Journal of the Ghana Institution of Engineers Vol. 2, No.2, 2004, pp 12–17

TOWARDS IMPROVED CHIP SEAL CONSTRUCTION IN GHANA

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ABSTRACT

Chip seal or bituminous surface-dressing constitutes the surfacing for more than 80% of the total paved roads in the country. Chip-sealed roads generally have a life of 5 to 7 years, however, it is common in the country to find some of such roads experiencing surface deterioration in as little as one to two years after construction. Concern for the unsatisfactory and sometimes poor performance of chip-sealed roads and the need to undertake early maintenance led the Ghana Highway Authority (GHA), under the auspices of the Ministry of Roads and Highways, to review the design and construction of chip seals recently. Today chip-sealed roads are constructed following a stricter design and construction procedure than was previously the case and using aggregates that are pre-coated to enhance binder-aggregate bonds, chip embedment and retention. This paper presents and discusses the main tenets and sustainability of the current approach to the design and construction of chip seals in Ghana.

Keywords: Chip seal, construction, embedment, pre-coated aggregates, primer-seal, sustainability.

1. INTRODUCTION

The importance of chip seal construction in the country lies in the fact that more than 80% of the paved road network is bituminous surface-dressed, mostly with a single seal, though recently, the shift has been towards double surface-dressing for roads that come under medium to moderately high traffic.

The terms chip seal and bituminous surface-dressing will be used interchangeably throughout this paper to reduce repetition as they refer to the same process. The Transport Research Laboratory (TRL, 1993) recommends chip seal for roads that come under low to medium traffic. Jackson et al. (1990) describe chip seals as having favourable cost and good performance on low volume roads and are to be considered the pavement surfacing of choice for all roads with average daily traffic less than 2,000veh. Even though chips seals are used mainly for low volume roads, Shuler (1990) has indicated that improvements in spray sealing practice and materials over the years have now made it possible to use the surfacing successfully for heavily-trafficked roads with traffic levels of the order of 20,000veh/lane/day.

Bituminous surface-dressing provides;
an economical, durable, dust-free, skid-resistant surface, permitting safe travel and improved riding qualities and comfort for road users;
reduced vehicle operating and maintenance costs and hence extended vehicle life and
protection for pavements from the degrading action of traffic and the weather.

In general, chip-sealed roads can be expected to last between 5 to 7 years, depending on the quality of construction and traffic levels, before resealing or any major rehabilitation works may be warranted (Shuler, 1990). However, in Ghana it is common to find some of such roads experiencing surface deterioration and multiple pothole development in as little one to two years after construction.

Concern for the general unsatisfactory performance and early deterioration of chip-sealed roads and the need to undertake early maintenance led the Ghana Highway Authority, under the auspices of the Ministry of Roads and Highways, to review the approach to the design and construction of chip seals in the country some five years back.

The review culminated in the drawing up of new specifications and manuals using the experience of chip seal construction and performance from Australia. In Ghana, specifications for roads drawn under the auspices of the Ministry of Roads and Highways are used by three governmental road agencies, namely, the Ghana Highway Authority, the Department of Urban Roads and the Department of Feeder Roads, who together manage the total network of roads in the country. However, because the major roads and the bulk of the country's paved road network is under the jurisdiction and management of the Ghana Highway Authority, the review process became more the responsibility of GHA than that of any of the other road agencies.

In the past, a number of factors accounted for the unsatisfactory performance of chip seals in the country; these included poor design, disregard for the effects of the operating environment on performance during design and construction, inappropriate construction practices, inadequate contractor performance, and inadequate quality control of the construction. Indeed, laxity in quality control allowed some contractors to execute poor and substandard work with some level of impunity. In order to tackle the problem in its entirety, therefore, the review programme also targeted contractor performance and required contractor demonstration of capacity and capability to undertake surface-dressing works.

A screening programme based on contractor performance history and equipment holding with respect to chip seal construction, developed by the Consultant (Snowy Mountains Engineering Corporation of Australia) with the assistance of the Ghana Highway Authority, made it possible to reduce the number of contractors, who hitherto could bid for and execute bituminous surface treatment works, by more than 60% from 81 to 30. It is possible that this number may eventually be trimmed down and even likely that in future, only specialized bituminous surface-dressing contractors would be used for road surfacing works.

In general, the operating environment sets the tone for the design, choice of materials and construction of chip seals and it is important to recognize at the onset that traffic occupies centre stage in this regard. More specifically, increasing traffic volumes, truck axle loads and tyre pressures increase the demands on chip seals in terms of moving and plucking of aggregate from the seal coat matrix, pushing of aggregate into the pavement, aggregate breakdown, and polishing of aggregates.

In addition, braking, acceleration and turning (scuffing) forces place increasing demands on surfacings in high stress areas of pavements such as intersections, inclines, sharp curves, roundabouts, etc. For such areas, it may be necessary for the design to consider the use of stronger seals with or without modified binders to improve performance and ensure the durability of the construction. At the construction stage, the level of traffic gives an indication of the type of traffic control measures to put in place during and immediately after placement of the seal as it is generally detrimental for both short- and long-term seal performance to allow traffic on a freshly-placed seal when sufficient bond strength for aggregate retention and embedment has not developed.

Other considerations within the operating environment are safety, noise levels and aesthetics. Where traffic speeds are high, larger aggregates must be selected to improve skid resistance and to ensure good drainage characteristics of the surface. In the case of traffic having a high proportion of trucks with high axle loads, large size aggregates provide an antidote for any potential reduction in surface texture depth emanating from the pushing of chippings into the pavement surface.

The direct benefit of all these is improved safety of traffic operations. On the other hand, in residential areas where traffic is generally low and devoid of heavy vehicles, the seal can be designed to use smaller aggregates to give a smoother surface to reduce noise. Aggregates of different colours may even be used to delineate different areas of the pavement, such as areas for pedestrian traffic or parking zones, to provide environmental appeal.

Today, the design and construction of surface-dressings are operating-environment-oriented and follow a stricter design and construction procedure than was previously the case. Aggregates used are pre-coated to enhance binder-aggregate bonds, aggregate embedment and retention. So far, the outcome of the review has been very successful.

Surfacings constructed to the new specifications appear smoother, are able to hold about 95% of the cover aggregate in place, look aesthetically pleasing, are not characterized by aggregate whip-off problems and look more like an asphaltic binder course. However, sustainability of the improvements depends on a number of factors including monitoring and evaluation as well as further training of bituminous surface-dressing contractors.

2. QUALITY CONTROL ISSUES

It is important for long-term performance to subject chip sealing operations to strict and adequate quality to ensure a successful product outcome. Quality control must be the joint effort of the contractor and the client (road agency) and must be exercised at all stages of the construction. The items to control are discussed in the following sections.

2.1 Binder quantity and placement

Binder quantity must be well controlled as inadequate binder will lead to insufficient aggregate embedment in the seal matrix, whereas over-application will cause bleeding in hot weather and loss of skid resistance. During binder application for placement of the seal, it is important to set the height of the spray bar of the bitumen distributor correctly so that the sprays from adjacent nozzles will overlap. This will eliminate streaking on the pavement surface when the seal is in place.

2.2 Binder temperature

Penetration-grade or viscosity-grade binders are always applied hot at a temperature of 135°C. Therefore, when such binders are used for the seal coat, their placement should be followed immediately by the spread of chippings otherwise when the binders fall in temperature, they become too viscous and incapable of providing adequate adhesion between them and the aggregates. This will increase the opportunities for aggregates to be dislodged from their placement positions and whipped to the sides of the road.

2.3 Aggregate quality and quantity

It is important that aggregates for the seal have a clean surface that will allow the bituminous binder to adhere to it. Dusty or dirty aggregates must be cleaned before use as the surface dirt will act as a shield against bonding. Pre-coating of the aggregates with a bitumen-based material will improve the aggregate's ability to bond with the binder in the seal. Application of excessive chip quantities is considered a deviation from proper practice during chip seal construction as it results in material wastage and sometimes damage to vehicles. In addition, the excess chips on the surface may push and dislodge those below and cause loss of cover aggregate.

2.4 Traffic control

Allowing traffic on a freshly-placed seal too soon when the binder has not yet set or cured sufficiently to ensure strong aggregate-binder bonds will cause aggregate embedment problems and lead to short-term loss of cover aggregate. Where possible, detours must be created to give the seal sufficient time to set and develop strength before allowing traffic on it, otherwise, vehicles must be controlled to move slowly on the seal. Slow-moving traffic is even believed to provide a level of chip orientation not achievable by conventional pneumatic-tyre rollers (Shuler, 1990).

In situations where the absence of detours, disruption to traffic and inconvenience to motorists may make early use of the sealed road unavoidable, the construction should be carried out with bituminous binders other than bituminous emulsions as the latter take long to set and develop adequate bond strength for chip embedment and retention.

3. PREVIOUS DESIGN AND CONSTRUCTION APPROACH

3.1 Aggregate size

Aggregate used as cover mat for priming was coarse sand or quarry dust (0-5mm). Application of quarry dust was always difficult when wet. In addition, sand or quarry dust was not able to stand heavy traffic resulting in pothole development on the primed base course. Aggregate used as cover mat for the main seal was fixed in size at 19mm. This was irrespective of shape characteristics and traffic levels but, generally, large size aggregates are required only when traffic is heavy and the potential for the aggregate to penetrate into the base course is high. The large aggregates tended to result in the surfacing being too hungry.

3.2 Priming

This was carried out using an MC-2 cutback (equivalent to MC-30 by current American Standards). The primer was applied at a fixed rate of 1.0-1.2 l/m^2 irrespective of the textural characteristics of the surface of the base course, and was followed by the spread of coarse sand or quarry dust. The base bitumen used in formulating the primer was 60/70 penetration grade and because, in most cases, the base course surfaces were dense, very little penetration of the primer into the surface was achieved. As a result, residual bitumen tended to stay on the primed surface and sometimes contributed to bleeding and loss of skid resistance when the main seal was placed. For maximum primer penetration into the base course, the time lag between spraying the bituminous cutback (MC-2) and the application of quarry dust should be at least 6 hours. This was a great nuisance to the travelling public. In addition, the 28-day waiting period between primer application and placement of the main seal was too long and unsafe for traffic operations as primed roads tend to have extremely low skid resistance especially in wet weather. Furthermore, because a primed surface is able to hold against the surface degrading effect of vehicular traffic only for a very short time, the 28-day waiting period tended to result in the primed surface sometimes becoming considerably damaged by the time the main seal was due, particularly where traffic was high. Such developments required extensive patching and, in some cases, light scarification of whole sections for re-priming before placement of the main seal was possible. There were also cash-flow problems for contractors which tended to result in delays in the application of the main seal layer beyond the 28 days, thus causing great damage to the primed surface.

3.3 Seal Coat Construction

The seal coat or the chip seal layer is the main surface on which vehicles run and it is this thin layer which prevents ingress of water into the base course and underlying layers and provides skid resistance for vehicular traction. The construction of the seal coat consisted of the application of S-125 bituminous binder (a Shell cutback product with 12.5% cutter) applied at the rate of 1.25l/m^2 followed by the spread of 19 mm cover aggregate. The base bitumen used in formulating the cutback was a 60/70 penetration grade. Because of its relative hardness, and under the harsh temperature conditions prevailing in most parts of the country, the residual bitumen tended to age-harden quickly, thus becoming stiff and brittle after being in service for only a short period. Once the binder assumed a brittle character, the incidence of cracking and, hence, the breakage of the binder aggregate bonds became high. This manifested in some of the pavements as early pitting and loss of cover aggregates.

3.4 Rolling

Even though pneumatic tyre rollers are more suitable for providing the kneading compaction required for early aggregate interlock and retention, they were seldom used for rolling the chip seal layer after placement; instead steel-wheeled rollers dominated compaction in bituminous surface-dressing operations. The disadvantages of using steel-wheeled rollers are that the rollers cause aggregate crushing and compact only high spots when aggregate spread is non-uniform. The outcome of this was that instead of helping the seal aggregates to assume a stable interlocking arrangement, the compactors helped crush them resulting in very poor compaction overall.

4. CURRENT DESIGN AND CONSTRUCTION APPROACH

4.1 Selection of aggregate size

The current design approach selects aggregate size on the basis of traffic intensity and whether the chippings are to be used in primer-seal construction or the main seal. For primer-seal construction, the recommended chipping size is 10mm, though the 7mm and sometimes the 14mm sizes may be used, whereas for the main seal, only the 10mm and 14mm sizes are specified. Table 1 provides designers with a guide to the selection of aggregate size for the main seal using information about the average daily traffic expected on the road. Where there are two sizes to choose from, it is recommended to use the smaller aggregates for roads in urban areas where traffic loads are low and low noise levels must prevail and the larger ones on rural highways where commercial vehicle traffic and axle loads are high.

Table 1. Selection of aggregate size for main seal

Traffic (veh/lane/day)	**Recommended Chipping Size (mm)**
<300 (very light to light)	10
300-1,200 (light to medium)	10, 14 (10mm preferable)
>1,200 (medium to heavy)	10, 14 (14mm normal)

4.2 Pre-coating of aggregate

Poor binder–aggregate bond is one of the major causes of loss of cover aggregate in surface dressings. Loss of cover aggregate leads to damage of the thin bituminous cover which subsequently results in pitting and pothole formation. To overcome this, the current design specifies pre-coating of the aggregates for the seal with a bitumen-based (cutback) material. This includes the aggregates to be used for the primer-seal construction and the main seal coat. The cutback for the pre-coating is formulated as 90% diesel and 10% AC-10 viscosity-grade. The recommended application rate for uniform coverage is 12 litres/m^3. Pre-coating must take place at least three days before the chippings are to be used and if rain is imminent, adequate cover must be provided to prevent the pre-coating material from being washed off.

4.3 Primer-seal construction

The main objectives of priming a base course is to achieve binder penetration of the order of 5-10mm into the surface layer so as to bind particles together and achieve some level of surface layer impermeability for the construction before the main seal coat is placed. As noted earlier, the practice of blinding the primed base course with coarse sand or quarry dust to allow for temporary usage of the road by traffic often resulted in surface damage when the main seal coat was considerably delayed. To overcome this problem, the current design specifies the construction of a primer-seal in place of the traditional primed surface. The primer-seal construction consists of using a more viscous primer binder for priming followed by an application of uniform size chippings instead of blinding with quarry dust or coarse sand. The primer-binder acts both as a primer and a binder. Because it is much more viscous than normal primer, not more than 5mm maximum penetration into the pavement surface is expected to be achieved. The primer binder to use is an AC-10 viscosity-grade or 80/100 penetration grade liquefied with a 16-20% kerosene cutter. The size of chippings for the primer-seal may be selected from any of the following; 7, 10, and 14mm. However, for low to medium traffic, 7mm chippings are recommended for use as this will provide a more uniform and less hungry surface for the final seal. Road surface temperature should exceed 20°C for better bonding between the bitumen and the road surface.

The rate of primer-binder application is a function of the size of aggregate to be used for the primer-seal; the volume of traffic anticipated on the road; the spray temperature; and the porosity of the pavement surface. The spray temperatures considered are for either cold or hot applications and are respectively 15°C and 135°C. The porosity of the pavement surface is placed into four types, namely,

Tightly-bonded,
Fine-bonded,
Coarse and
Crushed rock.

For both cold and hot binder applications, the aggregate spread rate is dependent only on the size of chippings selected. Table 2 provides an example guide to materials application for a tightly bonded pavement surface with the primer-binder applied cold. Similar tables are available for other surface types and for cold and hot binder applications in the seal manual (GHA, 2001).

Table 2. A guide to material selection and application for primer-seals

Size of Aggregate (mm)	**Primer Binder Application Rate at 15°C (l/m^2) (Tightly Bonded Surface)**			**Aggregate Spread Rate (m^2/m^3)**
	Traffic level (veh/lane/day)			
	<300	*300-2,000*	*>2,000*	
7	1.35			115
10	1.35	1.25	1.15	100
14	1.45	1.35	1.25	80

The construction of a primer-seal provides several advantages including the following:

Traffic is able to use the primed surface the same day and for a much longer period without significant surface deterioration even if the main seal coat is considerably delayed. In addition, the construction results in less disruption to traffic. Controlled traffic contributes significantly to better aggregate embedment.

The seal can last up to 24 months and is suitable in situations where placement of the main seal is expected to be delayed considerably.
When the final seal coat is placed, a surfacing intermediate between a single seal and a double seal is obtained. This leads to enhanced surface integrity which improves durability of the chip seal as a whole.

It results in minimal loss of chippings as about 95% chip embedment is achieved. This in turn almost eliminates aggregate whip-off and associated windshield breakage and results in an environmentally-friendly surfacing.

4.4 Seal coat construction

The binder specified for the main seal is either an AC-10 viscosity-grade or 80/100 penetration grade which is more viscous than the binder employed for the primer-seal. It is also possible to use a cationic rapid setting emulsion grade CRS-70 containing 70% AC-10 base bitumen but this is not encouraged. The binder is applied at a rate evaluated on the basis of a number of factors including surface texture characteristics, traffic level and aggregate characteristics. This is followed by the spread of chippings at a rate dictated by the Average Least Dimension (ALD). Table 3 provides a guide to the chippings application rate for a broad range of ALD values.

4.5 Rolling

Only pneumatic-tyre rollers of mass between 12 and 15 tonnes and a wheel load greater than 1 tonne with a tyre pressure of 550kPa are specified for use. Unlike steel rollers, which tend to compact only the high spots and crush aggregates, pneumatic-tyre rollers result in kneading compaction and are able to re-orient the aggregates to lie on their flat side with their least dimension vertical so that there is also embedment not just mere compaction. This results in a more interlocking aggregate layer for the seal.

5. IMPLEMENTATION OF CHANGES

It was recognized at the onset of the review that the successful implementation of the new approach to the construction of chip seals would require the following three important areas to be addressed and strengthened; Materials, Equipment and Training of Personnel

5.1 Materials

A greater emphasis on materials for surface dressing operations is placed on aggregates. A greater proportion of quarry productions in the country are tailored to the needs of the building industry. As a result, only a limited number of quarries produce aggregates in suitable sizes

Table 3. A guide to aggregate application rates (TRL, 1993)

Aggregate Size	Range	Aggregate spread rate (m^2/m^3)				
		ALD (mm)	Upper	Optimum	Lower
Sand		2.0	329	282	235
		2.5	263	207	141
5mm		3.0	235	188	132
		3.5	212	174	127
		4.0	193	160	122
7mm		4.5	179	150	113
		5.0	165	141	108
		5.5	152	133	105
10mm		6.0	143	124	100
		6.5	134	120	96
		7.0	130	115	91
		7.5	125	110	86
		8.0	116	107	82
14mm		8.5	112	102	80
		9.0	107	97	78
		9.5	102	92	75
		10.0	98	88	74
		10.5	93	83	71
		11.0	88	78	69
20mm		11.5	83	74	66
		12.0	78	69	64
		12.5	74	64	61
		13.0	69	59	59
		13.5	64	54	56
		14.0	59	49	54

for road use. Single size specification requirement demanded of road aggregate makes it difficult for available quarries to accumulate sufficient quantities of aggregates to meet the needs of the paving industry. In addition, the tremendous increase in road works involving bituminous surfacing in the last few years has put pressure on the few quarries that produce for the road sector.

Therefore, to ensure regular and sufficient supply of road aggregates there is the need for the road agencies, particularly GHA, to provide identified quarries with their annual surface dressing programmes so that the quarries could tailor their productions to meet the expected tonnage requirements of the road sector to avoid overproduction of a material which invariably has only a single consumer.

5.2 Equipment

The major equipment required for sprayed sealing works are bitumen distributor, aggregate spreader and a pneumatic-tyre roller. Bitumen distributors are to be well calibrated and the spray nozzles well maintained to ensure that there is uniformity in spraying. Defective equipment affects workmanship which is crucial to the performance of the chip seal. On large scale works, the use of self-propelled spreaders is recommended as they offer substantial economies in terms of more uniform spread and less aggregate wastage.

5.3 Training of personnel

This is seen as necessary to provide all persons involved with sprayed sealing works with the requisite skills and knowledge and the capacity to deliver a high quality product. Personnel to be trained include those from both the contractor and the cliesides. Further discussion on the topic is considered in the section that follows.

6. SUSTAINABILITY

Training and monitoring and evaluation have been identified as the two areas crucial to the sustainability of the new technology for chip seal construction in the country.

6.1 Training

This is considered necessary for capacity building, on the one hand, for personnel of the GHA to be able to play its supervisory role over chip seal contracts to ensure that the end product will meet GHA standards in a cost effective manner and, on the other hand, for personnel of contractors so that they would be able to deliver to the client a high quality product. Even though GHA intends to have about 90% of its maintenance and resealing operations carried out by contracting, it will have about 10% of maintenance works, which will include sprayed sealing operations, available to be carried out in-house under its Mobile Maintenance Unit. Thus, the training will not only help GHA provide effective supervision of contract sealing works, it will help the agency in carrying out its own maintenance works properly and effectively.

The training areas identified include the following:

Field supervision
Field crew management
Bitumen spraying
Aggregate pre-coating
Chip spreading
Rolling
Quality control
Traffic control and safety
Materials handling and storage
Reporting

These training areas are intended principally for field-based personnel such as supervisors, foremen, sprayer operators, truck drivers, and other technical personnel engaged on bituminous sprayed sealing works.

The new technology has to be monitored and assessed to provide a basis for further refinement or changes if warranted. This requires the establishment of a monitoring and evaluation desk made up of a core team of engineers and technical staff at the headquarters of GHA.

7. CONCLUSION

This paper has presented the background to the review of the design and construction of chip seals in Ghana and discussed the main components of the new technology. It has highlighted the problems that were associated with the design and construction of chip seals in Ghana in the past which tended to cause some chip-sealed roads to deteriorate in surface quality in as little as less than one year after construction. The changes that have been made include the use of softer base bitumen in liquefied asphalt formulation, the use of smaller aggregates, pre-coating of aggregates and the construction of a primer-seal to replace the traditional primed surface. Whereas in the past binder application rates and aggregate spread rates were fixed irrespective of the level of traffic and aggregate size, the current design selects those parameters on the basis of pavement surface characteristics, aggregate characteristics, traffic level and the presence or otherwise of high axle load vehicles.

A screening programme that used contractor past performance and equipment holding with respect to chip seal construction as part of the screening criteria helped reduce drastically the number of contractors qualified to bid and undertake sealing works. This was to ensure high quality work and bring sanity into the construction of chip seals as a whole. For sustainability of the new approach, it has been recognized that there should be continuous training of the technical staff associated with chip seal construction on both the contractors' and client's sides. A monitoring and evaluation team is required to assess the performance of the design over time and to suggest changes if and when necessary.

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