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TRANSPORT RESEARCH CENTRE

LONG-LIFE SURFACES FOR BUSY ROADS

Summary Document

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JOINT TRANSPORT RESEARCH CENTRE

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KEY FINDINGS

The following is a synopsis of the key findings of the Joint Transport Research Centre's report, *Long-Life Surfaces for Busy Roads*.

Maintaining safe, comfortable and durable surfaces on heavily trafficked motorways and major roads has long been a major challenge for road owners and their operational units, responsible for managing the construction and maintenance of their roads.

Long-life pavements are seen as particularly desirable on heavily trafficked roads to avoid the costs of road maintenance works, including the delays they inflict on road users, particularly in congested traffic conditions. Since long life properties are considered achievable for the structural, unexposed layers of pavements, this study has focused on the surface or wearing courses of road pavements.

Taking potential user cost savings into account, long-life pavement surfacing costing around three times that of traditional wearing courses should be economically feasible for a range of high-traffic roads. This assumes an expected life of 30 years, discount rates of 6% or less and annual average daily traffic (AADT) of 80 000 or more.

1. Candidate materials for long life surfacing

In the current study, the two prospective candidate materials identified as particularly promising – *epoxy asphalt;* and *high performance cementitious materials (HPCM)* – were researched and tested by national laboratories in the eight countries most actively involved in the project.

2. Epoxy Asphalt

Epoxy Asphalt has already demonstrated its ability to deliver 40 year service life as a road surfacing on steel bridge decks. The testing undertaken in this project focussed on its potential for long service life on underlying road pavements which are more flexible than stiff bridge decking.

The extensive testing undertaken indicated that Epoxy Asphalt should produce a durable, long lasting material suitable for use on heavily trafficked roads. It confirmed Epoxy Asphalt is a premium material that outperforms conventional binders on the important indicators of potential long service life.

The challenges of construction with this material are considered moderate as existing plant and equipment can be used. However, hardening of the material during delays in construction increases the risk of construction failures and damage to plant. It will also be important to establish when, after the initial blending of the Epoxy Asphalt, the curing reaction is complete, given the health effects of the uncured epoxy asphalt binder, which have resulted in restrictions on its use in some countries.

The conclusion reached is that, on the basis of its performance characteristics, Epoxy Asphalt surfacing material is ready for large scale demonstrations on the roads.

3. HPCM

The HPCM wearing course tested is an innovative new system which was developed during the study. It consists of a layer of ultra-high performance, steel fibre-reinforced fine mortar, in which hard, polish resistant aggregate particles are embedded, forming a 10 mm composite layer. The aim was to assess the feasibility of its use as an ultra-thin HPCM wearing course.

Testing has shown that HPCM has great strength and integrity. On the basis of the testing undertaken, there is a high probability that HPCM wearing courses will be practically maintenance-free during a likely service life of 30 years, even on high traffic roads.

Production of HPCM is seen as a manageable process using existing know-how and equipment. However, laying the HPCM mortar and inserting the chippings will require some modification of existing equipment or development of new equipment. Further testing in the field is also needed to achieve the best balance between mixing/handling/placing and the performance of the hardened material. Once this is done, it is expected the final HPCM product will be characterised by high safety, comfort, durability and moderate noise emissions and, on the basis of performance characteristics, will also be ready for field trials.

4. Comparison of Indicative Costs

Costs relative to conventional (reference) surfacings will be critically important for economic viability. For Epoxy Asphalt, the increased costs can be estimated with some confidence. For HPCM Material, mixing and transport costs may be extrapolated from current practice, but the increase in paving costs will depend on new or modified paving equipment that will be required.

Indicative cost estimates provided for Epoxy Asphalt and HPCM surfacings suggest that, in Western Europe, their costs could be between 2 and 3 times the cost of conventional treatments.

While the estimates are indicative only, the cost premiums for the Epoxy and HPCM wearing courses, by comparison with conventional (reference) surfacing costs, are probably less than expected previously. In part, this is due to a better understanding of the costs and production processes involved; and in part to the significant recent increase in the cost of conventional asphalt surfacing, particularly in Western Europe.

On this basis, there are reasonable prospects for economically viable, long life surfacings on heavily trafficked roads in many countries. It is now clearly open to each country to consider on a case-by-case basis – using their own data and analysis – where and when such advanced surfacing could be used.

5. Proposed Field Trials

Limited field trials under traffic – either on the road network or off-road – as proposed in the report are the logical next phase. As always, there are risks with such larger-scale trials of new materials and techniques. Nevertheless, some road authorities, perhaps in partnership with industry, can be expected to take this next step. The report recommends:

- Coordinated programmes of field trials of the Epoxy Asphalt and HPCM surfacing materials, to begin by 2009 and be completed by 2011, which will research production, laying and quality control as well as cost – and demonstrate the performance of such surfacings under real traffic and environmental conditions.
- Interested road authorities are invited to register their interest in joining the proposed trials as soon as possible after the publication of this report.

EXECUTIVE SUMMARY

1. Context

Maintaining safe, comfortable and durable surfaces on heavily trafficked motorways has long been a major challenge to road owners and their operational units, who manage the construction and maintenance of their roads.

Rigid concrete roads are often chosen for roads with much heavy traffic as they offer high strength and durability, but modern requirements for comfort and noise generation imply a limited initial macrotexture, which may lead to low skid resistance after some ten or twenty years of traffic.

Semi rigid pavements permit the use of flexible surfacing with a rigid, cementitious substrate, which can meet the bearing requirements for a heavy-duty road, but will require relatively frequent maintenance and repaving in order to provide the safety and comfort required, e.g. on motorways with high volumes of passenger vehicles travelling at relatively high speeds.

Flexible pavements, in which the surfacing as well as the base layer are made of flexible, bitumen-bound materials, constitute the third and probably most common pavement type for high-trafficked roads, despite their inherent problems of deformation and fatigue under the loads of the heavy-vehicle share of the traffic.

While recent research has resulted in significant improvement in the durability of the structurally important base layers of pavements, surface pavements have barely kept up with the increase in the loads and density of traffic. At the same time the demand for low noise pavements has also challenged the basic durability objective, inasmuch as the structures of low noise pavements tend to conflict with the service life of these pavements. Thus frequent closures of the roadways for the purpose of repairs and repaving are still the order of the day, but constitute a growing problem as an important factor in the increasing problems of congestion.

Therefore, "Long life surface pavements" have a great deal to offer on highly trafficked roads where road works are increasingly constrained because of the disturbances and delays they inflict on road users. In such environments, long life pavements will be expected to show high quality performance without the need for significant repair for more than 30 years. It is also in such environments that the benefits of avoiding major repairs and repavings may become large enough to justify the higher initial costs of such pavements.

2. Phase I Report

The OECD/ECMT's *Economic Evaluation of Long Life Pavements – Phase I* project was completed with the publication of the Phase I report in 2005.

The *Phase I* report explored the economic feasibility of long life surfacings and identified possible candidate materials, focussing on the performance characteristics and envelope of costs that would be required for such new wearing course materials to be economically viable.

2.1 Phase I Findings

The Phase I report drew the following conclusions on economic viability[1]:

> *"From a cost viewpoint, long-life pavement surfacing costing around three times that of traditional wearing courses would be economically feasible for a range of high-traffic roads. This would depend on an expected life of 30 years, discount rates of 6% or less and annual average daily traffic (AADT) of 80 000 or more.*
>
> *Sensitivity testing was carried out to establish the broad envelope of conditions under which long-life pavement surfacing becomes economically feasible. This work assessed the effect of different discount rates (3-10%), traffic levels (40 000 to 100 000 AADT), durability (30 or 40-year long-life pavements), wearing course cost (three-fold increase or five-fold increase), the proportion of heavy vehicles (5-20%) and the effect of day-time or night-time maintenance schedules. Details are provided in the report. Such increases in wearing course costs need to be seen in the context of typical pavement construction costs. For the example scheme chosen, a dual three-lane motorway, pavement construction costs would amount to USD 1.8 million to USD 2.25 million per carriageway kilometre. This estimate includes features such as earthworks, drainage, line markings, safety fences, etc., but not other structures such as over or under bridges, gantries, etc.*
>
> *At present, the surface layer (the wearing course) of such pavements represents around 9-12% of the above indicative pavement construction costs. A three-fold increase in the wearing course cost would imply an increase in overall pavement structure construction costs of up to 24%, and the surface layer would then represent around 30% of the construction costs.*

Two prospective candidate materials - epoxy asphalt and high performance cementitious materials (HPCM) – were identified for further research as possible innovative long life wearing courses.

3. Phase II Work – Findings

The scope of the Phase II study as approved by Transport Ministers in 2004 was as follows:

> *"This next phase of the project will coordinate sufficient initial testing by national testing laboratories to assess the durability of the wearing courses. This will involve small-scale testing (laboratory testing and accelerated load testing) of the most promising pavement materials".*

The intentions for the work in Phase II included to strengthen current knowledge about the potential and the limitations of the two materials (*Epoxy Asphalt and High Performance Cementitious Materials*) identified in Phase I as promising candidate materials.

The Working Group on Economic Evaluation of Long Life Pavements Phase II, which was established to undertake the project was chaired by Denmark and had 37 members from 18 countries and

1. Note: The typical costs of roadworks referenced in the findings of the Phase I report are specified in US dollars and take into account exchange rates applicable at the time the Phase I report was being prepared.

the Secretariat. This report documents and provides analyses of the results of this major coordinated research effort. A smaller group of members and countries led the research work. Nine national laboratories from 8 countries (AU, DE, DK, FR, NZ, UA, UK and US) participated actively in the wearing course testing programmes, which were guided by Technical Coordinators from the US Federal Highway Administration's Turner Fairbank Highway Research Centre and France's Laboratoire Central des Ponts et Chaussées (LCPC).

Each laboratory participating in the *Epoxy Asphalt* (EA) testing utilised local materials and standard as well as advanced test procedures (those typically used in the design of high volume pavements). Effectively the epoxy-asphalt pavement material was compared with a conventional reference pavement (typically with a modified binder) using the same testing and mix design. For *High Performance Cementitious Materials* (HPCM), in order to have a consistent set of data, each participating laboratory used the same constituents and mixtures in their tests.

It was recognised that the Epoxy Asphalt and HPCM surfaces will have to perform extremely well across a range of functional properties to be able to achieve the goal of a practically maintenance-free 30 year service life. Taken together, the testing provided valuable insights into the potential longevity of the EA and HPCM wearing courses when subjected to real traffic and environmental conditions.

4. Epoxy Asphalt

Epoxy Asphalt is a premium material, which has been used for many years as a road surface on stiff bridge decking. The first such application, in San Francisco, is still meeting performance requirements, after 40 years of service. Over time, Epoxy Asphalt has been more widely used for stiff bridge decking applications in a number of other countries (*e.g.* recent extensive use in China).

Administrations have not used Epoxy Asphalt for regular road pavement surfaces as cheaper materials have been available which, although they may not last as long, could be replaced relatively easily and each time at moderate cost. The Phase II work provided an opportunity to test the properties and suitability of Epoxy Asphalt for use in such highway environments.

The many tests performed on the acid-based epoxy asphalt materials in this project covered all the important questions regarding the properties which are known to be critical for the durability and service life of a pavement under heavy traffic. The testing focussed in particular on the *fatigue* and *fracture* properties which are crucially important for longevity. The effect of oxidation on the binder properties and condition of the surfacing was also considered to be crucial.

4.1 Main findings in Phase II testing of Epoxy Asphalt

On the basis of the comprehensive testing undertaken, acid-based Epoxy Asphalt mixtures were found to have greatly improved performance compared to conventional mixtures. In particular compared to conventional asphalts, cured epoxy asphalts are significantly:

- Stiffer (higher modulus) at service temperatures, with greater load spreading ability.
- More resistant to rutting.
- More resistant to low temperature crack initiation and propagation.
- More resistant to surface abrasion from tyre action, even after oxidation.
- More resistant to fatigue cracking (although the benefits are less marked at higher strain levels).

- Less susceptible to water induced damage.
- More resistant to oxidative degradation at ambient temperatures.

A limited accelerated pavement testing (APT) trial of epoxy Open Graded Porous Asphalt (OGPA) resulted in early signs of surface abrasion in the control section but not in the epoxy. Tests on the APT sections demonstrated that the skid resistance of epoxy asphalt was not significantly different from that of conventional asphalt.

In short, the tests undertaken confirmed that epoxy asphalt is a premium material that outperforms conventional binders. Test performance of the Epoxy Asphalt materials studied in this phase was considered greatly superior when compared with conventional materials, on the important indicators central to assessment of the potential for long service life.

4.2 Conclusions on performance expectations for Epoxy Asphalt

Performance expectations for the longevity and durability of Epoxy Asphalt surfaces were built up during the project taking into account the results of the tests undertaken and experience with their relationship to longevity in the field. Nearly all the testing has indicated that Epoxy Asphalt should provide a durable long lasting surfacing, even in the most heavily trafficked road situations.

There must be close consideration of the type of epoxy materials to be used and great care in the choice of aggregates if the best performance is to be achieved. Epoxy asphalt needs close supervision at time of production and laying to ensure full mixing is carried out and that time and temperature are carefully monitored to achieve the best performance outcomes.

If all aspects of the process are correctly handled, Epoxy Asphalt should be able to provide a surfacing material that can be expected to meet the aim for a much extended, practically maintenance life, i.e. 30 years or more.

4.3 Issues for future research and testing on Epoxy Asphalt

Important issues for consideration in future research include:

- *Curing and construction* time. Further laboratory studies are needed prior to any demonstration projects to optimise the curing profile with the desired rate of reaction for the local conditions (time for curing, distance of transport and laying etc).
- *Curing period.* It is important to establish when after the initial blending of the epoxy asphalt the reaction is complete.
- *Curing temperature.* Some epoxy systems have shown the ability to cure rather rapidly at a lower temperature than might be expected. The prospects for lower temperature curing – and the related potential for energy and cost savings during production - need further research.

4.4 Construction issues for Epoxy Asphalt

Epoxy Asphalt is a material with high stiffness that can be applied in thin surface layers. Production experience to date for the relatively small quantities used has almost exclusively been with a batch plant that gives good control of mixing time - an important part of its subsequent curing and post-curing properties. However, for the trials in New Zealand a continuous mix drum plant was used without problems.

Due to the thermosetting nature of the material, extra care is required in the timing of manufacturing and construction phases to ensure the product is not over-cured before compaction. The risk of construction failures and damage to plant is greater than with conventional bitumen. For both these areas, the perceived risk is likely to diminish in importance as experience with the material grows.

When uncured, certain epoxy materials are strong allergy provoking compounds. These were not used for the Epoxy Asphalts in this project. However, if such materials are used, special equipment and safety precautions would be required for all involved in handling them while uncured.

5. High Performance Cementitious Material (HPCM)

High-Performance Cementitious Material (HPCM) is an innovative product which was developed and tested for road surfacing applications for the first time during the present project. This pavement consists of a layer of ultra-high performance, fibre-reinforced fine mortar, in which hard, polish resistant aggregate particles are embedded, forming a 10 mm composite layer. As a new surfacing material with no obvious reference material, considerable work was undertaken on the development of HPCM mixes with the most suitable properties and evaluation of the HPCM needed to focus principally on the actual test results.

The initial mix-design developed based on early research was improved during the project. It evolved through a number of stages which included: selection of constituents, mix-design and laboratory application processes and assessment of behaviour. It was assessed against critical properties such as: skid resistance; binder function; protection of lower pavement layers; cracking behaviour; and bond between the cementitious mortar and the bituminous substrate.

Overall, the thickness of the fibre-reinforced mortar layer needed to be minimised for cost reasons. At the same time, it needed to be thick enough to allow for good penetration of the chippings in the fresh mortar.

The improved mix design took into account the results of the extensive materials testing undertaken by national laboratories. A thin cementitious surface layer is likely to develop discrete cracks unless the layer is restrained by the underlying pavement structure. However, regardless of the restraint provided by the bond to the underlying structure, micro cracks will inevitably develop to compensate for natural shrinkage and temperature strains. To ensure that crack openings remain micro level, some reinforcement is needed and - given the thinness of the mortar layer – the research indicated that it required steel fibres added to the mix to fully meet this need.

5.1 Main findings in Phase II testing of HPCM

The test programme was undertaken primarily at laboratory scale and focussed on the main performance issues:

- General physical properties of HPCM particularly in regard to bond to substrate and capability to establish a lasting bonding of chippings to the matrix.
- Ductility and fatigue properties.
- Durability under environmental impact.
- Surface properties, noise and skid resistance.

Testing of the HPCM matrix for compressive strength, tensile strength and modulus of elasticity indicated the material can be characterised as High Strength/High Modulus. The results indicate HPCM wearing courses will have good bonding properties as well as durability, confirming these objectives have been achieved.

Testing at medium scale demonstrated that a durable bond between asphalt binder course and HPCM can be established, provided the asphalt surface prior to paving of HPCM has been carefully scarified and cleansed. It is also critical for this asphalt to be in the high range regarding E-modulus and temperature resistance. While a loss of chippings in the order of 10% could be expected, primarily in the very early stages of the pavement service life, the bonding between matrix and chippings appeared to be of a sufficiently high quality to indicate that the majority of the chippings will stay in place for the full service life of the pavement.

5.2 Conclusions on performance expectations for HPCM

Testing has shown that HPCM has great strength and integrity. It is clear that certain requirements need to be met - including a strong and even lower layer and careful embedding of chippings - to ensure maximum performance.

By comparison with Epoxy Asphalt, the HPCM solution needs more development, including operational laying techniques, before being ready for commercial introduction as a long life surfacing.

However, the tests undertaken in Phase II at the same time the HPCM mix-design was being developed indicate there is a high probability that the current uncertainties about HPCM applications will be overcome.

From the testing and performance in the tests, it is considered that, if the HPCM layer performs well for the first 1-2 years, then it is unlikely to fail in the following years. It is the expectation that this surface, based on further trials, can be developed into a final product characterised by high safety, comfort, durability and limited noise emission.

Figure 1. **The TRL Pavement Testing Facility (UK)**

5.3 Issues for future research and testing on HPCM

A number of issues were identified for future research and testing, including:

- *Effect of water dosage on HPCM properties.* The water dosage has a significant impact on mortar engineering properties, such as: ease of mixing (at industrial scale) and workability; chippings loss; and bond with the asphalt.

- *Industrial application technology.* The adaptation of existing equipment or the practical development of new pavement laying equipment needs to be given a high priority to support the proposed Phase III field testing.
- *Two-dimension cracking tendency.* The test pad chosen for testing two-dimension cracking tendency needs to be fully representative of a real pavement and laid on a sufficiently stiff asphalt material.

5.4 Construction issues for HPCM

Production of HPCM is seen as a manageable process using existing know-how and equipment. However, some modification of existing equipment or development of new equipment will be required for laying the HPCM mortar and inserting the chippings. Construction factors that are important include the availability of constituent materials, the mixing process and the workability of the freshly mixed material. The application of the chippings should ideally take place immediately after placing the thin mortar layer, i.e. with the same machine or with a chip spreader. A light rolling or tamping action is required to ensure the desired embedment of the chippings and a flat, even running surface.

6. Summary Conclusions from the Project

The project reflects the concerns of road owners for the slow and limited innovation in pavement technology where industry has been leading the way for many years. It has intended and succeeded in demonstrating the scope for significant advances available in materials which are not normally considered in the traditional thinking of pavement development. Having now demonstrated the real potential for using alternative materials, it is expected that industry and road owners together can move towards the implementation of these innovations.

6.1 Properties and performance of current premium pavements

Maintaining safe, comfortable and durable surfaces on heavily trafficked motorways has long been a major challenge to road owners and their operational units, who manage the construction and maintenance of their roads.

- Rigid concrete roads are often chosen for roads with much heavy traffic as they offer high strength and durability, but modern requirements for comfort and noise generation imply a limited initial macrotexture, which may lead to low skid resistance after some ten or twenty years of traffic.
- Semi rigid pavements permit the use of flexible surfacing with a rigid, cementitious substrate, which can meet the bearing requirements for a heavy-duty road, but will require relatively frequent maintenance and repaving in order to provide the safety and comfort required, e.g. on motorways with high volumes of passenger vehicles travelling at relatively high speeds.
- Flexible pavements, in which the surfacing as well as the base layer are made of flexible, bitumen-bound materials, constitute the third and probably most common pavement type for high-trafficked roads, despite their inherent problems of deformation and fatigue under the loads of the heavy-vehicle share of the traffic.

While recent research has resulted in significant improvement in the durability of the structurally important base layers of pavements, surface pavements have barely kept up with the increase in the loads and density of traffic. At the same time the demand for low noise pavements has also challenged the basic durability objective, inasmuch as the structures of low noise pavements tend to conflict with the service life of these pavements. Thus frequent closures of the roadways for the purpose of repairs and repaving are still the order of the day, but constitute a growing problem as an important factor in the increasing problems of congestion.

6.2 Expected advantages of long life surface pavements

The two long life surface pavements types which have been the objects for the research described in this report are intended to serve as a cure to the problems of today's pavements. They are both developed with a target service life minimum of 30 years, and interpretations and extrapolations of the results of the tests conducted during this project do not contradict the assumptions that this target is achievable.

One of the two long life solutions, Epoxy Asphalt, has already demonstrated its ability to deliver such long service lives as pavement on bridge decks of steel. The laboratory tests and the testing in accelerated pavement loading facilities confirmed that this material has the superior qualities on performance indicators useful for assessing longevity, such as stiffness and resistance to rutting, low temperature cracking, fatigue cracking and surface abrasion (even after oxidation) and is less susceptibility to water induced damage.

Experiences from the testing as well as separate consideration of the available technologies provided insights into the production and construction process which will be needed for larger scale use of the EA materials for surface pavement on highways. It was concluded that these processes do not present unusual problems, although timing and proper protection of the workers' health are important considerations.

The other long life solution, High Performance Cementitious Material with steel fibre reinforcement, represents a novel application of a material class which has been intensively researched for other construction purposes in recent years. It was therefore known from the onset, that it provides exceptionally high strength, even when used as here in a wafer thin pavement of only 10 mm. Much research was spent on designing the concrete mix to achieve a composition of materials which is not susceptible to the formation of cracks, and then to determine the best way to ensure a long-lasting bond to the substrate. Further efforts were spent on finding ways of embedding the aggregates in the matrix in ways that make them stick and provide for a good multi-year friction performance. This challenge was also met. HPCM has, in short, demonstrated its long life performance capabilities by properties such as its ability to bond to the substrate and establish a lasting bonding of chippings to the matrix, its fatigue properties, durability under environmental impact, and its surface properties, particularly skid resistance.

Production of HPCM is seen as a manageable process using existing know-how and equipment, while it is less straightforward to lay it with existing technology without some modification or equipment development.

It is concluded that both materials, High Performance Cementitious Material with steel fibre reinforcement as well as Epoxy Asphalt, are likely - at high levels of probability - to be able to provide long life solutions to the demand for surface pavements which can be placed on existing pavements if these have a long remaining life.

There is of course a cost to this, which must be considered, and which is summarised in the next section and the associated table. It is also obvious that both materials now need to be tested under traffic in limited trials after using realistic production and laying methods. This is discussed in the final section.

6.3 Indicative Costs for Epoxy Asphalt, HPCM and conventional wearing courses

This section provides a comparison between the indicative cost estimates for EA and HPCM surfacing. It also compares these indicative estimates with current surfacing costs using conventional (reference) surfacing materials.

The actual costs for both types of surfacing are, of course, likely to vary depending on the amount used, and a range of other factors including the experience of the contractor and supplier involved and the location and country/region concerned.

Epoxy Asphalt costs and risks

The indicative costs set out in the Table below were estimated principally on the price of natural aggregate materials and of epoxy asphalt materials, and a typical price for mixing, transport and paving, assuming use of current production technology. Because experience is very limited, only a few countries were able to provide cost estimates.

The skid resistance of an epoxy asphalt surface will lessen in time and may need restoration within the structural life of the surface layer. Such a treatment was considered in the economic analysis carried out in Phase I but has not been included within the initial works costs that are included in Table 1.

HPCM costs and risks

As there are yet no commercial applications, there is currently greater uncertainty about HPCM surfacing materials and costs than about EA surfacing costs.

The indicative costs of HPCM wearing courses are assessed by extrapolation of material, mixing and transport costs for current cementitious pavements and on estimated paving costs, which will be higher – although how much higher will depend on any new or modified paving equipment that has to be developed.

Conventional (reference) surfacing

Cost estimates were provided by several countries and assume typical 30mm thin surfaces or SMA type wearing courses as used in each country. Responses indicated that current costs for conventional surfacing which had risen significantly – particularly in Western Europe – could now be taken as around € 20 per square metre. The actual range was from € 13-25, depending on location.

Comparison of indicative costs

Table EA. 1 shows indicative costs for Epoxy Asphalt, HPCM and conventional (reference) asphalt 30mm 'thin surfacing' which has been used as a typical standard base material. The figures in the table are thought to be realistic assessments of indicative costs, as may be appropriate in Western Europe.

The estimates in Table ES.1 suggest that the cost of an advanced surfacing could be between 2 and 3 times the cost of a conventional resurfacing treatment. The indicative cost premiums for the Epoxy and HPCM wearing courses, by comparison with conventional (reference) surfacing costs, are probably less than assumed for Phase I of the study. In part, this is due to having a better understanding of the costs and production processes involved, but is also due in part to the significant increase in the cost of asphalt surfacing, particularly in Western Europe, in recent years.

The whole life costing exercise completed in Phase I showed that the use of advanced surfacing on high-traffic roads would result in net benefits when the discount rate used in the analysis is below about 6 % p.a. and when the advanced surfacing does not cost more than about three times as much as conventional materials.. These benefits were estimated on a whole life cost analysis over a period of at least 30 years and take user delay costs during maintenance into account. The indicative cost estimates set out in Table ES.1 would appear to be broadly consistent with this envelope of costs.

Table 1. **Comparison of indicative costs between materials**

TYPICAL SURFACING COSTS IN €/M2 FOR WESTERN EUROPE			
Description	**Epoxy Asphalt 30mm wearing course**	**HPCM 10mm wearing course**	**Conventional 30mm asphalt solution**
Expected Lifespan	~30 years	~30 years	7-15 years
Milling 50-100mm	0.75-1.25	0.75-1.25	0.75-1.6
Binder course (50mm)	6-10	8-12	6-12
Tack/bond coat	0.25		0.1
Wearing course	18-33.5	18-22	6-12
Total costs	25-45 (1)	27-35	13-25 (2)

Note: 1. Cost of restoration (once) of skid resistance during the service life not included. 2. Costs of minor repairs during 15 years of service not included.

In these circumstances, it is clearly for each country to consider, using their own analysis with their own national data to decide on a case-by-case basis, when advanced surfacing could be appropriate and whether the long term benefits including reduced maintenance costs and associated user cost savings outweigh the increased initial costs. However, the indications are that there are reasonable prospects that this will be the case.

Having now demonstrated the real potential for using alternative materials, it is expected that industry and road owners together can move towards the implementation of these innovations. It is also obvious that both materials now need to be tested under traffic in limited trials after using realistic production and laying methods. This is discussed in the final section.

7. Recommendations for Phase III Trials

The research in Phase II has provided comprehensive results from laboratory testing and trials in various accelerated pavement testing machines.

The expectations for the durability and long-life capabilities of the materials are based on extrapolations of observations made during the testing reported here, but nobody can give full guarantees for the behaviour of materials in the extrapolated time domain. Therefore, if the potential economic benefits of these advanced technology pavements types are to be realised, then the innovation process must be taken to the next phase, in which the materials are tested in larger scales under real traffic on roads or off roads.

The project has therefore progressed to the point where limited field trials under traffic - either on the road network or off-road - are the logical next phase, and necessary if the potential economic benefits of these materials and techniques are to be realised. It is also obvious that – as always with such larger-scale trials of new materials and techniques – there are risks. Still, it is assumed that some road authorities, perhaps in partnership with industry, will be prepared to take this step.

While such steps could be taken individually, jointly planned and coordinated trials and demonstrations offer shortcuts to a broader based and earlier establishment of better practices for all.

Such a coordinated trials programme would aim to demonstrate that the performance assumed from the laboratory tests and the accelerated testing will hold within the period of the trial under real traffic and environmental conditions – and that a large number of collateral aims and the material-specific aims described below will also be achieved.

7.1 Overall aims of the trials

The overall aim of a coordinated programme of field trials of the Epoxy Asphalt and HPCM surfacings – which offer real prospects for use on long life pavements – is as follows:

- To demonstrate that the performance envisaged on the basis of the laboratory tests and the accelerated testing will hold within the period of the trial under real traffic and environmental conditions.

Collateral aims include to:

- Develop construction methods (in particular substrate preparation requirements) that are compatible with the properties of the materials and the quantum and quality specifications of the resulting pavement.
- Improve the basis for realistic estimation of construction costs using these materials.
- Study variations in performance under varying conditions of traffic, the effects of limited variations in aggregate properties which can affect long-term friction properties and the noise properties of the test pavements under real traffic.
- Increase the comfort level for contractors by providing opportunities for them to gain experience with these advanced paving materials.

The last of these is especially important. As contractors move up the learning curve, it can be expected that construction practices will adapt as necessary and the paving costs of advanced surfacings will ultimately drop as experience and volumes increase.

7.2 Specific targets for Epoxy Asphalt Phase III trials

The Epoxy Asphalt material is ready for large scale demonstrations on the roads, and the challenges of producing and laying this material are considered as moderate. The major practical issue is linked to the health effects of the uncured epoxy asphalt binder, which has resulted in serious restrictions to use in some countries. Any reservations by the health authorities should therefore be prompted and cleared at this stage.

There are a number of EA-specific trial aims, including: testing of locally available materials; determining the performance of EA materials having different chemical formulations – and the impact of aggregate type on long life surface characteristics; testing of various EA layer thicknesses; and testing in various climatic regions.

7.3 Specific targets for HPCM trials

There are a number of HPCM-specific trial aims, including: use of locally available materials as opposed to material from one supplier; development of techniques for laying the mortar and inserting the chippings; and testing of several asphalt base courses and several mixtures with water-cement ratio ranging from 0.20 to 0.30 to achieve the best balance between mixing/handling/placing and the performance of the hardened material.

7.4 Proposed Phase III Field Trials: Summary of Recommendations

Field trials are recommended to: allow the new surfacing materials to be tested on the ground in real traffic and environmental conditions; promote improved production and laying techniques and the development of new equipment where needed; and to focus on quality control.

It is recommended that:

- Interested road authorities be invited to register with the JTRC Secretariat their interest in joining the proposed trials as soon as possible after the publication of this report and before a year has passed.
- When a minimum of three trial offers have been received with any of the materials, a preparatory meeting be called by the host organisation. Such preparatory meetings must appoint a project coordinator and agree on the fundamental plans and principles for the management of the trials.
- Participants may begin trials whenever it suits their plans after the preparatory meeting, but not later than May 2009. The trials must last a minimum of 2 years and must be terminated no later than May 2011.
- Participants must be prepared to deliver their final report within 3 months after their trials have been completed and no later than in July 2011. The two consolidated reports, one for each type of material, are drafted by the coordinators for the two series of trials and final meetings are held to edit and agree the final versions of the reports.

It is further recommended that:

- The JTRC assumes the role of the host organisation and responsibility for calling the meetings of the participants in this Field Trial phase.
- The responsibility for the funding and management of the field trials as well as recording and disseminating of the results of the trials rests with the sponsoring organisations, the participants and the project coordinators.

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