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GEOTEXTILE REINFORCEMENT OF PAVEMENTS

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Introduction

Since the early 1960's, polymeric geotextiles have been used to seal, bond, and ultimately reinforce asphalt pavements. This paper looks at the development of a new generation of paving grade fabrics and composites and the potential for reinforcement they offer. Their design, handling and placing in the construction are examined. Design considerations relating to bituminous macadam and asphalt mixtures are also discussed as well as the importance of mixing, transportation and rolling temperatures.

Fabrics and Composites

The design of pavement fabrics is the product of tensile strength, bitumen retention and thickness. Whilst the tensile strength of a paving fabric has importance mainly in resisting installation stresses whilst improving the strength of the pavement through the benefits of improved interface bond, sealing and stress reduction, a paving composite offers high tensile strength to add direct reinforcement to the pavement. The bitumen retention characteristics of a paving fabric are important to the achievement of bonding strength and interface stress reduction.
The mechanical placement of paving fabrics at the site is recommended, though hand-laying is possible. Fabrics should be laid wrinkle-free into a pre-determined volume of residual bitumen, and site traffic should be kept to a minimum to ensure cleanliness.

Design of Mixtures

Whilst the inclusion of a paving fabric or composite in a pavement system will improve its performance, equal consideration must be given to mix design, transportation to the site and temperature control both at the plant and during compaction. The size and shape index of the aggregates used in the mix composition, and the grade of bitumen in the high temperatures experienced in India are of paramount importance in the successful conclusion of the works.

Conclusions

The addition of paving fabrics or composites as part of a pavement system is only one part of the equation. The mix design, depth of construction based upon up to date traffic analysis, and a functioning drainage system all play a significant part in the long-term performance of the road.

According to O'Flaherty,(1) ' A highway pavement is a structure of superimposed layers of selected and processed materials whose primary function is to distribute the applied vehicle loads to the sub-grade.....the effect is to reduce the stresses through the pavement layers so that they do not exceed the bearing capacity of the sub-grade'.

A simple, basic design concept which was well known in Roman times, and was even mentioned in the Bible - Genesis 11:3.....'they used bricks for stone and bitumen for mortar'.

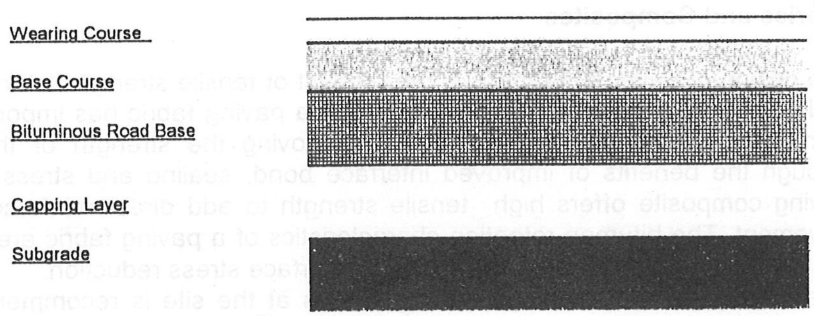
With such a wealth of knowledge and experience, how do we continue to get it so wrong, with rising maintenance costs forced by failures a regular occurance - perhaps engineers are not interested in history, or more likely cost constraints and modern traffic conditions conspire to cause cost cutting in design or low estimates of traffic growth.

Pavement Types

In considering the basics, there are three generic pavement types, with a range of possible variations:

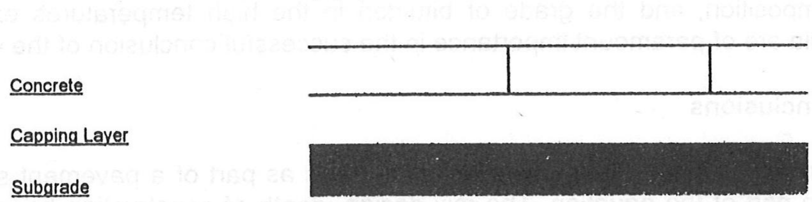
- Flexible pavement design depends on structural mechanics causing the pressure on the sub-grade to be reduced by lateral distribution of the imposed load within the depth of the pavement structure. (Fig.1)

(Fig.1) FLEXIBLE PAVEMENT CONSTRUCTION



- Rigid pavements rely mainly on beam and slab distribution of the imposed load from the pavement structure onto the sub-grade. (Fig.2)

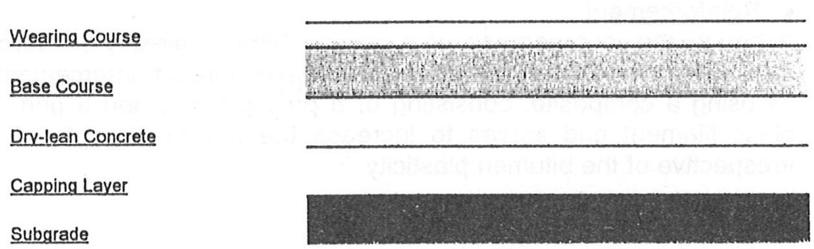
(Fig.2) RIGID PAVEMENT CONSTRUCTION



Sub-grade deflection under the rigid slab causes the slab to act as a bridge over local problem areas in the sub-grade, with the pavement design being based primarily on the tensile or flexural strength of the slab. However in flexible pavement design the strength and uniformity of the sub-grade is of prime importance. The evaluation of the sub-grade service strength and performance throughout the pavement life should be the engineers aim.
Given that the pavement is not overloaded, the sub-grade will not fail in isolation - more often the causes of failure can be traced to collapse of the drainage system and poor sealing of the pavement surface, which together do not maintain the sub-grade in its design condition.

- Composite or semi-flexible pavement design consists of bituminous mixtures laid on lean-mix concrete, and is one of the most cost-effective methods of pavement construction, but its inherent failure patterns of reflective cracking have made it less attractive to highway engineers.(Fig.3) (2)

(Fig.3) COMPOSITE PAVEMENT CONSTRUCTION



Fabrics and Composites

The technique of introducing a fabric to prevent the development of reflective cracks is not new. As long ago as 1935 (3) cotton fabrics impregnated with bitumen were used in southern California in the USA. In the 1950's trials using galvanised steel grids were carried out which showed little or no benefit in the control of reflective cracking. Under the auspices of the Federal Highways Administration (FHWA), many states in America have since carried out tests to evaluate the application and performance of paving fabrics, and the majority of these studies conclude that they serve as a waterproofing membrane which significantly reduces reflective crack damage on deteriorated pavements. In Europe, the use of paving fabrics began in the mid - 1970's, using similar technology to that employed in the USA but continuing product refinement and development through laboratory research and practical application. It is widely recognised that the introduction of a paving fabric alone cannot improve the bearing capacity of the pavement. Rather, they act as a component of a bitumen binder system which improves and therefore indirectly reinforces the pavement.
Since the early 1960's, polymeric geotextiles have been used to seal, bond, and ultimately reinforce asphalt pavements and overlays. The development of manufacturing techniques and the search for better, more cost effective highway maintenance methods has resulted in the introduction of a new range of composites which offer direct reinforcement, as opposed to the secondary reinforcement of paving fabrics alone. Both galvanised steel and polymer grids have long been used in basal reinforcement of road structures, but they neither seal the pavement nor do they offer improved the interface bond necessary in road maintenance - the challenge was to design a composite paving geosynthetic to

reliably achieve direct reinforcement together with the sealing, bonding and stress reduction properties of a fabric.

Functions

- <u>Sealing</u>

The primary function of a paving fabric is to permanently prevent the penetration of surface water and oxygen into the road structure. This is achieved by the application of a bituminous tack coat directly onto the existing road surface followed by the installation of the paving fabric. The saturated paving felt acts as a bitumen reservoir, effectively sealing the pavement structure.

- <u>Bonding/Stress Reduction</u>

The shear resistance at the interface between the existing road surface and the new overlay must be sufficient to prevent shear yielding through traffic stress. The adhesion between the pavement layers is a significant factor in the stability and durability of the road construction, and the inclusion of a paving fabric achieves a higher level of bond security than is possible with normal techniques.

- <u>Reinforcement</u>

Although the incorporation of a paving fabric indirectly reinforces the pavement structure through improvement of the system, direct reinforcement can be achieved by using a composite, consisting of a paving fabric and a grid. The addition of a glass filament grid serves to increase the tensile strength of the asphalt layer irrespective of the bitumen plasticity.

Installation

The installation of a paving fabric can be easily separated into three parts;

- <u>Preliminary Works:</u> The site is cleaned, and pot-holes and cracks exceeding 4mm wide are cleaned and filled. In extreme cases it may be more suitable to apply a regulating course.
- <u>Installation Works:</u> The selected bituminous tack-coat is applied through a metered spray-bar and the fabric or composite is mechanically laid. In small or restricted areas the paving fabric may be hand-laid. Wrinkles in the fabric must be avoided.
- <u>After-care:</u> Surfacing work should proceed as soon as possible after installation. If surfacing is delayed, traffic movements must be kept to a minimum to ensure cleanliness of the fabric and to prevent damage.

Mix Design

In the early part of the 20th century, the main requirements of a road surface were basically that it should be low cost and durable. At this time, the majority of both major and minor routes in the UK were surfaced using bitumen macadam to BS1621, which appeared less durable as traffic volumes and axle loadings increased. Highway engineers saw that durability would be improved if dense, impermeable mixes were used, and the publication of BS594:1950 (4) 'Rolled Asphalt for Trunk Roads', and the development of dense bitumen macadam which first appeared in BS1621:1961 (5), reflected this awareness. Later, in the early 1970's it could be seen that these 'recipe' mixes were unable to cope and were deforming under ever increasing traffic. For today's traffic volumes, bituminous mixes must fulfill a wide range of requirements including:

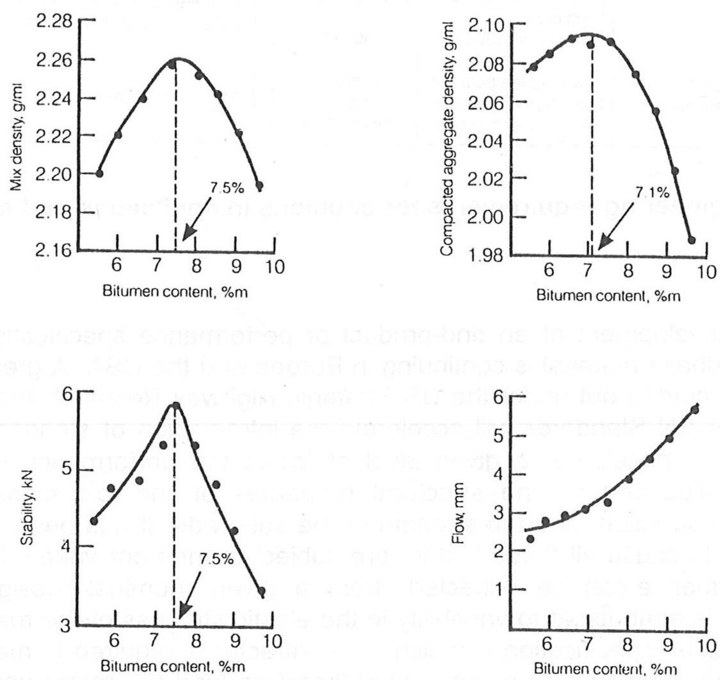
- resistance to deformation and fatigue cracking
- impermeability, to protect the road structure

- durability, to reduce maintenance costs
- strength, to add to the pavement structure

Additionally it should be quiet, skid resistant and smooth.

Recipe mixes are defined in terms of aggregate grading, mix composition, and the method of manufacture, installation and compaction. They are based on wide experience of known mixes which have performed well in a given situation. They are however limited in application, as the conditions at the site are unlikely to match the conditions when the recipe mix was first evaluated, and mixing variances at the plant could result in necessary changes which cannot be assessed. Although changes in the mix are easily checked against the relevent specification, it is by no means certain that a mix failing to meet the specified limits is defective; indeed the opposite could be true.

Design mixes involve the choice of aggregate type, aggregate grading, bitumen grade and bitumen content to deliver the optimum engineering properties as well as the performance required in the pavement. The bitumen content is the most critical part of design mix methodology, and is based on laboratory test procedures using the Marshall method or other methods involving the use of triaxial or creep tests. Generally the method employed today is to average the optimum bitumen contents shown to produce peak values for certain mechanical properties, density and voids content as used in BS598:1985 (6), Marshall Design Curves (Fig.4). (7)



$$\text{Optimum bitumen content} = \frac{7.5 + 7.5 + 7.1}{3} = 7.4\%$$

For a 30% stone content mix the design bitumen content = 7.4 + 0.7 = 8.1%

(Fig.4) Marshall Design Curves to BS 598:1985

Effect of High Temperatures

Permanent deformation occurs theoretically throughout the pavement structure, however as asphalt mixes have a low thermal conductivity, in practice the majority is plastic deformation of the wearing course. This occurs under moving or statonary traffic, and particularly under the high shearing stresses caused by braking, accelerating or turning. The primary factor influencing plastic deformation is the mix composition, but behaviour is also influenced by the viscosity of the bitumen. The viscosity/temperature relationship or Penetration Index in this region is important because it determines the temperature range over which the viscosity of the bitumen remains at a suitable level for compaction. (Tab.1)

Behaviour during	Condition		Significant property of the bitumen in the mix
	Temperature, °C	Time of loading, s	
Application			
Mixing	High (>100°C)	–	Viscosity, approximately 0.2 Pa.s
Laying	High	–	Viscosity
Compaction	High	–	Viscosity, minimum 5 Pa.s, maximum 30 Pa.s
In service			
Permanent deformation	High road temperature (30-60°C)	Long $>10^{-2}$	Minimum viscosity determined by penetration index and the softening point of the bitumen
Fatting up	High road temperature (30-60°C)	Long $>10^{-2}$	
Cracking			
– Traffic stresses	Low road temperature	Short (10^{-2})	Maximum bitumen stiffness
– Thermal stresses	Low road temperature	Long	
Fretting	Low road temperature	Short (10^{-3})	

(Tab.1) Engineering requirements for bitumens in application and service

Conclusion

Work on the development of an end-product or performance specification (8) for bituminous roadbase material is continuing in Europe and the USA. A great deal of work has been carried out under the US Strategic Highway Research Programme, and in Europe CEN Standards will accelerate the introduction of standards based on 'fitness for purpose'. For a given level of traffic the performance of a road pavement is influenced by the structural properties of the laid materials, the thickness of construction, and the strength of the subgrade. It has been shown by Powell (9) that because all these factors are subject to inherent variability, a wide range of performance can be expected from a given nominal design. Some of this range is attributable to variability in the elastic stiffness of the roadbase. A performance based specification in which the contractor is required to maintain his material at a specified level of quality would therefore lead to greater uniformity in pavement performance.

An adequately stiff bituminous roadbase limits the vertical compressive strain and hence the deformation of the subgrade, but it does not provide a measure of the deformation of bituminous materials. Assessment of deformation in the bituminous layers is important for heavily trafficked roads, and can be measured by a creep test.(10)

The resistance to cracking of a roadbase layer under traffic is commonly associated with repeated uniaxial loading in the laboratory, which can underestimate the observed pavement life. However a fatigue test will indicate whether a particular roadbase material is susceptible to premature cracking.

The selection, design, installation and performance of a paving fabric or composite requires an assessment of all the contributing factors to ensure the full benefits of the system are maximised. Some improvements will certainly be accrued from its inclusion in the pavement but it is not the remedy for all the ailments of a poorly constructed road, nor will it make up for inadequate or badly maintained drainage. Questions to be asked include:

- What were the design parameters of the original construction?
- Is the subgrade damaged?
- Is the road crust sufficient - what is the mix design and construction depth?
- What is the condition of the drainage - are the ditches free of vegetation and obstructions?

Finally, having designed the overlay and taken the decision to include a paving fabric, a question often asked is 'How much can we reduce the pavement thickness now that we are installing a paving fabric?' The answer is simple - do not reduce the overlay thickness. The inclusion of a paving fabric will increase the design life by a factor of two or three - if the thickness of the overlay is reduced, that benefit is also reduced.

References

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