Cold Mix Asphalt Concrete and Microsurfacing for coloured wearing courses

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ABSTRACT

Coloured bituminous surfacings are used to make roads in urban or touristic areas more visually attractive and also for reasons of comfort and safety. In these materials black bitumen is replaced by a translucent synthetic binder, whose colour can easily be modified by pigments. This is done, for example, for the wearing course in tunnels. In tunnels, these light-coloured surfacings are preferred to traditional black surfacings as they provide an improvement in visibility and safety with a lighting saving of approximately 30%. Using microsurfacing overcomes the problems posed by removal of the heat and fumes produced when hot mixes are laid. This paper aims to present the results of research which has let the development of two coloured emulsion products that are able to meet the specifications for tunnel wearing courses. The first part of the paper deals with the development of a coloured microsurfacing with continuous or gap 0/6 grading. The laboratory mix design study is presented, then a number of applications, both white and red, are described. The second part of the paper deals with a light-coloured emulsion asphalt concrete with 0/6 grading that is laid with a paver in a thickness of 2 to 3 cm. The results of the laboratory studies which have established the performance of this product in terms of workability, rutting resistance and skidding resistance are described. We then present a worksite where the product was used. This product was awarded the Siemens Price for Innovation in 2001.

KEY WORDS

Wearing course, colour, emulsion

1. THE REQUIREMENT

Coloured bituminous surfacings are a response to one of the major concerns of infrastructure owners: the differentiation of traffic lanes and making urban sites more visually attractive. The development of the use of synthetic pigmentable binders has resulted in a considerable increase in interest in colour in the area of roads (Brosseaud, 2002).

The worksites where coloured materials are laid are rarely large. In addition, the manufacturing and laying equipment must be perfectly clean to avoid modifying their colour. The organizational constraints are therefore stronger than for worksites where traditional materials are used. Although emulsion-based materials require a high degree of technical skill, they provide flexibility during laying which is very much appreciated under these circumstances.


Figure 1 : Red microsurfacing applied on the bench of the Seine river in 2000.

Coloured surfacings are also of particular interest in another domain − tunnel pavements. Light-coloured surfacings are preferred to conventional black surfacings in tunnels. First, they improve visibility and safety, and second, they allow the level of lighting to be reduced by approximately 30% (Apville, 2002). The use of hot mixes to construct wearing courses is now well mastered, but it raises issues of the removal of heat and fumes. The constraints associated with resolving these problems increase the complexity of worksite organization. An effective and elegant response to this question is to construct the wearing course using emulsion-bound materials, which overcomes the problems related to temperature and the removal of fumes.

Thus, the development of coloured microsurfacing is able to provide a response to these various requirements.

In view of the foregoing considerations, Colas has improved an existing product, a microsurfacing, to enable it to withstand the stresses that are generated by high traffic levels. What we have learnt in the course of this optimization has enabled us to develop a very thin cold mix asphalt concrete with in-service properties which are comparable to those of hot mix very thin asphalt. The aim of this paper is to present the two new products.

2. AGGREGATE AND PIGMENTS

The aggregates were selected as specified in the french standard XP P18-540. The minimum characteristics were those of materials in class B III a. The polished stone value was also taken itno account in this class. The colour of the aggregate was selected on the basis of the colour desired for the surfacing. This is because after a few months of service the binder film which covers the aggregate is removed under the action of traffic and the natural colour of the aggregate appears. While it is true that the mastic around the aggregate particles retains the colour given by the pigment, it is better if the aggregate itself plays a role in ensuring the surfacing's colour durability.

Mineral pigments are to be preferred to organic ones as they have greater chemical stability and therefore withstand UV radiation better. The proportion of pigment is generally between 0.5 and 2% by mass of the total mass of the granular skeleton.

Figure 2 : Red microsurfacing on the bench of the Seine River (Rouen) in use.

The pigment should be considered as being a part of the granular formula when the target binder content of the mix is being assessed. In addition, it has been observed that the nature of the pigment has a considerable influence on the workability and cohesion build-up of microsurfacing or very thin cold mix asphalt concrete. A laboratory investigation of the compatibility between the pigments and the emulsion must therefore be systematically undertaken.

The mineral pigments used are metal oxides or salts, see Table 1.

Table 1- Some types of mineral pigments

Desired colour	Pigment
Red, yellow	Iron oxides
Light yellow	Lead Chromate
Green	Chromium oxide
White	Titanium Dioxide
Blue	Cobalt oxide or aluminate

The final colour depends on how well the pigment is dispersed in the final mixture.

The selected pigment can be added to the granular mixture just before it is fed into the mixer. It is also possible to add the pigment to the emulsion. However, for this method, which has the advantage that it simplifies manufacture of the mix, it is necessary to solve the question of the stability of the dispersion of the pigment in the emulsion. In addition, if the binder and the pigment are added together, their proportions cannot be varied separately. Lastly, in the case of microsurfacing, the pigments can be added to the granular mixture when the granular formula is recomposed. This last solution results in homogeneous proportioning and mixing of the colouring. The amount of materials necessary in order to perform the works must, however, be accurately evaluated.

3. THE EMULSION

This is a slow or semi-slow breaking cationic emulsion, with a synthetic binder content of 60%. A 70/100 pen or 50/70 pen binder is used depending on the traffic or the climatic stresses to which the wearing course will be subjected. In the case of traffic levels higher than T2, we recommend the use of an elastomer-modified binder emulsion. Colas now produces its own range of synthetic binders.

The emulsion is designed in order to provide the microsurfacing or the very thin cold mix asphalt concrete with the workability and cohesion build-up required for the application (Deneuvillers, 2000, Serfass 2002). The average characteristics of these emulsions are set out in Table 2.

Table 2: Average characteristics of the emulsions used for coloured mixes

Characteristic	Average values	Test standard
Water content (%)	39 - 41	NF EN 1428
Sieve test Retained fraction (630µ) (%) Retained fraction (160µ) (%)	 < 0.1 < 0.1	NF T66-016
STV pseudo-viscosity, sec. (4mm, 25°C)	< 10	NF EN 12846
pH at 25°C	< 3.0	NF EN 12850
Settlement after 7 days (%)	< 10	NF EN 12847
Breaking index	> 120	NF EN 13075-1

The proportion of emulsion in relation to the granular mixture depends on the type of product that is manufactured.

4. COLORIMETRIC CHARACTERISTICS

The perception of colours is a complex process which involves both quantifiable physical phenomena and the observer's reaction, which is influenced by culturally determined factors such as the ability to perceive and describe the differences between shades of colour.

4.1. The aggregate

An attempt can be made to reduce this complexity by measuring the colorimetric characteristics of aggregate to help in aggregate sourcing decisions. In the course of our research we have specified a technique for determining these characteristics. In particular, in the case of white aggregate we have decided to define whiteness criteria on the basis of research conducted in order to measure the whiteness of paper.

4.2. The surfacing

Increasing use of coloured surfacings has led the French Government to lay down guidelines for the choice of colours according to the intended use of the coloured structure (SETRA-CSTR, 1998). However, this note provides no instructions for colour measurement. The only quantities that are measured are the photometric properties of the surfacing, that is to say those which are involved in the reflection of light by the surface of the wearing course (SETRA-GNCSS, 1997).

Our research used a colour referencing system derived from the CIELAB-1976 system, on the basis of which we were able to define and measure quantities that express brightness, the red-green chromatic component and the yellow-blue chromatic component. Field observations combined with ageing tests have enabled us to establish the origin of the early age change in colour. We then undertook research to determine the relationship between the initial colour parameters and the colour parameters after three months of average sunshine in France. Likewise, for the photometric characteristics, we have developed mix formulae which enable the light-coloured surfacings in question to be classed in the category R1 as defined by the International Commission on Illumination (C.I.E.).

5. MICROSURFACINGS

5.1 The classes of microsurfacing defined

These are described in Table 3.

Table 3: The classes of coloured microsurfacing

Grading	0/4	0/6	0/8	0/10
% passing,				
10 mm	100	100	100	95-100
8 mm	100	100	95-100	85-95
6.3 mm	100	95-100	85-95	80-95
2 mm	35-45	35-45	40-50	40-50
0.08 mm	6-10	6-10	6-10	6-10
Richness modulus	4.2	4.0	3.9	3.8

If sand with either no filler content or a very low filler content is available, a 0/1 formula is possible, for use for example on cycle paths on a new substrate.

No special machinery is required for laying the microsurfacing. However, to obtain the desired colour, the laying equipment must be perfectly clean.

5.2 Examples of works

In 2000, the banks of the Seine in Rouen were surfaced with a 0/4 red microsurfacing. The total surface area of the site was 11 000 m², see figures 1 and 2. The banks were renovated for the “Armada du siècle” tall ships event and are now open to pedestrians, cyclists and skaters.

In 2001, the hard shoulders which are used as cycle paths on the National Road 1 in Saint Benoît in Reunion Island were surfaced using white 0/6 microsurfacing. The total surface area for this application was 6,500 m² and quartzite was used as the white aggregate. The proportion of titanium dioxide was 1%. The same microsurfacing had been laid as a wearing course on the RN2 – at St Pierre, in Reunion Island once again. Photometric measurements place these surfacings in class R1 according to the CIE standard definition. As a result of the success of this first application, in 2002, 37,000 m² were laid on the emergency lane of the RN1 as a cycle path.

6. VERY THIN COLD MIX ASPHALT CONCRETE

6.1 The product.

The research that we undertook for the mix design of the microsurfacing led to advances in the formulation of synthetic binder emulsions that are able to coat 0/6 aggregate particles and provide the mix with controlled workability and cohesion build-up. We therefore decided to apply this knowledge to the formulation of a very thin 0/6 cold mix asphalt concrete to be laid with a paver and which would have similar service properties to a hot mix very thin asphalt concrete. The characteristics of the aggregate and the emulsion were identical to those described above.

The mix is manufactured in a conventional cold mixing plant. An additive is used to adjust the workability of the mixes to suit the characteristics of the worksite in question, principally transport distance and weather conditions. The mix is laid with a paver and compacted using the usual techniques for mixes of this type. We should mention once again that in order to obtain a controlled colour it is essential to use perfectly clean equipment. The first experimental worksites were conducted by Colas Centre Ouest in the framework of an innovation charter which brought together Colas, the SETRA and Cofiroute, (Ballié and Poirier, 2002).

The works were conducted on a rest area on the A10 motorway. Bonding to the substrate was obtained by means of a rapid breaking synthetic binder emulsion, with a spread rate of 300 g/m². The mix was laid in a thickness of 2 cm. The laying train consisted of a paver and two compactors. The final binder content of the mix was 6.1% and the pigment content (titanium dioxide) was 1.5%. The characteristics of this mix are described in the next section of this paper.

The points below emerged from one year's monitoring of the site. There was no change in the photometric characteristics; the surfacing scattered light in all directions with a high brightness coefficient. The average specular reflection was < 0.42 and the average luminance coefficient Qo was high, of the order of 0.1. These results, which were the same for all the measurement points, confirm that this surfacing satisfies the requirements for category R1 of the CIE standard surfacings. The colorimetric properties of this very thin emulsion asphalt concrete are at least equivalent to those of the best hot very thin asphalt concrete.

The macrotexture, which contributes to the frictional characteristics of the surfacing, was evaluated by means of the sand patch test: the average value was between 0.6 and 1 mm depending on the paver settings.

6.2 In-service characteristics

The mix was designed using the Colas group's internal procedures. The articles that describe these experimental procedures are listed at the end of this paper. Table 4 shows the selected formula.

Table 4: Composition of the very thin asphalt concrete laid on the rest area of the A10 motorway

% passing	
10 mm	100
6.3 mm	96
4 mm	45
2 mm	31
0.08 mm	6.3
Pigment, titanium dioxide (%)	1.5
Residual binder content %	6.1
Richness modulus	3.77

The dosage of the workability control additive was fixed at 0.5% during the study. During laying, the actual figure was varied between 0.3 and 0.5% in order to take account of the meteorological conditions during placement.

The compactibility was determined by means of a giratory shear press. The level of compaction after 1 gyration was 80.7% and after 25 gyrations 86.8%. This density value corresponds approximately to the end of water expulsion as identified by this test. This is therefore the maximum early age density that can be achieved at a worksite.

After curing at 35°C and 20% relative humidity, the elastic modulus of the specimens was measured under diametral compression. The modulus values are set out in Table 5; the density of the specimens was 87%.

Table 5: Elastic modulus values under diametral compression

Measurement conditions	Modulus, MPa
10°C 20 ms	5900
10°C 25 Hz	6200
15°C 10Hz	4200

These values are approximately 20% lower than those usually measured for very thin asphalt concrete made with pure bitumen (Poirier et al, 2002). This is because the modulus of synthetic binders is lower than that of bitumens with the same penetration grade.

Water resistance and compressive strength were measured by the Duriez test, see Table 6

Table 6: Duriez test values

Compressive strength in air at 18°C, MPa ,(r)	4.42
Compressive strength in water at 18°C, Mpa (R)	4.00
r/R	0.94
Density (%)	87.6

The high wet strength value is not surprising as the adhesion of well-formulated synthetic binders is usually excellent. This point should nevertheless be checked.

7. CONCLUSION AND OUTLOOK

Performance at the worksites that have been constructed to date is very encouraging. To use an analogy from rugby, a try has been scored with both products. We can consider that it has been converted in the case of the microsurfacings as use of this product is steadily increasing. For the very thin asphalt concrete, we need to be able to lay the mix on two or three experimental worksites before we can state that the product can be used industrially and is safe. Until now, when necessary, our contractors have always either used a hot mix or microsurfacing, with the cold, very thin asphalt concrete suffering from the latter's success. Perhaps the very thin cold mix asphalt concrete, which received the SIEMENS innnovation prize in 2001, is too revolutionary.

Nevertheless, we are convinced there is a niche for this product in view of the uniformity of the mosaic, the durability of the surfacing under aggressive traffic, its ability to achieve good evenness and its ability to withstand mechanical cleaning – all of which are necessary for wearing courses in tunnels.

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