CURRENT PRACTICE FOR THE CONSTRUCTION OF HOT ASPHALT SURFACINGS BY HAND

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Abstract

The surfacing of roads with asphalt is common on high traffic roads and/or high strength pavements, and is done using plant intensive construction. The historic laying of asphalt by hand has been superseded by plant as quality standards for asphalt surfacings have changed with increasing vehicle loading and speed. Now the use of asphalt in labour intensive construction is limited to small quantities for field maintenance. But recent research into the road surfacing/tyre interface has indicated an increased role for asphalt as a surfacing on light construction/low traffic roads. To introduce asphalt as a material for labour intensive construction of high quality road surfacings, the appropriate technology practice and design must be developed. To codify construction practice, this paper combines the limited literature with field interviews of practitioners still laying asphalt by hand.

The manufacture of asphalt, and haulage to site for both plant and labour intensive construction is proposed to be by plant for reasons of speed and volume. On site, labour intensive construction is codified for site preparation, priming/tacking of the basecourse, stockpiling of the asphalt, spreading and laying the asphalt, and screeding. Emphasis is placed on the supervision of the work force to obtain the quality and finish expected of an asphalt wearing course. The equipment used by labour is identified, and recommendations made on the effective use of hand tools with asphalt. Designs for the screed plank and screed rails are discussed. It is shown that compaction of the asphalt is necessary by plant based techniques. It is evident that asphalt surfaces can be built satisfactorily by labour intensive construction. Research is continuing into the design of labour-friendly mixes with good performance.

Keywords: labour intensive construction, asphalt, hot mix, surfacing, road

1 Introduction

1.1 Historic construction of asphalt surfacing by hand

The production of manufactured asphalt was trialed in 1869 in New Jersey, and extended to New York in 1872-3. It found ready acceptance, and by 1910 it was the most commonly used paving material in US cities. Early construction was by hand, and mechanical spreading of these asphalt mixes did not occur until 1928 (Lay, 1990). Since then there have been substantial changes in vehicle speed, vehicle weight and tyre pressures, traffic loads, and riding quality standards. These have been accompanied by changes in asphalt design and construction. Asphalt roads are now built using plant based construction techniques for reasons of speed, quality, economy, worker safety, and preference. The technique for asphalt surfacing by hand has been substantially lost. The current position on the suitability of asphalt for hand or labour intensive construction is that "hand work should be limited to correcting known paving deficiencies and spreading asphalt in areas inaccessible to the paver" (SABITA, 1992).

1.2 Surfacing of light traffic roads

Labour-intensive road construction in Africa is undertaken in many countries, such as South Africa, Kenya, Botswana, Lesotho. Such programmes have usually been initiated by governments as part of their policies for development; these have included the creation of employment opportunities and the provision of infrastructure. (McCutcheon, 1990). They tend to be focussed on light traffic roads, which are usually unsurfaced gravel or earth roads. Road surfacing using labour intensive construction is limited, and often refers to stone or concrete block type pavements. The use of stone surfaced pavements occurs in countries with abundant good quality material such as Cape Verde and Madagascar (Keddeman, 1998)

The surfacing of light traffic/light construction roads is usually justified on traffic volumes, minimisation of dust, and wet weather accessibility (Emery and Vos, 1993). For economic reasons, flexible or bituminous surfacings are generally used, and these are typically seals (chip and spray) constructed by plant. When labour intensive construction of roads became an issue in South Africa in the 1990s, the possibility of labour intensive construction of bitumen surfacings was researched by SABITA (1993a, 1993b). This included hot asphalt surfacings (asphalt is also known as premix or asphalt, as bituminous concrete in the UK, asphaltic concrete in the USA; hotmix in Australia; it is typically a mixture of 95% aggregate and 5% unmodified bitumen).

2 Research

2.1 SABITA Research in South Africa

The research undertaken by SABITA was governed to a large extent by quality issues. It was seen as important to control sufficient dimensions of quality to ensure that the surfacing met the standard expected of plant based construction. As an example of this, in a surfacing seal, the application rates of the bitumen and stone should be closely controlled to avoid bleeding or stone loss and get the development of a well-knit matrix.

In the SABITA research, each bitumen surfacing type was broken down into its components, to find those components which could be done using labour based techniques without sacrificing quality. It was assumed that small scale equipment would be used such as drum trolleys with hand sprayers, pedestrian rollers, rakes, brooms, etc. Originally asphalt was assessed as 'not really suited' for new layers, because there was no documented or personal experience with manufacturing and/or laying asphalt in large qualities by hand for new layers. Since the quality of construction could not be assured, then it was felt better to exclude it.

However a number of practitioners subsequently reported having laid asphalt by hand successfully, although none of these projects had been documented or researched. The need for further research was noted since asphalt is an appropriate surfacing for roads in urban developing areas (Emery, S.J, Alli, N. et al., 1994).

2.2 New role for asphalt on low traffic roads

Recent research into the road surfacing/tyre interface has indicated an increased role for asphalt as a surfacing on light construction/low traffic roads. Using the "Stress-In-Motion" technology for the measurement of tyre/pavement contact stresses, it was found that the three dimensional contact stresses of the tyre on the pavement play a major role in the life of flexible pavement surfacings. A tyre generates significant lateral and horizontal stresses on the road surfacing, as well as vertical stresses, even with free rolling, slow moving tyres. These lateral and horizontal stresses explain numerous examples of "surface" related distresses on light traffic pavements such as micro-cracking, ravelling (or loss of surfacing material), bleeding of surfacing seals, and degradation or "breaking-up" of the surfacings of low volume roads (De Beer M, Kannemeyer L et al., 1999).

With the new insight into stresses, it can be seen that the performance of the surfacing on roads is dependent on the tensile strength of the surfacing (to resist the stresses). Since bituminous pavements are usually primed to provide interlock between the surfacing and the basecourse, the quality of the prime and the tensile strength of the surfacing/basecourse combination are also of importance. This explains many field observations such as rapid failure of single sand seals relative to multiple sand seals, surfacing failures over weak basecourses, and better performance of thicker surfacings such as Cape Seal and asphalt (Emery, S.J., Van Zyl, G.D., et al., 1992). Asphalt will perform very well as a surfacing because of its inherent tensile strength, with typical specifications requiring a minimum of 800 kPa indirect tensile strength.

In fact suitably thick asphalt (say 40-50mm) could have sufficient tensile strength to replace the conventional seal/prime/base combination on roads with light traffic and suitable wearing course and lower layers. The gravel road could be directly surfaced by asphalt. This is a unique opportunity for effective but simple labour intensive upgrading suitable existing earth and gravel roads.

Currently in South Africa, when unsurfaced roads are being surfaced, there is usually extensive (and plant intensive) layerworks specified, because the uppermost layer or wearing course is below the standard needed for a surfaced road basecourse. However it means that any surfacing becomes a project of some magnitude with substantial investigation, design and engineering required. This typically leads to projects being at least a minimum size and cost to economically spread these overheads and leaves a large gap for most communities between what can be afforded and what is desired.

The concept of direct surfacing is that the asphalt is laid directly on the gravel wearing course. There would still be some preparatory works needed, including repair of ruts and corrugations, provision of suitable drainage, and removal of loose gravel and material before surfacing. However this should not be major works, and minor surface irregularities can be taken out by the asphalt. Some gravel or earth roads would be of too low a standard to surface at all. But for many unsurfaced roads, the concept of direct surfacing by asphalt opens a door to lower cost upgrading where the increased cost of asphalt over a thin seal would be more than balanced by the reduction of layerworks.

2.3 Research at University of Witwatersrand

It was timeous to research the technology for hot asphalt surfacing by hand, since this would allow direct asphalt surfacing to be done as a series of affordable small-scale labour intensive projects within the community. This research is in progress at the Centre for Employment Creation at the University of Witwatersrand with two aims:

- to capture, update to modern standards, and codify practice for using asphalt in labour intensive construction, and
- to develop a design method for asphalt that is labour-friendly but still has good performance.

This paper addresses construction. A literature search found very limited information on hand laying of asphalt. So extensive field interviews were then conducted in Cape Town, Durban, and Witwatersrand with practitioners who were laying hot asphalt by hand.

3 Construction

The construction of hot asphalt using plant based construction is shown in Figure 1. The process for labour intensive construction is broadly similar to this, except that the placement is done by hand.

3.1 Site preparation

The site preparation for labour intensive construction of asphalt surfacing is similar to plant based construction. This involves basecourse preparation by patching, levelling, and sweeping. Then a bituminous emulsion prime/tack coat is applied. There are various methods that can be used for the application of the prime/tack coat. These vary from hand distribution using a watering can, through backpack sprayers to the use of a hand held distributor spray bar that is attached to a hand pump and drum trolley. "Backpack sprayers tend to clog up easily and require a lot of maintenance; hand lances using a 220 litre drum are preferable to use" (Visser, 1999).

A watering can with a sawn off spout can be effective. The correct volume of binder to cover a predetermined surface area, e.g. 1 m^2, is calculated. The watering can is filled up with this determined volume and the comparative area required to be primed or tacked is marked out. This sets out the required spray rate for the labourer manning the watering can.

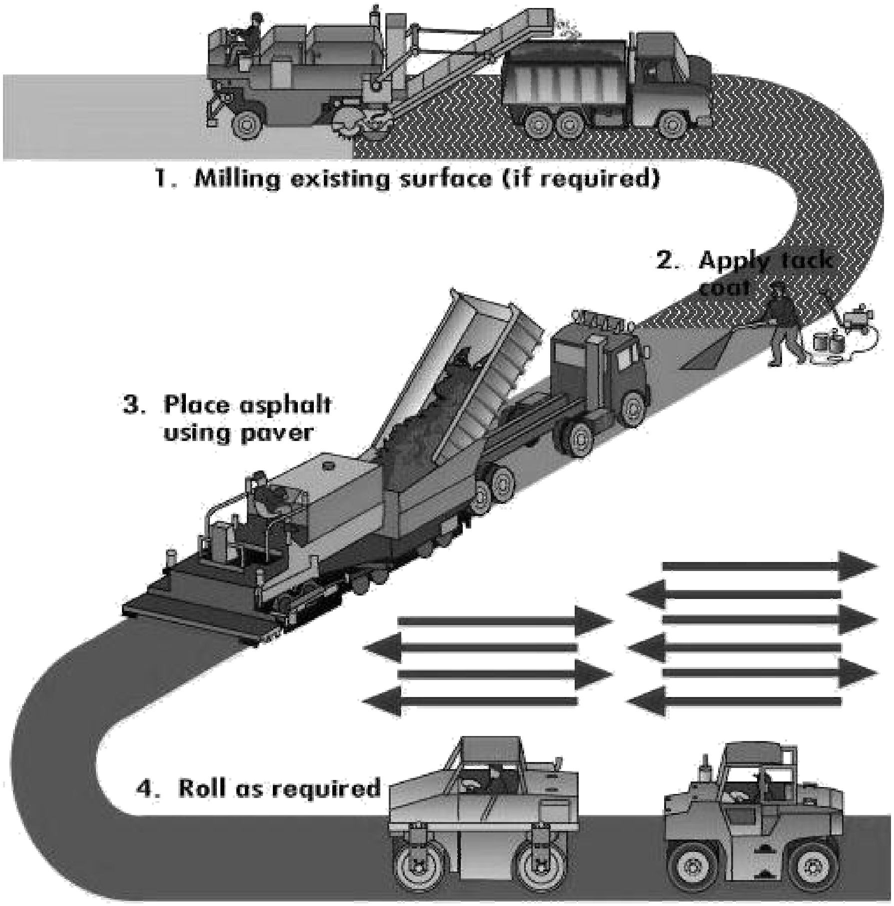

Figure 1 Asphalt construction process

3.2 Hot asphalt manufacture

Hot asphalt is manufactured (mixed) in fixed or mobile asphalt manufacturing plants, and there is no hot asphalt manufactured by hand in South Africa. Nor is manufacturing of hot asphalt envisaged using labour intensive methods. Apart from the safety issues of handling hot stone and binder, hot asphalt is a material requiring a complex mixing procedure to ensure uniformity of the product. Given the large volumes and tight production schedule involved (typically 50 to 200 tonnes per hour produced at $150^{o}C$), labour intensive methods are not suited. There is very limited production of small quantities of cold asphalt by hand using cutback bitumen or bituminous emulsion binders. This cold mix asphalt is used for patching, but the resultant product is often of poor performance and is not considered further here.

3.3 Hauling

The hot asphalt has to be hauled from the production plant to the site. In South Africa, and especially in urban areas, most asphalt manufacturing plants are in a fixed location and it is normal to haul asphalt by truck to the road construction site. For a kilometre of two lane road with a 40mm thick asphalt surfacing, some 600 tonnes of asphalt are needed, which would be a substantial quantity to move by hand. Labour intensive construction of asphalt would therefore usually involve truck haulage to site.

At the site the asphalt is unloaded to stockpile. When unloading, labourers should never stand inside the truck bed on the asphalt mass to shovel material over the side. This is dangerous for the shovel handler and also for the crew on the ground. Standing on the mix also causes differential compaction of the material in the truck bed (Grobler, 1999). A chute can be attached to the back of a tipper truck to assist in load placement of the asphalt. Trucks can also be equipped with side gates for easy access to the asphalt, and also for easier tipping into wheelbarrows if appropriate.

3.4 Site stockpiling

Asphalt can be successfully stockpiled on site for several hours until it cools down too much to be properly compacted. The asphalt cools down slowly in bulk when it is being hauled and stockpiled, and cools rapidly when it is spread in thin layers. It typically leaves the plant at 150^{o}C, and arrives on site at 130-150^{o}C. 'If the truck mix temperature is unsatisfactory, the mix should be rejected" (Everitt, 1999). 'It is imperative that the mix arriving from the plant should be as hot as possible" (Boucher, 1999). This suggests 135^{o}C as a likely lower limit for material acceptance for labour intensive construction.

In the relatively warm climate of South Africa, and with covered stockpiles of say 10 tonnes or more, the storage limit is probably 6 hours between manufacturing plant and laying in summer. In an urban areas with a haul of an hour, this translates to over 4 hours stockpile life.

In general, it is recommended to keep the stockpile mass larger rather than smaller, as this retains heat. The stockpile is often equivalent to one truck load (Newell, 1999). Splitting the asphalt into smaller piles dissipates the heat from the mix quickly. Since 10 tonnes of asphalt (which is a convenient truck size; any smaller will lose the advantage of heat retention in bulk) will cover 15 metres of 2 lane road at 40mm thick, this would be equivalent to stockpiles every 15 metres along the road. 'The layer of one truck load should be almost finished before the next load of the next truck is tipped, therefore reducing temperature losses" (Boucher, 1999).

Stockpiles will compact, due to the self-weight of the mix, at the base of the pile. Therefore mix from the base of a stockpile will be pre-compacted more than mix taken from the upper stockpile (Everitt, 1999). 'These pre-compacted areas will result in surface humps when the rollers are brought onto the mat for compaction" (van Steenderen, 2000), unless dumped or broken up before laying.

'The stockpile can be insulated with a tarpaulin placed on the ground prior to material placement, as well as by a tarpaulin covering the stockpile. This will retain the asphalt temperature, thereby improving the workability of the mix by ensuring adequate compaction" (Pillay, 1999). Bergh (1999) also recommends that asphalt should not be tipped onto the ground on site as this immediately cools the bottom layer of the asphalt. 'The stockpiled material can also be placed on steel plates, which will not only prevent ground contamination, but also retain heat from the stockpile" (Grobler, 1999).

3.5 Weather

Weather conditions are a large factor in the time available for stockpiling, laying and compaction, because of its effect on the rate of cooling of the asphalt. For plant based construction, thickish layers of asphalt can be laid down to near freezing conditions and even in damp conditions. For labour intensive construction, the minimum air temperature limit is much higher. It "should preferably be done in hot seasons" and "don't lay asphalt using labour intensive construction methods in rain" (Bergh, 1999). This is echoed by Boucher (1999) who adds that "hand laying of asphalt should be done only on nice hot days". Everitt (1999) also emphasises this point. Since wind plays a big role in cooling, a windy day may also find the asphalt cooling below minimum temperature too quickly to get density. Work should not start if rain will occur before compaction can be completed.

3.6 Construction team

The asphalt construction team is typically made up of the following people:

- Foreman,
- Rake men and labourers, with wheelbarrows, shovels, brooms, rakes/lutes to spread the asphalt,
- Screed board operators, with screeds to level the asphalt prior to compaction,
- Roller operators,
- Traffic controllers, surveyor, and checker (if required) (Newell, 1999).

Bergh (1999) estimates that at full productivity, a team size of seven labourers could spread, lay and compact seven tonnes per day of asphalt road surfacing, with complete finishing to a high quality standard. As a comparison, Boucher (1999) reported that during carpark construction (25mm thick of fine graded asphalt surfacing) he was laying 30 tonnes of asphalt per day with the following 9 people:

- three labourers manning wheelbarrows;
- two rakers;
- two labourers loading and shovelling;
- one roller operator (using a full sized roller);
- one Foreman (working as a raker).

3.7 Tools for spreading and laying

The main spreading tools for asphalt are the rake and the lute. A square nose shovel can also be used to level off any irregularities on the surface of the loose mat. The rake is used for the lower asphalt layers and the lute is used for finishing off the upper asphalt layers. The rake and lute are also used for the construction of both the longitudinal and transverse joints (NAPA, 1994).

- Rakes should be made of steel and are used to move large volumes of mix and so work well on bases and large stone mixes (NAPA, 1994).

- Lutes should be of a lighter construction than rakes and preferably made of aluminium. Lutes consist of both a rake and a flat blade and should be treated with more care. They are often used as the finishing tool on the final layers of asphalt (NAPA, 1994).
- A normal rake width is 30 cm. However, the wider the rake width, the better its levelling capabilities are as well as its ability to produce a smooth surface finish. De Jager (1999) modifies an ordinary rake into a lute by bolting on a 1 m long skirting board to the rake. This rake/lute combination is cheap, easily replaceable and also lightweight. Smooth surface finishes are achieved with this tool modification.
- The rake tines should not be less than 13 mm longer than the loose depth of mixture and spaces between the tines should not be less than the maximum aggregate particle diameter with the minimum width between tines of 25 mm (Country Roads Board of Victoria, 1954).

The wheelbarrows and all the steel tools should be preheated at the beginning of the working day by inserting into a mass of asphalt or warming up using a gas burner. The wheelbarrow can also be loaded with hot asphalt to warm it, which is then dumped. The cold surface interface of the tools will cool asphalt so rapidly that it sticks to the tools and reduce the ease of handling. "The tools should also be kept clean for ease of work with them by periodically dipping and cleaning the tools in a container filled with diesel" (Fredericks, 1999). This ensures that no unnecessary excess asphalt accumulates on the tools. The container can be a wheelbarrow for ease of motion or a 100-gallon drum cut in half. The tools should be wiped dry after cleaning to prevent excess diesel from coming into contact with the asphalt on the road.

3.8 Spreading and laying

The hot asphalt is moved from the stockpile to the road by wheelbarrow. "The labourers should load the wheelbarrows asphalt from all sides of the stockpile to prevent a temperature differential occurring across the mass of the asphalt. This will maintain a reasonably constant temperature throughout the mass of the asphalt stockpile" (Grobler, 1999).

The asphalt is spread from the wheelbarrows by shovel. The material in the shovels should be kept in a mass when placed. "Do not dribble or broadcast the mix off the shovel, this only results in a segregated mix with poor compaction qualities" (NAPA, 1994). "It should be deposited from shovels into small piles and spread with lutes" (Asphalt Institute, 1983). "The raker should indicate to the shovel hand where to deposit the mix off the spade. A straight, controlled throw, keeping the wrist rigid, will ensure that the mix is kept in a mass when placed a distance from the shovel. This technique ensures regular and neat placement of the mix, minimising segregation" (NAPA, 1994). "The best and most uniform placement of the mix with the shovels is obtained when the material is deposited by merely turning the shovel over above the desired point instead of sliding the material off the end of the shovel or slinging it. Sliding the material off the shovel deposits it in individual piles that require excess raking time and effort" (Newell, 1999).

The asphalt is dumped on the surface, and spread by rake and lute. "The best tool for raking premix is not the rake but a lute" (Newell, 1999). Nearly all of the rakers' work should be done with a lute, not a tined rake (Colas North, 1999; Wallace and Martin, 1967). The lute/rake work should be higher than the previously laid pavement to allow for proper screeding and compaction. The new area should be even and parallel to the required finished surface. A good finish depends on the right amount of material being placed prior to compaction. Where paving commences from previous work such as a longitudinal or transverse joint, the rake man should hand work the mix to be sure that it is level and matched with the existing pavement. "Sight by eye, and then check with a straightedge if there is any doubt" (Newell, 1999).

When hand raked, the larger particles are worked to the surface (segregation) leaving an open surface texture and unsightly appearance. The tined rake causes worse segregation than a lute, so should be predominantly be used to loosen partially compacted areas preparatory to reshaping it (Wallace and Martin, 1967). A good raker uses a least amount of time necessary to spread the material evenly before rolling, because excess raking cools the mix rapidly (Colas North, 1999). Treat any segregated areas with fines from the asphalt before compaction (BACMI, 1992). Raking is done to remove oversize aggregate and lumps, improve appearance, and ensure that it is not crushed and exposed at the edge of a longitudinal joint during compaction (NAPA, 1994).

The labourers should not work into a corner, and especially not walk on the finished work areas prior to screeding (Newell, 1999; Asphalt Institute, 1983). Walking on the material prior to screeding will result in differential compaction of the mat during the rolling procedure. This will lead to surface irregularities occurring during the screeding and the rolling process.

3.9 Screeding

Screeding (levelling and smoothing) of the asphalt must be undertaken to ensure that the particle orientation in the wearing course is correct. A "surface evenness equivalent to a [machine] paver finish can be achieved by screeding the mix" (Pillay, 1999). Screeding is undertaken manually by means of a screed plank, and screed rails upon which the screed plank is drawn; this is operated by two or more labourers.

Lane width, ease of handling of the screed plank over the screed rail, and roller width all dictate the paving width. However, screed planks spanning more than 4m will result in a difficult screeding procedure for the labourers manning the plank. The excess hot mix asphalt accumulating in front of the plank will make it difficult for the screed plank to be manoeuvred and thus slow down the screeding process.

The screed rails variously consist of:

1. Varying diameters of galvanised steel plumbing pipe depending on pre-compacted lift thickness (Grobler, 1999, Pillay,1999). Galvanised piping is preferred as a screed rail compared to wooden planks. The length of screed rail can consist of 3 x 6 m galvanised pipes on either side. The pipe diameter will relate to the uncompacted depth of asphalt required (Visser, 1999).
2. Various cross-sectional steel material shape lengths such as I-sections, box-sections or even castellated I-sections for long spans that require a lighter screed rail for manoeuvrability.

The manoeuvrability of the screed rails is important, and this is mainly dictated by the mass of the screed rails. The rails should not be too light and flexible as this could lead to unsatisfactory surface smoothness tolerance as the rails conform to the unevenness of the base upon which the wearing course is laid.

There are various recommendations for the screed plank:

1. Bergh (1999b) recommends a heavy steel box section, thick scaffolding timber or a heavy I-section. Handles can be welded on each side of the box section/I-section. Everitt (1999) also notes that a steel box section or I-section should be used as a screed plank.
2. Grobler (1999) recommends that a railway beam be used as a screed plank. Steel handles using solid bar can be strategically welded to the rail for ease of manoeuvrability.
3. A heavy steel angle iron can be used as a screed plank (Visser, 1999).
4. Boucher (1999) finds that asphalt tends to stick to a steel screed and that the labour finds it difficult to screed the asphalt.
5. A spirit level can be mounted on the screed plank so that the roadway crown can be checked any time (Sabita, 1992).

While screeding, a bow wave formation will occur in front of the screed plank. This bow wave should be kept constant at a height of 50 mm above the screeded level (Visser, 1999), to reduce the resistance imparted by it to the screeding action. Everitt (1999) comments that the bow wave should be kept as small as possible to prevent the screed plank from being obstructed by the excess asphalt accumulating in front of the plank. The rakers should handle and distribute the material that accumulates in front of the screed plank as well as that material that is lacking after the asphalt has been screeded.

Visser (1999) recommends that the screed operators drag the screed plank longitudinally along screed rails, without oscillating the screed plank perpendicular to the screed rails. This is to ensure that a constant bow wave is maintained in front of the screed plank and that the screeded surface finish is smooth and free from scuffing blemishes.

Walking on the screeded asphalt mat prior to rolling must at all cost be prevented, as this will damage all the levels so carefully prepared by the rake men. Use a straightedge and level or a stringline frequently to check any irregularities and cross falls of the screeded material, prior to rolling and these corrected if required (Country Roads Board of Victoria, 1954; Asphalt Institute, 1983). The mat behind the screed board should be examined frequently for excessive or insufficient binder and for aggregate segregation. Unsatisfactory material should be removed by a rake or hoe and replaced with new asphalt (Country Roads Board of Victoria, 1954).

3.10 Compaction

The time available for compaction of the asphalt is limited by the increase of viscosity of the bitumen in the cooling asphalt. The upper viscosity value for compaction is 20 Pa.s., and laboratory test results for a 60/70 grade bitumen suggest 85°C as a cessation temperature for asphalt compaction. Specifications often state that substantial completion of compaction is needed by 90^{o}C.

In plant based construction, the ideal compaction time for a bituminous material is taken to be about 12 minutes. This provides for breakdown, intermediate and final rolling, and allows the required number of passes to be made, consistent with typical paving and rolling rates. Times less than 8 minutes are considered to be too short to enable a sufficient number of roller passes to be achieved (Nicholls and Daines, 1993).

Steel wheeled rollers can be used for all three rolling stages. Pneumatic tyred rollers (PTR) are rarely used for breakdown rolling but are generally preferred for intermediate rolling. Vibrating rollers are also used primarily for intermediate rolling (Sabita, 1992). The number of roller passes required to meet the specified density varies with mix. A typical method statement is 4 passes with a steel wheel roller and another 6 passes with a PTR. These all have to be completed in the short time available for compaction.

It was generally found that the interviewees visited on labour intensive construction sites used the same conventional rollers that are used on larger plant construction projects. Boucher (1999) had a 8 tonne vibratory roller that he also used in the static mode as well as a Bomag 90 pedestrian roller. However, he commented that he hardly ever used his smaller pedestrian roller, preferring to achieve quicker compaction with the heavier vibratory roller. Fredericks (1999) had three rollers on his site; a 2.5 tonne vibratory roller, an 8 tonne static roller and also a 9 wheel PTR.

Grobler (1999) uses conventional heavy-duty rollers for compaction on labour intensive construction of asphalt mats. The compaction of the asphalt mat is the most critical phase of the construction process and so therefore, compaction has to be achieved in the shortest optimum possible time. 'Employment is created either way, whether an operator stands behind a pedestrian roller on sits on and operates a self-propelled roller".

This use of plant was unexpected, but because the available time for compaction is so short, these contractors have found that compaction requires the same methods as plant based construction.

4 Summary

The practices captured in this paper have come from extensive interviews and a review of the limited literature available. They are considered sufficient to codify the labour intensive construction of hot asphalt surfacings to modern standards. It is evident that asphalt surfacings can be built by hand using these techniques. The research did not quantify or compare the quality of surfacings constructed by labour and plant, but the interviewees were constructing asphalt surfacings of sufficient quality to be accepted by consulting engineers and road authorities.

The next stage in the research is to measure the performance and workability of various hot asphalt mixes. It is known that the workability of asphalt varies with the design and type of mix. There is often an inverse linkage between workability and performance, with a very workable mix being prone to shoving or rutting under traffic, and possibly bleeding. The goal is to develop the asphalt mix design guidelines for a labour friendly mix which give good performance.

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