the treated and untreated sections should be kept. Once sufficient data has been collected to reliably estimate the behaviour and performance of the road and the number of rejuvenations over a period of five years, the field studies can be halted.

ix. The data collected should be analysed to determine the cost-effectiveness of the additive compared with traditional maintenance techniques, bearing in mind that the construction and maintenance of short sections is more expensive than conventional construction. If the additive is not cost-effective under any circumstances, the study should be terminated.

x. If the additive proves to be cost-effective, specialised testing to determine potential impacts associated with upgrading the road to a higher standard (eg potential salt damage to bituminous surfacings) should be carried out, if deemed necessary, to assess whether the additive can be used in a long-term stage construction process.

xi. The final phases of the protocol entail the preparation of a guideline document on the use of the additive, fit-for-purpose certification and technology transfer to industry.

This research protocol has been successfully followed in investigations into calcium chloride[9], lignosulphonate[10] and various synthetic polymer emulsions.

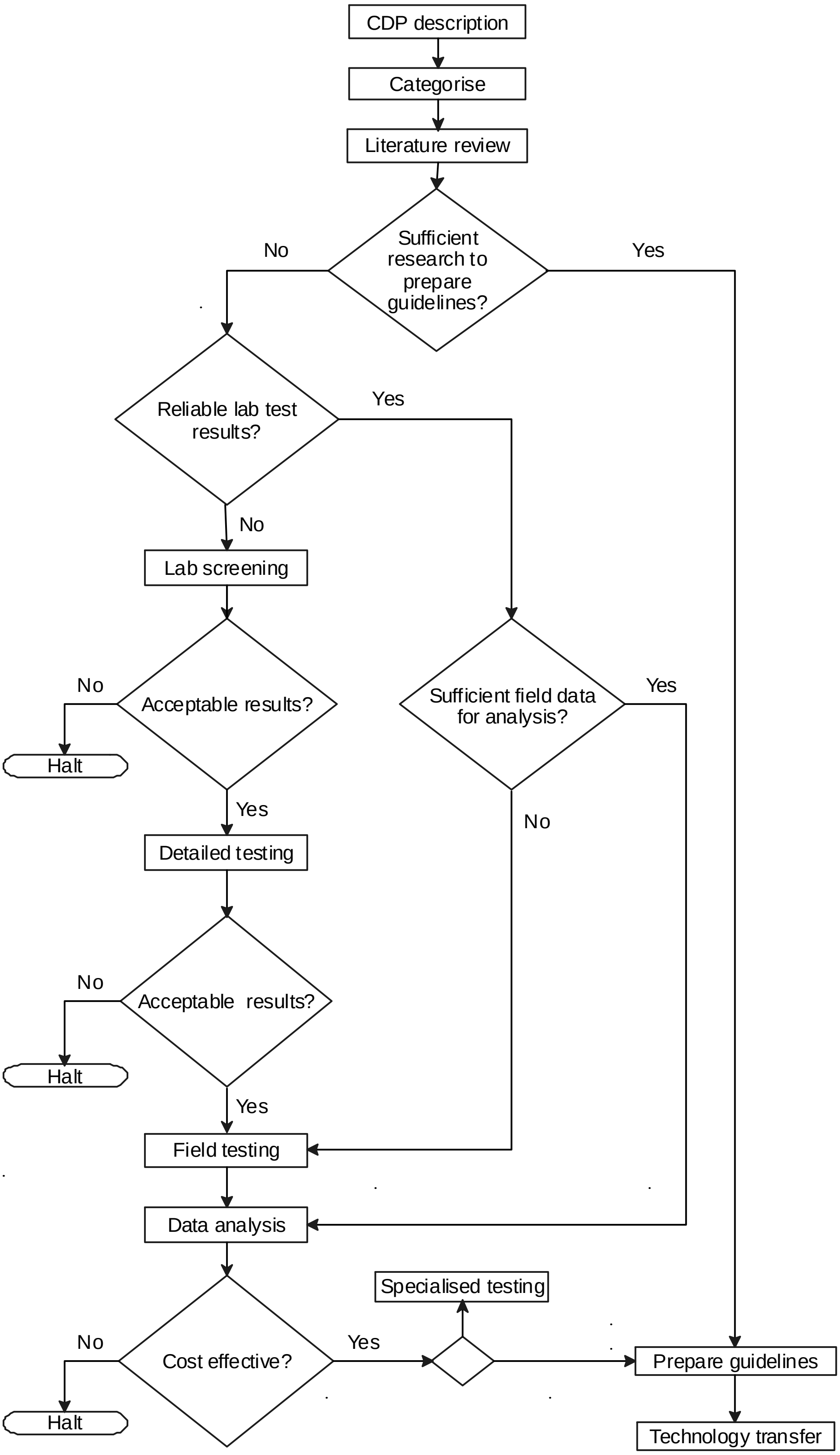

Figure 1 Research protocol for road additives.
(CDP = Chemical dust palliative)

FIT FOR PURPOSE CERITIFICATION

Fit-for-purpose certification facilitates owners of new technologies in introducing their products into the industry. It provides potential users with a scientifically sound basis for their decisions on whether or not the product would be fit for its envisaged purpose in terms of product characteristics, benefits and limitations. Other benefits include[11]:

- The standing of a certificate would be similar to that issued by a standards organisation
- Marketing costs are reduced as the assurance of fitness-for-purpose saves valuable selling time
- Certification assures the customer that an approved quality management system has been implemented
- The value of a certificated product is enhanced by additional data revealed during the assessment programme

Fitness-for-purpose can be expressed in terms of functional performance, constructability, maintenance requirements, safety aspects and/or environmental characteristics. The role of the certification body entails:

- Assessing the fitness-of-use of innovative, non-standardised products on the basis of scientific and practical knowledge
- Taking impartial decisions in relation to the interest of the manufacturer concerned or their agents
- Collating the contributions of all of the interested parties in a balanced assessment of the product

The certificate usually includes the following:

- Part 1: Producer's description of the product
- Part 2: Assessment of the product and description of its characteristics
- Part 3: Statement by the certification body

CRITERIA FOR CERITIFICATION

Once additive suppliers have conducted detailed background research and guideline documentation is available, some form of control testing will still be necessary before a fit-for-purpose certificate can be issued by the certification body with confidence. Based on previous research and discussions with road authorities and consulting engineers, the following criteria were considered important for control testing[11]:

- Resistance to abrasion (effect of traffic and wind on treated surfaces)
- Resistance to erosion
- Resistance to leaching
- Increased shear strength (all weather passability)
- Long-term durability
- Maintainability

Resistance to abrasion, erosion and leaching and increased shear strength would need to be correlated with the rate of gravel loss, riding quality deterioration and all weather passability improvements in terms of unsealed road performance. Their compliance with specifications for stabilized pavement layers for sealed roads, to allow practitioners to compare the costs and benefits of a treatment with those of the existing unsealed road or with the use of a traditional stabilizer such as cement, lime or bitumen emulsion should be assessed. Long-term durability and maintainability (ie can the road be maintained using traditional unsealed road maintenance techniques), although related to abrasion resistance, can generally only be assessed under full-scale field trials and would need to be established from documented results in terms of the protocol described above.

CONTROL TEST DEVELOPMENT

Assessment of Existing Test Methods

The only known formalised procedures for assessing chemical stabilizers in South Africa are those prescribed in the Technical Recommendations for Highways series[12] for pozzolanic stabilizers and the ASTM standard guide for evaluating the effectiveness of chemicals for soil stabilization[13], which assesses the influence of the stabilizer on particle size distribution, plasticity and strength, but not abrasion. Neither of these testing programmes was considered suitable for control testing for fit-for-purpose certification. The following individual tests were thus identified as being potentially suitable as components of a suite of tests for controlling road additives:

- Agglomeration
    - Sieve analysis

    - Wet and dry durability tests
- Resistance to abrasion
    - Wet and dry durability tests
    - Pellet abrasion tests
    - Wheel tracking tests
    - Wind tunnel tests
- Resistance to erosion
    - None
- Strength increase
    - California Bearing Ratio (CBR)
    - Unconfined compressive strength (UCS)

Each of these tests was reviewed and in some instances, methodologies were modified to suit the evaluation of treated materials. Pilot testing was carried out and results compared with field performance. On completion of this evaluation, none of the agglomeration or abrasion resistance tests was considered suitable for control testing for fit-for-purpose certification. The CBR and UCS tests were considered suitable, with modification, for assessing strength improvement. Two new tests were therefore developed to assess abrasion and erosion resistance.

Abrasion Resistance

From the review of existing test methods, some form of brushing test was considered most suitable for assessing agglomeration and resistance to abrasion. The adaptation of the existing modified wet-dry durability test[14] was therefore explored. This test was originally developed to determine the durability of cement and lime stabilized subbase and base materials. Since the stabilization mechanism and strength of the stabilized materials differs significantly from the effects of commonly used road additives, only the basic principles of the test (ie mechanical brushing of a compacted specimen) were retained. A number of issues therefore had to be considered during the development of an appropriate control test for certification, which, in essence, needed to simulate tyre abrasion of agglomerated particles. Criteria for a number of issues needed to be established before the test method itself could be developed. Extensive testing was carried out to assess these issues[1], from which the following recommendations are made:

- Test material characteristics
    - Maximum size: 4.75 mm
    - Per cent passing 0.075 mm: 20 - 30
    - Plasticity index: slightly plastic - 4%
    - Building sand sourced from a building supplier will typically meet this specification. It is also readily available, which is important when considering wider use of the test and problems associated with sourcing a suitable material from borrow pits. If necessary, the sand can be blended with a small percentage of clay to achieve the required properties.
- Specimen size, method of compaction and degree of compaction
    - Specimen size: 100 mm diameter x 115 mm high
    - Compaction method: static (hydraulic press)
    - Compacted to: 95 per cent of Mod AASHTO density
- Curing/conditioning
    - Hygroscopic salts: Dry to constant mass at 50°C. Allow to reabsorb atmospheric moisture for 24 hours in an environment with a temperature of at least 25°C and relative humidity of at least 50 per cent.
    - Natural polymers: Dry to constant mass at 50°C.
    - Synthetic polymers: Dry to constant mass at 50°C.
    - Modified waxes: Dry to constant mass at a temperature 5°C below the congealing point of the wax.
    - Petroleum resins: Dry to constant mass at 50°C.
    - Tars and bitumens: Dry to constant mass at 50°C
    - Sulphonated oils Dry to constant mass at 50°C
    - Enzymes Dry to constant mass at 50°C
- Cycling
    - None
- Testing
    - The treated and untreated specimens should each be weighed and then subjected to 250 revolutions with a brush loading of 2.0 kg. The brushed specimens are then weighed and the mass loss recorded as a percentage of the original dry mass. Treated specimens should then be subjected to a further 250 revolutions before final weighing and determination of percentage mass loss.

- Notes - the test material should be used for control testing for certification purposes to facilitate comparison of different products over time. However, the test method can be used on any material to assess an additive for a specific road.

Brushed specimens with various treatments are illustrated in **Figure 2**. The proposed test method is included at the end of the paper.

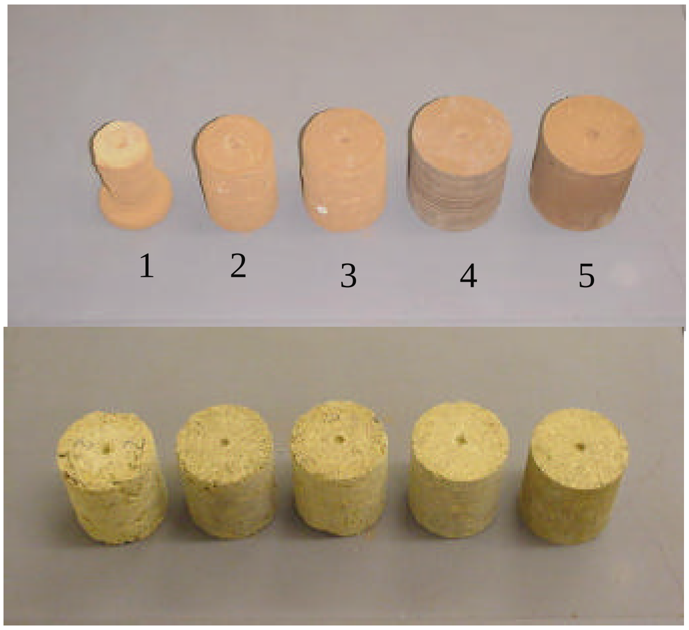

Figure 2 Sand (top) and shale (bottom) specimens treated with natural polymer after 250 revolutions. (1 - control, 2 - 0.25 kg/m^2, 3 - 0.5 kg/m^2, 4 - 1.0 kg/m^2, 5 - unbrushed)

Erosion Resistance

No suitable erosion resistance test could be found in the literature and one was therefore developed to suit the requirements of fit-for-purpose certification of road additives.

An apparatus, which allowed water to flow over a prepared specimen at a constant rate, was required to simulate water flow over a compacted road. The apparatus was designed around the specimen used in the abrasion resistance test in such a way that specimens could be easily placed and secured without damage. The apparatus was designed to fit into a laboratory sink at an angle of 35° to allow for the runoff of water and soil. The apparatus is illustrated in **Figure 3**.

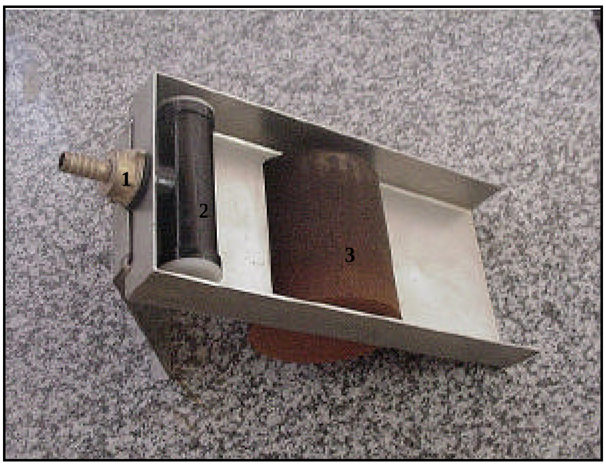

Figure 3 Erosion resistance testing apparatus. (1 - water inlet, 2 - water jets, 3 - specimen)

Criteria for a number of issues needed to be established before the test method itself could be developed. Extensive testing was carried out to assess these issues [11], from which the following recommendations are made:

- Specimen
  - Same as that for abrasion resistance
- Configuration
  - Number of jets 9
  - Jet spacing 10 mm
  - Jet size 1.0 mm
  - Water delivery Constant head (height 1.0 m)
- Testing
  - The treated and untreated specimens should each be weighed, clamped into the apparatus and then subjected to water spraying for a period of exactly 5 minutes. Specimens should then be removed, placed on a pan and dried for 24 hours in an oven set at 105°C and then reweighed. Mass loss should be determined as a percentage of the original dry mass.

Strength Improvement

The unconfined compressive strength test (UCS) and California Bearing Ratio (CBR) tests were selected for assessing strength improvement in line with standard procedures for assessing stabilized materials. However, the procedure for preparing specimens was changed as follows to bring the test in line with the erosion and abrasion resistance tests and obtain more repeatable results:

Criteria for a number of issues needed to be established before the test method itself could be developed. Extensive testing was carried out to assess these issues [11], from which the following recommendations are made:

- Specimen
  - Material 1 - same as that for abrasion resistance
  - Material 2 - clay/sand blend with PI of 12 - 15%, CBR of 5 - 10% and OMC of 12 - 15%.
- Curing and soaking
  - UCS - curing as per other tests, 2 hour soak
  - CBR - curing as per other tests, 48 hour soak
- Testing
  - As per standard test methods[15]

Tentative Limits

Tentative limits for the above three tests were defined based on the results of testing of a variety of materials, selected according to a factorial experimental design, based on material type and plasticity. A second round of testing which involved comparison of the results of the tests on treated and untreated specimens with field performance data collected from various experiments that had been carried out previously or were ongoing followed the first round of testing to further verify the limits. Data from experiments with the following four dust palliative categories were used to develop these limits:

- Hygroscopic salt (HS) (calcium chloride - 34% solution)
- Natural polymer (NP) (lignosulphonate)
- Synthetic polymer emulsion (SP) (acrylate)
- Petroleum resin (PR)

Abrasion Resistance

The optimal application rate and the rates at which acceptable, average and unacceptable performance respectively could be expected for each product were determined from field test data[1]. Specimens were then tested at these application rates to establish a pattern of performance for each product. The limits for abrasion resistance need to be relatively stringent since the purpose of incorporating control testing is to provide an indication of expected performance.

Recommendation: based on the results obtained, the tentative limit for acceptance/rejection was arbitrarily set at 10 per cent mass loss. If necessary, application rates could be increased in order for an additive to meet this limit, although this would result in an increase in the cost of treatment. These limits are considered as tentative and could be adjusted, if necessary, when additional performance data have been collected and the limit can be finalised.

Erosion Resistance
Detailed comparisons of erosion resistance of treated roads with the results of the erosion resistance test in the laboratory are currently being carried out. Based on the testing described above, a maximum permissible loss of 10 per cent is tentatively proposed until additional performance data have been collected and the limit can be finalised.

Strength Improvement
Numerous experiments have been carried out to relate material strength to passability[16]. The South African unsealed road specification[17] addresses passability by requiring a minimum soaked CBR at 95 per cent Mod AASHTO compaction of 15 per cent. On mine and forest haul roads, or roads when high numbers of trucks are common, the figure is often raised (typically 45 per cent) to ensure passability during prolonged rainfall. The minimum CBR for upgrading an unsealed road to low volume sealed standard is usually set at 45 per cent (UCS of about 0.4 MPa).

In the UCS testing described above, only the synthetic polymer at an application rate of 1.0 l/m2 strengthened the specimens to a degree that they could be crushed. The materials with other treatments disintegrated before the 120 minute soak had elapsed. In CBR testing, synthetic polymers, sulphonated oils and enzymes raised the CBR of the material by varying degrees. Based on observations of field trials, hygroscopic salts and natural polymers do not offer any "waterproofing" of road gravels. Synthetic polymers, sulphonated oils and enzymes have improved passability in the short term to some extent, with effectiveness dependent on the material characteristics. Disintegration time in the UCS therefore appears to be a good indicator of the degree of waterproofing. However, insufficient data is available to set limits that could be used with confidence to predict whether a road will become impassable.

Recommendation: If a product is marketed as a strength improver or stabilizer, its addition to marginal materials (ie those not meeting a specification) should increase the strength to above the minimum relevant specification (ie it should raise the CBR of unsealed road materials to at least 25 per cent, materials that will be used for upgrading unsealed roads to sealed standard to at least 45 or 80 per cent) depending on the design. Alternatively, a minimum UCS of 0.75 MPa can be specified in line with the minimum requirements for a cement or lime treated subbase or base[12].

RECOMMENDED PROCEDURE FOR CERTIFICATION

Based on extensive experience of testing unsealed road additives and discussions with road authorities and consulting engineers, the following procedure for fit-for-purpose certification of road additives is recommended (**Figure 4**):

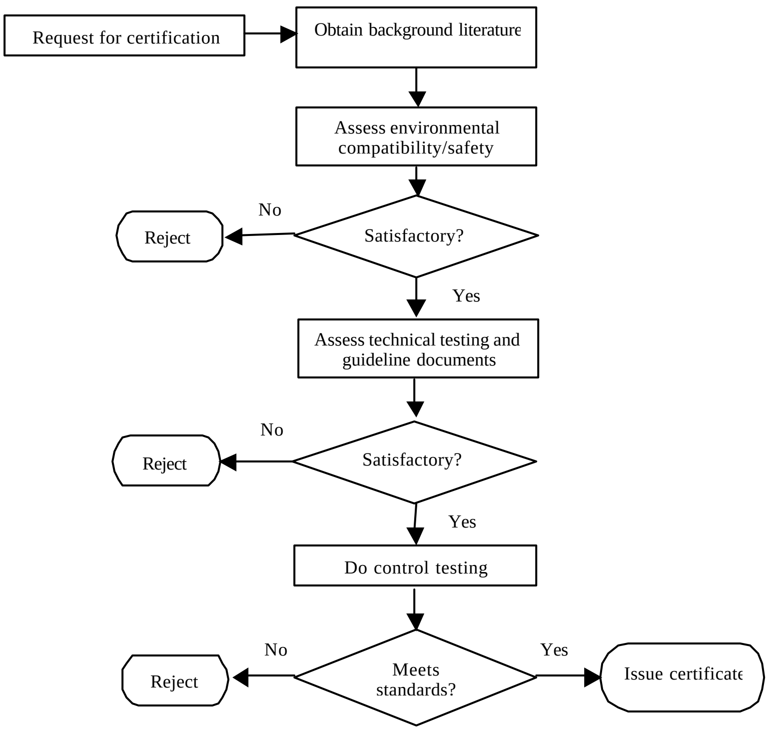

Figure 4 Recommended certification procedure.

Table 1 Checklist for additive documentation assessment.

Issue	Yes	No	Comments
Is product development complete?			
Is there proof of successful use?			
Have comprehensive guideline documents been compiled?			
Has a documented comprehensive, scientifically designed laboratory-testing programme been carried out?			
Has a documented comprehensive, scientifically designed and monitored field-testing programme been carried out?			
Have potential environmental and safety impacts been assessed?			
Are material selection and testing criteria compatible with SA specifications?			
Have climatic limitations been addressed?			
Are application, construction and maintenance procedures clear?			
Are maintenance and rejuvenation programmes provided and explained?			
Are long-term performance prediction models provided for use in cost/benefit analyses?			
Does the manufacturer/supplier have a recognised quality control system in place?			

- Assess background documentation provided by applicants using a checklist (Table 1).
- Ensure that all environmental compatibility requirements are met and that a valid material safety data sheet is available
- Ensure that sufficient background research has been conducted and that appropriate guideline documentation describing the type of materials that can be treated, climate and traffic limitations, application and maintenance methods and performance characteristics is available.
- Do control testing (as per test method at end of paper) and compare the results with the proposed tentative limits to check that minimum requirements for abrasion and erosion resistance and shear strength are met. Review background documentation to assess long-term durability and maintainability.
- Issue certificate.

CONCLUSIONS

There is a clear need for additives to reduce dust, improve all weather passability and minimise maintenance requirements on unsealed road networks. There is also a role for stabilizers to improve marginal materials to the point that they can be used in upgrading unsealed roads to a low-volume sealed standard. However, suppliers of road additives can seldom provide sufficient information for road authorities and engineers to make a decision on the appropriate use of the products instead of using more conventional stabilizers in a more expensive design. The use of non-traditional additives is currently not covered in any detail in guideline documents used by the roads industry. The research undertaken by many suppliers on the performance of their products is often insufficient to prepare appropriate user guidelines or to predict the performance over time.

The development of a research protocol for road additives will ensure that appropriate research is carried out and that results will be comparable, thereby facilitating decision-making on the use of additives by road authorities and consulting engineers. A fit-for-purpose certification system would further ensure that appropriate research on additives is undertaken by product suppliers and would provide a measure of confidence in their use to road authorities and consulting engineers. A certificate would also allow road authority staff, who are regularly approached by additive suppliers, to decide on whom to meet. Suppliers without a certificate could simply be referred to the certification body.

REFERENCES

1. JONES, D. 2001. **Dust and dust control on unsealed roads**. PhD Thesis. University of the Witwatersrand. Johannesburg, SA.

2. FOLEY, G., Cropley, S. and Giummarra, G. 1996. **Road dust control techniques**. Melbourne, Australia: ARRB Transport Research. (Special Report 54).

3. BOLANDER, P. 1997. Chemical additives for dust control: what we have used and what we have learned. **Variable tire pressure, flowable fill, dust control and base and slope stabilization**. Washington, DC: Transportation Research Board. (Transportation Research Record, 1589).

4. BOLANDER, P. 1999. Laboratory testing of nontraditional additives for stabilization of roads and trail surfaces. **Proceedings 7th International Conference on Low-volume Roads**. Washington, DC: Transportation Research Board. (Transportation Research Record, 1652).

5. **Evaluation plan for the group evaluation of soil stabilization and dust suppression products**. 2000. Washington, DC: The Highway Innovative Technology Evaluation Centre (HITEC) and The Environmental Technology Evaluation Centre (EvTEC).

6. VOROBIEFF, G. 2001. **Personal communication**. Sydney, Australia: Australian Stabilisation Industry Association.

7. ANDREWS, R.C. 2001. Opportunities for improved unsealed road asset management with chemical stabilization. **Proceedings 20th ARRB Conference**. Melbourne, Australia: ARRB Transport Research.

8. JONES, D. and Paige-Green, P. 2000. **Draft TMH12 - Pavement Management Systems: Standard visual assessment manual for unsealed roads. Version 1**. Pretoria, SA: Transportek, CSIR. (Contract Report; CR-2000/66).

9. JONES, D. 2000. **User manual for the application of Roadtreat - 4th Revision**. Pretoria, SA: Tranmsportek, CSIR. (Contract Report; CR-2000/28).

10. JONES, D. 2000. **Interim guidelines on the of Dustex as a road additive - 2nd Revision**. Pretoria, SA: Transportek, CSIR. (Contract Report; CR-2000/50).

11. JONES, D. and Ventura, D.F.C. 2001. **Development of certification testing for unsealed road additives - Phase I and II**. Pretoria, SA: Transportek, CSIR. (Contract Report, CR2002/32.

12. **Cementitious stabilizers in road construction**. 1986. Pretoria, SA: Department of Transport. (Technical Recommendations for Highways. TRH13).

13. **Standard guide for evaluating effectiveness of chemicals for soil stabilization**. 1994. Annual Book of ASTM Standards. Philadelphia, PA: American Society for Testing and Materials. (Designation D4609-94).

14. SAMPSON, L.R. 1988. **Development of the mechanical wet/dry brushing test for the durability testing of stabilized materials**. Pretoria, SA: Transportek, CSIR. (Confidential Report C/DPVT/3.1).

15. **Standard methods of testing road construction materials**. 1986. Pretoria, SA: Department of Transport. (Technical Methods for Highways (TMH) No1).

16. PAIGE-GREEN, P and Bam, A. 1991. **Passability criteria for unpaved roads**. Pretoria, SA: Transportek, CSIR. (Research Report, RR-91/172).

17. **The design, construction and maintenance of unpaved roads**. 1990. Pretoria, SA: Department of Transport. (Technical Recommendations for Highways. TRH20).

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TEST METHOD

1 Scope

This method covers the determination of the resistance to abrasion and erosion and strength improvement of materials treated with dust palliatives.

2 Apparatus

1. Balance capable of weighing 5.0 kg having a sensitivity of 0.1 g
2. Standard drying oven capable of maintaining a temperature of 45°C (± 5 °C)
3. Compression testing machine (UCS press)
4. Soaking bath
5. 100 ml beaker
6. Spatulas, pans, etc
7. A steel mould having an inside diameter of 100 mm and 175 mm in length. Two endcaps 30 mm long and diameter that will fit snugly into the mould. These are pressed into the mould to form a specimen with the diameter of the mould and 115 mm in height.
8. A plunger used to extract the specimens from the moulds, which fits into a recess machined into the base of the endcap used as a base plate.
9. The apparatus required to determine the optimum moisture content and maximum dry density (OMC/MDD) as given in TMH1 test method A7[15].
10. A brushing apparatus as described in Sampson (1988)14 with a standard brush.
11. An erosion resistance testing apparatus as described in Section 5.4.2 of this report.
12. A stopwatch.

3 Method

1. Prepare the material to be tested using the prescribed procedure in TMH1 Methods A1(a) or A1 (b)[15], except that aggregate retained on the 13.2 mm sieve is discarded.
2. Determine the OMC at the proposed palliative content mixing the required percentage of chemical to the soil and testing the mix according to Method A7 in TMH1. It is advisable to add the required quantity of chemical to the water to be added to the sample as this will assist with the dispersion of the chemical throughout the soil.
3. Determine the mass of dry material required to fill the mould using data from (2).
4. Weigh the calculated quantity of chemical by pouring it into the tarred beaker and add the required amount of water to bring the material to OMC.
5. Add the contents of the beaker to the dry material and mix well. Cover the bowl with a moist cloth and let this stand for 30 minutes to allow the moisture to equilibrate throughout the soil. After this, remix the material.
6. Place the bottom end cap in the mould and fill the mould with the prepared material. Once all the material is in the mould put the top cap in place. It may be necessary to lightly tamp the material into the mould, as the loose material will have a volume that is greater than the mould volume.
7. Using the compression machine, press the top end cap into the mould until it is flush with the top of the mould.
8. Extrude the specimen from the mould, weigh it and place it on a carrying plate.
9. Dry/cure the specimen as prescribed by the product supplier. If the specimen must be dried back, place the specimen in an oven at a temperature of 50°C (± 5°C) until constant moisture content is reached (approximately 48 hours).
10. Remove from oven and allow to cool to room temperature.
11. Weigh the specimen and proceed to either 12, 13 or 14 below.
12. To determine the resistance to abrasion of the treated specimen, place the specimen in the mechanical brushing machine (brush weight set to 2.0 kg), place the brush on the specimen and brush for 500 revolutions. When placing the specimen in the brushing machine care must be taken not to damage it, as this will give erroneous results. On completion of the brushing weigh the specimen and record the amount of material lost as a percentage of the original dry weight (recorded in (11)).

13. To determine the erosion resistance of the specimen, clamp the specimen onto the erosion resistance testing apparatus using the strap and wing nuts provided. Place the erosion device into a sink and open the tap supplying water to the constant head apparatus (water container) so that water flows slowly out of the overflow pipe. Open the tap at the bottom of the water container (which is connected to the erosion device by a rubber hose), allowing water to be jetted onto the surface of the specimen. At the same time start the stopwatch. After five minutes have elapsed turn off first the tap to the erosion device and then the tap to the water container. Carefully remove the specimen from the erosion apparatus and place it onto a pan. Place the pan in the oven set at 105°C and allow to dry for 24 hours. Weigh the specimen and calculate the percentage mass lost.
14. To determine the unconfined compressive strength, place the specimen in a soaking bath for two hours (25 mm of water cover). Remove from the bath and surface dry with a paper towel. Weigh the specimen to determine the quantity of moisture absorbed. Place in a compression testing machine and load at an approximate rate of 100 N per second until failure. The load at failure must be recorded. It is advisable to take a small sample for moisture content determination.