A REASSESSMENT OF THE USE OF LIGNO SULPHONATE AS AN ADDITIVE FOR UNSEALED ROADS

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ABSTRACT

Ligno sulphonate has been widely used as a dust suppressant on unsealed roads in North America and Europe since the beginning of the century and research on its use there has been carried out over a period of time. However, much of this research was undertaken on by-product streams from pulping plants, without identification of the source plant species or process used to extract the lignin, both of which can influence performance in the road. In recent years comprehensive research has been carried out to find other uses for the product and it is now widely used as a concrete admixture, and for pelletising, oil-well drilling and other speciality markets. These markets require further processing, concentration or spray-drying of the product. As a result of this, a better quality product has been made available for use on roads. Previous research findings are therefore, in many instances, no longer relevant. In addition, potential users of the product now require far more detailed information in terms of performance and cost-effectiveness before they are willing to implement the use of the product on a wide scale.

At the request of the ligno sulphonate manufacturers in South Africa, a reassessment of the use of ligno sulphonate in unsealed roads was initiated. A detailed study of the literature was conducted and a State-of-the-art review prepared. This was followed by a comprehensive laboratory testing programme. Based on the laboratory results, a number of controlled experiments were constructed which are currently being monitored. To date, the investigation has found that the guidelines developed for the United States are generally inappropriate for the improved product, especially under local conditions. Interim guidelines for the use of the product have been compiled and monitoring and experimentation will continue in order to develop appropriate material, climatic, construction and rejuvenation guidelines for various material, climatic and traffic conditions. The interim guidelines are based on the performance-related material specification used for southern African unsealed roads, and include maximum size, grading, plasticity, strength and hardness parameters. Conservative interim performance prediction factors have been developed to enable economic analysis. Construction, maintenance and rejuvenation guidelines have been prepared for various application techniques.

INTRODUCTION

Most countries have an extensive network of unsealed roads, much of which is susceptible to the generation of unacceptable levels of dust under traffic. Control measures are increasingly being used to reduce this dust thereby reducing the rate of road surface material loss. The current emphasis on the provision of infrastructure in developing areas, the typical high maintenance costs of unsealed roads, together with increased public awareness of health and pollution problems, increased road user costs, and the unacceptable loss of surface fines, have led to greater awareness of the quality of unsealed roads and to the re-evaluation of current dust control management.

Apart from spraying of water, minimal dust palliation has been carried out on South African roads, with past work being restricted to a limited number of experimental sections. A detailed research project on calcium chloride, carried out over a number of years, resulted in the development of comprehensive guidelines and performance prediction models for that product. With this information, calcium chloride is being increasingly used as part of road maintenance programmes by a number of road authorities, forestry companies and mining houses. However, calcium chloride has a number of limitations in terms of material compatibility and minimum humidity levels and a product that would compliment it was therefore sought. Although there are numerous products available in South Africa, comprehensive specifications of their properties or records of their performance are not available. Ligno sulphonate was identified as a suitable product (in terms of cost, availability and expected performance) to complement calcium chloride and a comprehensive investigation was initiated.

This paper provides a background on the use of ligno sulphonate in roads and details the new research that has been undertaken. Interim guidelines on the use of the product are summarised.

BACKGROUND

Product

Lignin, a natural polymer, is a major component of wood. It imparts rigidity to the cell walls and acts as a binder between the wood cells creating a composite material that is resistant to impact, compression and bending. Ligno sulphonate is produced as part of a chemical wood pulping process when the cellulose and lignin are separated. The binding action of ligno sulphonate is both chemical and physical in nature and results from intermolecular forces between the sulphonated lignin molecules on the surface of the particles being bonded. Depending on the supplier, ligno sulphonate is available in either powder or liquid form.

Use

Ligno sulphonate based products have been used as dust palliatives and surface stabilisers in many northern hemisphere countries for a number of decades. However, its use on roads in the southern hemisphere has been limited. International research (mostly in the USA and Europe) has been carried out on the use of the product, and this information has formed the basis of current research into the use of ligno sulphonate in southern Africa. However, the manufacturing process, lignin characteristics and product properties are rarely clarified in the literature, all of which influence performance in the road.

The first recorded application of ligno sulphonate on a road was in 1916 when it was used as a dust palliative on a gravel road in Sweden[1]. It has been extensively used in the United States since the late 1940's as a dust palliative and surface stabilising agent for unsealed roads and, in certain instances, for base courses for sealed roads. It has also been used in Canada for similar purposes and for controlling frost heave[2-7]. In the Sahara, French engineers have used ligno sulphonate in powder form for base stabilisation during the construction of bitumen-surfaced roads, since even small amounts were found to have good binding properties under dry conditions[8]. The use of ligno sulphonate on unsealed roads has also been reported in a number of sub-Saharan African countries[8], Australia and New Zealand[9]. However, only limited information on material types, quantities of application and general performance is available.

In South Africa, the product has been used since the establishment of a cellulose pulp factory in 1954 created a supply of ligno sulphonate. Uses for this supply were sought, one of which was as a dust suppressant on unsealed roads. During the period 1961-1964 an investigation was conducted into the use of ligno sulphonate on unsealed roads under South African conditions[1]. The work included laboratory testing, field experiments, and economic studies. Research has also identified numerous other uses for the product in which it is widely used, including:

- binders (gravel, animal feed, coal, etc);
- resins (epoxy, ion exchange, plywood adhesives, slow releasing pesticides);
- sequestering agents (plant micronutrients, leather tanning, batteries), and
- dispersants (oil well drilling muds, concrete additives, bricks, tiles, fire fighting foam, etc).

Ligno sulphonate has been used as both a dust palliative and stabiliser for subbase and base materials on all of the continents. The results of international work have been published covering experiences with application and the benefits of using the product. In many instances, the performance of ligno sulphonate has been compared with other products including calcium chloride, magnesium chloride, petroleum emulsions and polymer emulsions. Much of the fundamental research was carried out between 1940 and 1960 with the findings still being considered relevant today.

A detailed review of the international literature was undertaken by Fossberg in 1966[1]. More than 30 references are cited in his text. Since then, the literature has focussed mainly on the monitoring of ad hoc experiments to determine the suitability of the product for particular applications. No details on a comprehensive study following a scientific experimental design considering traffic, climate and materials have been located, indicating that such a study has probably not been carried out. However, recommendations on the use of ligno sulphonate have been developed in Canada[6] and the United States[7]. In most of the literature, reference is made to the issue of water solubility, indicating that the period of effectiveness of ligno sulphonate is relatively short. No research appears to have been carried out on the development of an application programme over a period of time to alleviate this problem.

Reference is also made in the literature to use of the product for subbase and base stabilisation. However, the type of pavement structure and traffic characteristics were not specified. Performance of the product was also not compared with traditional stabilisers such as lime, cement and bitumen emulsion.

RESEARCH INVESTIGATION

Laboratory Testing

Following the literature review, a laboratory investigation was initiated to determine environmental compatibility and the influence of the improved product on various parameters including particle size distribution, Atterberg limits and bar linear shrinkage, maximum dry density, optimum moisture content, California Bearing Ratio, durability, electrical conductivity, pH and product penetration. A factorial experimental design was used to ensure that a representative group of materials was tested. Seven different materials selected according to engineering geological classification and plasticity were sampled and characterised. Two different formulations of ligno sulphonate powder (standard and low sugar, extracted from *Eucalyptus* species using a calcium bisulphite process) were mixed with the materials at two different application rates (0.5 and 2.0 per cent by mass)[10].

The results of environmental compatibility testing indicated that the application of ligno sulphonate at the recommended rates will have no negative environmental impact on ground and surface water or on adjacent vegetation. Standard procedures for the handling of non-hazardous chemicals should, however, be adhered to. Ligno sulphonate has a high biological oxygen demand and bulk spills into surface water resources must be avoided.

The results of the initial laboratory testing indicated that both products tested have the potential for use as additives to reduce dust and thereby limit the loss of fines on unsealed roads. However, these findings would have to be confirmed with full-scale field experiments before final recommendations on the use of the products could be made. Laboratory test results are summarised in Tables 1 and 2[10].

In summary, the products agglomerated the fine particles effectively, which should prevent them from becoming entrained in the wind turbulence generated by a moving vehicle. The resistance to abrasion of the treated material, determined in two different tests (extended sieve abrasion and mechanical brushing), also appeared to be significant. The plasticity index and linear shrinkage of high plasticity materials was generally slightly reduced by the addition of the products. However, this reduction was too small to warrant their use to reduce plasticity in order to make more materials comply with current specifications. Treatment may, however, result in a reduction in slippery conditions and poor passability on unsealed roads constructed with materials with a high plasticity. The products had no influence on compacted density, while their effect on optimum moisture content varied depending on the plasticity characteristics. However, the change was too small to influence construction procedures or costs.

TABLE 1: Summary of laboratory test results for ligno sulphonate (standard)

Test Parameter	% change at application rates of 0.5 and 2.0% by weight													
	Granite		Diabase		Ferricrete		Calcrete		Chert		Shale		Sand	
	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0
Reduction in P0.075	43	84	87	78	22	68	42	62	71	83	82	75	41	54
Change in Plasticity Index	-12	-21	11	9	-5	-6	3	30	0	10	-15	-13	-32	13
Change in Linear Shrinkage	-24	-24	-4	-8	-24	-24	-4	15	4	-4	0	0	19	-19
Change in Max Dry Density	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Change in moisture (OMC)	-3.6	1.2	5.7	11.3	-1.7	0	0	0	-12.5	-5.8	7.1	17.9	-13.0	-10.0
Change in CBR	-22	-50	-17	33	95	-34	-58	-53	-36	-77	-20	-45	25	27
Increase in abrasion resistance	99	NT	12.5	NT	85	NT	60	NT	69	NT	75	NT	98	NT
NT – Not tested														

TABLE 2: Summary of laboratory test results for ligno sulphonate (low sugar)

Test Parameter	% change at application rates of 0.5 and 2.0% by weight													
	Granite		Diabase		Ferricrete		Calcrete		Chert		Shale		Sand	
	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0	0.5	2.0
Reduction in P0.075	64	89	90	91	58	63	52	58	73	88	77	91	60	63
Change in Plasticity Index	-26	-14	8	14	0	0	33	21	7	20	-11	-8	-68	7
Change in Linear Shrinkage	-16	-34	-2	-8	-29	-29	-15	10	7	0	0	0	-38	0
Change in Max Dry Density	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Change in moisture (OMC)	1.2	6.0	17.9	23.6	-2.6	-2.6	6.7	7.8	-9.2	-9.2	14.3	16.1	-13.5	-6.7
Change in CBR	-12	-34	116	33	61	-34	-50	-35	-51	-74	-20	-10	31	-27
Increase in abrasion resistance	99	NT	25	NT	77	NT	40	NT	95	NT	50	NT	98	NT
NT – Not tested														

The addition of ligno sulphonate improved the CBR strength characteristics on three of the materials tested and reduced it on four of the materials. This reduction in CBR was attributed to the plasticising effect of the products in the moist state. Since conflicting results were recorded, no further conclusions will be drawn until performance has been monitored in full-scale experiments. Addition of the products altered the pH (increase or decrease depending on the pH of the untreated material) and increased the electrical conductivity. They easily penetrated the surface of a compacted specimen provided that they were applied over a period of time[10].

In most instances, the low sugar ligno sulphonate performed better than the standard ligno sulphonate. However, the difference was generally marginal and acceptable performance should be expected from both products.

Field Testing

Based on the findings of the laboratory investigation, a factorial experimental design was developed for full-scale field testing to compare laboratory findings with actual conditions and to determine long-term cost-effectiveness of the products. The experimental design considers traffic, climate, material type and construction method[11]. Traffic is divided into three classes, less than 100, 100 to 300 and more than 300 vehicles per day. The influence of heavy vehicles is being determined from experiments on mine and forest haul roads. Climate is being considered in terms of Weinert N-value[12], a climatic parameter widely used in road material performance modelling in southern Africa. Material type is being considered in terms of the engineering geological classification system used in southern Africa. Two application methods, namely mix-in and spray-on treatments are being used.

Owing to the high costs of monitoring and the often-limited opportunities for experimentation on certain material types, only 12 sections have been selected from the experimental design for initial testing, of which five had been constructed at the time of preparation of this paper. These experiments are being monitored on the most commonly used material types in South Africa over a range of traffic volumes and climatic conditions. Although it is unlikely that the interim specification will change significantly, experiments in the remaining cells will be monitored when the opportunity arises to ensure that the performance prediction factors used in cost-benefit studies are widely applicable.

Material was removed from each section during construction for full laboratory characterisation. Each section is then monitored on a regular basis. A visual evaluation is carried out by the road owner at monthly intervals. Detailed monitoring is being carried out at three monthly intervals and involves the following:

- Determination of insitu density and moisture content by means of a suitably calibrated nuclear density gauge;
- Determination of the strength of the base by means of a dynamic cone penetrometer (DCP);
- Determination of gravel loss using precise levelling surveys;
- A comprehensive visual survey with measurements of the location and depth of ruts and potholes, location and size of stones, and the depth and frequency of erosion channels, corrugations and ravelling;
- Determination of riding quality with a linear displacement integrator;
- Determination of dust levels with the CSIR Dust Monitor;
- Removal of a sample for the laboratory determination of moisture content, conductivity and pH, and
- Recording of climatic data.

All information is being stored in a database for further processing and analysis.

INTERIM GUIDELINES

Interim guidelines have been developed from the information gathered from the literature, past experience, laboratory test results and the field test results collected to date. The guidelines include economic analysis, material selection, climatic limitations and application and maintenance techniques[13].

Economic Analysis

The decision by a road authority to use a dust palliative will usually be made on economic grounds. In certain instances, social justification may also be sought (eg treating an access road to a school or clinic in a developing community). Factors influencing the decision include routine maintenance costs (eg grader maintenance and in the case of the mining industry, water spraying), periodic maintenance costs (eg reshaping and regravelling), vehicle operating costs, accident costs and road user time costs. Currently, road agency costs are the single biggest factor in the decision and the costs of using the product must be offset by reductions in the costs of routine and periodic maintenance. Savings in road user costs are considered as an additional benefit but usually (incorrectly) do not influence the decision unless the road owner will benefit directly (eg, the forestry and mining industries). Issues such as reduced environmental impact, improved quality of life, improved agricultural yields etc are difficult to quantify in monetary terms and are therefore not usually considered in the analysis.

Given the above, it is important that an economic justification for using the product can be carried out. The detail of the justification will depend on the requirements of the individual client and will vary from a simple comparison between the costs of water spraying and the application of the product on a mine haul road to the inclusion of performance prediction models in a road management system.

In an elementary analysis, the following methodology should be used[13]:

- Establish the primary and secondary motives for wanting to do dust control;
- Determine the surface area to be treated;
- Quantify the costs of the current programme. This will include the cost of operating the spray tankers (including depreciation), the consequences of equipment downtime and the associated road maintenance costs.
- Calculate the cost of applying ligno sulphonate over the period of required dust control (eg annual cost on a mine, ripening and picking season on a farm, period of deviation operation during construction of a new road, annually on an unsealed local authority road).
- Compare the two costs, keeping in mind the non-quantifiable benefits of dust control.

In a more detailed analysis to determine the cost effectiveness of the product against traditional unsealed road performance, the following methodology should be used[13]:

- Establish the primary and secondary motives for wanting to do dust control;
- Determine the surface area to be treated, usually a road link or network;
- Quantify the costs of the current programme. This will entail checking actual records for maintenance and regravelling, or if these are not available, predicting the maintenance and regravelling frequencies.
- Obtain traffic data (vehicles per day and heavy/light per cent split) and material characteristics.
- Calculate the discounted cost of the current programme for the road owner and the road user.
- Calculate the discounted cost of applying ligno sulphonate over the period of required dust control. This will usually be an annual cost but a cycle can also be considered (eg the period between regravelling). Appropriate software packages can be used to do the analysis.
- Compare the two costs, keeping in mind the non-quantifiable benefits of dust control.

Interim factors, based on the literature, past experience with other products and observations of treated roads in the United States, have been developed to calculate savings in road maintenance and regravelling. These factors can be used in conjunction with actual data or with unsealed road performance prediction models (eg South African[14] or World Bank (HDM4)[15]). **These factors should be used as a guide only and should by no means be considered as final.** Revised factors will be published on completion of the field experiment monitoring. The factors are:

Gravel loss - multiply predicted/actual loss for untreated road by a factor of 0.5

Blading frequency - multiply predicted/actual blading frequency of untreated road as follows:

- <7 days - multiply by 12.8 (90 days)
- 7-14 days - multiply by 7.1 (100 days)
- 15-45 days - multiply by 4.0 (120 days)
- 46-90 days - multiply by 2.0 (180 days)
- 91-120 days - multiply by 3.0 (360 days)
- >120 days - allow one blade per annum

Material

Analysis of the literature and observations of roads in South Africa and the United States showed ligno sulphonate to be effective as a surface stabiliser on a wide range of unsealed road materials[13]. Long-term dust suppression was, however, generally lower on very stony sections. Observations made during the course of the evaluation indicate that the application of ligno sulphonate to a well-constructed, well-drained road will generally result in the improved performance of that road. Use of the product will, however, not change an inherently bad road to a good road.

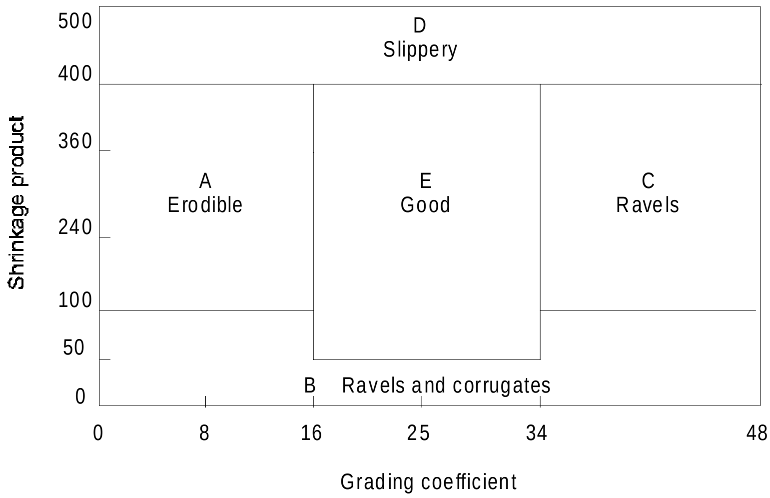
An interim performance-related material guideline for southern Africa, adapted from the South African Guidelines for Unsealed Roads[16] is recommended for ligno sulphonate applications where high riding quality, year-round passability and low maintenance are required (Table 3)[13]. Although developed specifically for southern Africa, it is probably applicable with minor modification over a much wider geographic area. The monitoring of field experiments to finalise this guideline and to study materials which do not meet the guideline is continuing. The guideline will be further relaxed if performance of the roads in terms of dust palliation and riding quality is acceptable. The test methods are those prescribed in TMH1 - Standard methods of testing road construction materials[17,18].

TABLE .3: Material selection guideline for ligno sulphonate treated unsealed roads

Characteristic	Guideline		
	Rural	Urban	Haul
Maximum size (mm)	37.5	37.5	75 - 100
Oversize index (%)	.5	0	.10t
Shrinkage product[a]	50 - 400	50 - 400	50 - 400
Grading coefficient[b]	16 - 34	16 - 34	16 - 34
CBR[c] (%)	.15	.15	.40
Hardness[d]	20 - 65	20 - 65	20 - 65

a = linear shrinkage x % passing 0.425 mm sieve
b = (% passing 26.5 mm - % passing 2.0 mm) x % passing 4.75 mm/100
c = California Bearing Ratio - soaked at. 95% Mod AASHTO
d = Treton Impact Value

The predicted performance for non-conforming materials is illustrated in Figure 1.



Climate

The performance of ligno sulphonate is not particularly dependent on climatic conditions, however, rainfall frequency and intensity will have some influence in terms of the product life-cycle.

Rainfall affects the performance of ligno sulphonate, in that significant increases in the moisture content of the material can result in leaching of the product to lower levels in the pavement, and into the sub-grade. At this depth, the product will have very little dust suppression effect. The problem is exacerbated during high intensity storms, although some product will return to the surface as moisture evaporates. Over longer periods (ie more than three years), product build up in the pavement layer from periodic rejuvenations and the consequent binding of the soil particles should result in minimal leaching.

Evaporation may influence the performance of ligno sulphonate, in that high rates of evaporation result in lower moisture contents in the road material, which in turn leads to increased levels of dustiness. The rate of evaporation is mainly dependent on humidity and temperature. However, treated roads in very dry areas have performed satisfactorily. This parameter is being monitored in field experiments in very dry regions.

Based on these findings, the determination of a precise climatic specification for the application of ligno sulphonate is considered unnecessary at this time.

Product Application

The performance of roads constructed with ligno sulphonate and the frequency of rejuvenation measures depend on the method of application of the product to the road surface. Incorrect application methods will result in wastage of the product and the likelihood of poor performance.

Although application of the product to a poorly maintained road will result in reduced dust levels on that road, the use of the product will not ameliorate the effects of other road conditions, such as potholes, rutting, corrugations and ravelling. These defects will in fact detrimentally affect the performance of the ligno sulphonate. Corrective road maintenance should therefore be undertaken before application of the product.

The product can be applied in the following ways:

- mixed with water and applied as a spray-on application
- after ripping the road, product is mixed with water and applied to the spread material, mixed and then recompacted

- mixed with the compaction water and applied during road construction or regravelling
- after ripping the road or spreading imported gravel, ligno sulphonate powder is spread onto the surface, mixed, watered, mixed again and then compacted.

The application rate depends on material, traffic and climate and will vary between 1 and 3 kg/m^2 of solid material per annum. If liquid ligno sulphonate is used, the solids content must first be established to ensure that sufficient product is applied (eg if the solids content is 50 per cent, then 2 kg of liquid will be equivalent to 1 kg of solid material).

Surface Treatments

Surface treatments involve the spraying of the product directly onto the road surface with minimal preparation. Although the duration of effectiveness of surface treatments is shorter than that of mix-in treatments they are ideal in situations where:

- Short term palliation is required.
- There is ongoing deposition of dust.
- It is undesirable to disturb the compaction of the road.
- Mix-in processes are impractical because of the nature of the material or the lack of suitable equipment.

A consistent application procedure should be followed to ensure successful performance of the product. The following application process is recommended[13]:

- Blade the road, ensuring a 4 per cent camber and adequate side drainage.
- Dampen the road with water to assist penetration. The application rate will depend on the moisture content of the road, but should not exceed 0.5□/m^2.
- Apply the product in a minimum of six applications over a period of three weeks. Avoid puddling and runoff.
- On mine haul roads, product should be applied at a rate of 0.01 kg/m^2 as part of the normal watering program until dust reduction is evident. The intervals between spraying will increase as the product takes effect.

Mix-in Treatments

A mix-in process will provide effective dust palliation for longer periods than spray-on treatments. The process is especially suitable for regravelling operations where the ligno sulphonate solution can be used to supplement compaction water. The additional costs incurred during construction will usually be offset by the necessity for less frequent rejuvenation, by improved performance and by decreased road maintenance and vehicle operating costs. The following procedure should be followed[13]:

- Rip the road to a depth of 100 mm. Break down lumps with a rotavator. If regravelling, windrow the dumped material on top of the lightly scarified surface.
- Calculate the volume of water required to achieve optimum moisture content.
- Add two-thirds of the required product into this water. Mix thoroughly. (Note that powder takes approximately 60 minutes to dissolve in a tanker of water).
- Apply the solution onto the prepared surface in two to four applications, mixing thoroughly with a rotavator, disc plough or grader between applications.
- Shape with a 4 per cent camber. Ensure adequate side drainage.
- Compact with a pneumatic tyred or vibrating smooth drum roller.
- Apply the remaining product as a surface treatment while the road surface is still damp.
- Standard quality control measures applicable to good engineering practice should be followed throughout the construction process. These measures include material testing, correct ripping depths, thorough mixing, the use of accurate spraying equipment and density and moisture measurements The safety of workers and road users and appropriate environmental protection measures should also be considered.

Ligno sulphonate can also be applied using pavement recycling equipment or labour intensive methods. Pavement recycling equipment (Wirtgen 2500) was used to apply product on three of the experiments that are currently being monitored. If labour intensive methods are used, a concrete mixer should be used to mix the product with the gravel, which is then dumped from wheelbarrows between shutters on the road, levelled and compacted.

Maintenance

The type and frequency of maintenance on treated sections will depend on the material characteristics, climate, construction method and traffic and should be carried out before significant deterioration of the road has occurred. In cases of isolated disintegration of the surface, material can be replaced manually, sprayed with product and compacted. If grader maintenance is required, the road must be lightly sprayed with water (± 0.5 □/m^2), in order to soften the crust, and then bladed following accepted techniques. Dry blading will damage the surface and lower the riding quality. Under no circumstances should deleterious untreated material from the side of the road be bladed onto the road to fill deformations as this will result in poor riding quality, high dust levels and possible slipperiness. It is often useful to lightly spray the road with water or a light application of ligno sulphonate (0.1 - 0.3 kg/m^2) after blading to facilitate compaction and assist with capillary suction of the remaining product towards the new road surface. Long-term evaluations of treated sections currently being monitored will enable suitable blading frequencies to be determined and existing models to be modified.

During prolonged exceptionally dry periods, an occasional very light application (maximum 0.5 □/m^2) of water will enhance the dust-suppressing potential of ligno sulphonate. Spraying of excessive quantities of water should be avoided, as this may result in any or all of the following conditions:

- Leaching of the product to greater depths.
- Run-off, which will remove the product from the surface layer and cause erosion.
- Slipperiness.
- Accelerated formation of potholes.

In arid sandy areas, a sand cushion can be applied to protect the treated base[19].

Rejuvenation

Roads treated with ligno sulphonate will require periodic rejuvenation to ensure continued dust suppression. The intervals between rejuvenation of these treated roads will depend on the material characteristics, application method, climatic conditions and traffic.

References in the South African literature to observations made during monitoring evaluations in the 1960s indicate that, on sections where product was mixed-in to the material, rejuvenation was usually required at the beginning of each dry season and approximately every three to six months on sections where the product was sprayed directly onto the surface. This may, however, vary considerably, depending on the material and traffic characteristics of the road (eg on mine haul roads, rejuvenation frequency will be much higher, albeit at lower application rates). In northern hemisphere countries where the dry season is much shorter, different criteria apply depending on the actual length of the dry season. Based on these findings, and as an interim recommendation, an average of 0.5 kg/m^2 of solid product should be sprayed onto the road, preferably after blading, each year after initial application. Depending on operating conditions, the application may be split into two applications at three monthly intervals. On mine haul roads, the continual deposition of dust on the haul road will require more frequent rejuvenation. An application of 0.4 kg/m^2/month is recommended in the interim until further performance information has been collected.

Long-term evaluations are being carried out to establish the application rates and frequencies of subsequent rejuvenations and to develop an optimal plan for various traffic and climate scenario's.

CONCLUSIONS

Ligno sulphonate has been widely used as a dust suppressant on unsealed roads in North America and Europe since the beginning of the century and research on its use there has been carried out over a period of time. However, much of this research was undertaken on by-product streams from pulping plants, without identification of the source plant species or process used to extract the lignin, both of which can influence performance in the road. The availability of refined products, together with road authority requirements for more detailed performance information has resulted in the need for more detailed research into the use of the product on unsealed roads.

A holistic study was initiated to review the literature, carry out a laboratory investigation and to monitor performance of the product in a number of field experiments. The laboratory investigation found that addition of the product resulted in a durable agglomeration of the fines in all materials tested. The influence on plasticity characteristics varied depending on the material, but reductions in shrinkage were noted on higher plasticity materials. Maximum dry density and optimum moisture content were not affected. The influence on CBR varied among materials and no firm conclusions could be drawn. The product penetrates compacted materials effectively.

Full-scale field experiments, selected according to a factorial experimental design, are currently being monitored. Performance to date has been good when compared to the untreated control sections. Based on the findings of the literature review, laboratory study and field experiments to date, interim guidelines on the use of the product have been prepared. These include economic analysis, material selection, climatic limitations and application and maintenance techniques. Final guidelines and recommendations will be published on completion of the monitoring of the field experiments.

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