PROGRESS IN THE DESIGN AND CONSTRUCTION OF PAVEMENTS

21 September 2007 (am)

TECHNICAL COMMITTEE ON ROAD PAVEMENTS (TC 4.3)

INTRODUCTORY REPORT

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EXECUTIVE SUMMARY

The need to innovate and the advances in technology are inescapable issues in terms of meeting the expectations of the public and road users. These expectations are increasingly specific and demanding in many ways, including lower costs, better performance, and contribution to sustainable development, environmental protection, mobility and safety.

In the 2004-2007 period, the work of PIARC Technical Committee 4.3 on Road Pavements focused on three main issues: long life pavements, recycling and the impact of road works on the road users and the surrounding environment. This work led to several observations pertaining to the obstacles that must be overcome in order to further the development and introduction of new pavement technologies.

Depending on the development status of a product, a process, or a technique, various actions can be taken to support the innovation effort, and to bring winning products up to the practical application stage. A new concept can only be introduced if the client is made fully aware of the various factors related to the innovation. In order to realize the benefits of an innovation, the client must also be convinced that the concept can be replicated on a large scale in practice.

In order to gain acceptance, the concept of long life cycle pavements must be supported by clear technical demonstrations that establish that their observed performance and value-per-dollar are advantageous. Many techniques cited in work carried out by TC 4.3 have already proven their worth, including recycling. However, they have not yet attained their full potential. Therein lies the great importance of the need to clearly inform clients and to provide designers and enterprises with technical tools. Although the many steps that have been taken to mitigate the impact of road works are well known, more innovations are required in order to meet the expectations of users and neighbouring residents during construction work.

Finally, innovation efforts are more likely to succeed if the largest possible number of stakeholders is involved in the various stages. The client has a role to play in creating conditions that are conducive to technological progress. Meanwhile, engineers and enterprises must display creativity and excellence in engineering in order to develop superior performing new products and processes at attractive costs.

This introductory report is intended to stimulate discussion and to enrich deliberations concerning the technical advances that can be made with pavements, and more specifically, in the three issues that are covered by the work of TC 4.3 during the 2004-2007 period.

ACKNOWLEDGEMENTS

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INTRODUCTION

The work of the Technical Committee on Road Pavements (TC 4.3) in the current 2004-2007 cycle began in the spring of 2004, and focused on three main issues:

- Long life pavements;
- Pavement recycling;
- The impact of road construction and maintenance on users and neighbouring residents.

These three main issues are the subject of reports and guides that have been or will be published by PIARC. Many other issues raise questions on these main topics, and these are related to the focus of this introductory report: what progress has been made in terms of pavement design and construction with respect to the three issues covered by TC 4.3, and what obstacles are hindering these technological advances?

In fact, many fields of road engineering are facing more or less similar obstacles when the time comes to introduce new processes or techniques. Client awareness of these new ways of doing things always proves to be crucial in an effort to introduce innovations.

The introduction of every innovation must be accompanied by tools that are accessible to future designers and users in order to make the transition as smooth as possible. In addition, the technical basis of the innovation and the demonstration of its feasibility in industrial production mode must be such that the new processes retain full credibility in terms of performance, while remaining competitive from an economic standpoint. Finally, contract awarders and government agencies often have an interest in monitoring the development of these new approaches very closely, by creating or consolidating a market that is conducive to their survival, especially in terms of innovations whose benefits materialize in the longer term.

This preliminary report reviews the main findings of the work that has been carried out by the three subgroups that explored the issues that TC 4.3 focused on in 2004-2007. Even though each topic has its own particularities, the observations and conclusions that result from all of this work intersect in terms of the general obstacles that must be overcome in order for pavement technology to progress.

1. LONG LIFE PAVEMENTS

Several pavements that were designed and have been used in recent years have already exceeded their theoretical lifespan. How can this be explained? What key factors have led to this success? Are the design methods statistically valid, or was their design overly pessimistic at the outset; using excessively high safety factors or ignoring significant performance factors? Can the wide range of observed performance be explained by differences in the variables (material properties, effects of weather, traffic) that are used in the design process?

The goal of TC 4.3's work in this area is to identify the key factors that led to outstanding performance, and to try to reproduce those winning conditions in other situations, in the hope that the same design and constructor factors will produce the same benefits. This report will cover the analysis and synthesis of success stories that were presented to TC 4.3, along with recommendations for achieving outstanding performance and a discussion of the costs/benefits.

A long life pavement must perform very well while supporting traffic conditions that exceed those for which it was designed. Even though the concept of long life pavements applies mainly to heavily trafficked roads due to major gains in reducing traffic disruptions, it can apply equally well to roads with little traffic.

In order to be considered long life cycle, a pavement must perform better than expected at the design phase, with no structural maintenance. Work to restore functional features such as skid resistance, with no reinforcement, does not alter a pavement's characterization as long life pavement.

Documenting cases of pavements with a substantially longer life cycle than expected at the outset can establish that the concept of long life pavements is not only theoretical, but is a reality. The main problem lies in compiling useful data pertaining to all of the conditions and factors that can account for this outstanding performance.

Information that can assist in the evaluation of a long life pavement is sometimes difficult to obtain over the life of the pavement but would typically include:

- design vs. actual traffic load over long periods,
- precise weather data,
- quality and capacity of drainage,
- evolution of type and extent of pavement distresses with times,
- maintenance data,
- the statistical range of the various design parameters, material characteristics, properties, etc.

The many success stories that have been brought to attention of TC 4.3 cover a variety of pavement types, including rigid, flexible, semi-rigid and composite. The initial analyses of these success stories revealed various key factors that remain dominant in the pursuit of outstanding performance: the importance of the quality of materials, homogeneity at the time of construction, drainage, the quality and load capacity of the improved subgrade, thickness compliance, layer rigidity, binding between layers, compaction quality, etc.

These analyses will make it possible to highlight the key factors that led to outstanding performance. Current design methods can then be improved. Long life pavements must demonstrate these characteristics not only from a structural standpoint, but also in terms of withstanding the effects of the environment.

To achieve its full potential, this type of pavement, with its outstanding performance, must be a clearly stated goal in the design phase, based on an organized, rational approach. It must not be the outcome of accidental over design stemming from excessively high safety factors or from wrong incorrect calculations; or the result of a random dispersion of the variables used in the design process. Therefore, the choice must be based on a solidly mastered procedure.

In light of this, introducing the concept of long life pavements implies a solid, well-documented technical foundation in order to demonstrate their validity. One must also remember that even long life pavements still need a minimum of maintenance work, carried out at the right time, in order to ensure structural longevity.

The benefits take the form of not only reducing direct construction and maintenance costs, but also reducing the indirect costs borne by users. The main advantage of long life pavements lies in the fact that there will be fewer traffic disruptions due to the reduction in the extent and frequency of maintenance work. The use of long life pavements makes it possible to predict the timing of rapid resurfacing operations that only impact the upper layers of the pavement. For freeway concessionaires, this can reduce whole life costs, and lead to maximum revenue by causing fewer nuisances for users.

Alongside the technical considerations, a cost-benefit analysis must be carried out before adopting the use of this type of pavement. What is the value of investing in complete initial construction when the upfront cost is higher? Is phased construction more cost-effective? Therefore, in cases where long life pavements might be used, they should represent the lowest whole life cost, taking into consideration subsequent maintenance work and the impact on users.

2. PAVEMENT RECYCLING

In many areas of human activity, there is a tremendous interest in recycling in order to preserve natural resources and reduce waste. Despite the progress that has been made, the use of recycled and alternative materials for pavement construction has yet to attain its full potential. In light of this, PIARC took an interest in informing all countries of the available options in order to improve practices and increase the use of recycling in pavement construction and rehabilitation.

Sustainable development implies minimizing waste, using materials efficiently, and recycling discarded materials. Ultimately, the first approach involves reducing waste production at the source, either by executing road works that lasts as long as possible (e.g.: constructing long life pavements), or not wasting construction materials. Another way is to make maximum reuse of existing pavements, in order to take advantage of their structural contribution and avoid demolishing them. Resurfacing is a good example of this.

A third approach is to reuse recyclable materials that optimize quality in the layers closest to the surface, such as cold recycling techniques. Finally, waste disposal at landfill sites is the least preferable, because it entails the use of virgin materials to replace those disposed of.

In 2003, the Technical Committee on Road Pavements published three technical guides aimed at stimulating the use of recycled materials:

- In situ cement recycling;
- In situ recycling with emulsion and foamed bitumen asphalt;
- Hot recycling at a plant.

The main technical conclusions that emerged at the time were as follows:

- Recycling must result in performance that is at least equivalent to conventional processes or superior to, at a lower or equal cost.
- Recycling must remain competitive, and must factor in the costs of processing and environmental protection.
- Recycling standards are often non-existent.
- Knowledge of the long-term performance of recycled materials has yet to be thoroughly mastered.
- The gains produced by recycling are so significant that the use of recycled materials remains an option that must be considered.
- Equitable risk-sharing among partners in order to stimulate the development and use of recycling processes is also very important.

Despite the benefits and the current state of knowledge, many factors continue to impede the use of recycled or alternative materials. Most of these obstacles are non-technical, and they can be summarized as follows:

- *Client education (awareness)*: Clients know little about the possibilities and successful applications of using recycled and alternative materials, which are perceived as costing more and resulting in inferior quality with mediocre performance.
- *Waste reuse and disposal, legislation and regulations*: Complex regulations lead to countless delays in obtaining permits and exemptions.
- *Supply and demand*: Difficulty balancing supply and demand with alternative materials.
- *Site planning*: The location of sorting centres and processing in or near urban centres.
- *Standards, specifications, and testing*: The lack or scarcity of suitable technical references for alternative materials.
- *Contractual requirements*: Contract clauses that do not encourage innovation and flexibility in application.
- *Environmental factors*: Fears of the pollution that can be caused by contaminant lixiviation and dust generation.

Countries have developed different ways to overcome these obstacles to the use of recycling techniques. A wide range of actions can be taken in order to encourage and foster the use of recycled materials in pavement construction.

Many countries consider planning in advance and coordination among the various parties to be essential for balancing supply and demand, and thereby creating and maintaining a market that is conducive to recycling. Recycling supply centres must be established in order to meet local demand. It is still very difficult to obtain the necessary permits near urban centres.

Most countries also responded that the test methods that have traditionally been used for conventional materials are not always suitable for recycling alternatives, although in some cases they can actually be used. Many developed countries have proven the value of using recycling techniques, and have developed the technical references needed to support the state of knowledge in this field.

There are also come concerns pertaining to the risks of contamination caused by the presence of alternative materials. This makes it very important to accurately determine a material's properties prior to its use. The same considerations must be applied to noise and dust control at the production and construction phase.

The use of alternative materials is generally, and often mistakenly, considered to be more costly than conventional materials. An accurate comparison requires analyzing whole life costs in order to select the best solution in terms of economics and the environment. In this respect, taxes on waste disposal can be adjusted so that the use of alternative materials can be assessed fairly and remain competitive from a financial standpoint.

Countries that have made recycling an objective have adopted a series of measures to stimulate the use of these techniques: financial incentives for reusing pavement materials, regulations that make recycling mandatory, training and awareness-raising sessions for clients, specifications and technical guides pertaining to recycling, classification of the various materials used in road works, road tests to demonstrate the good performance of recycled materials, etc.

Even though very good knowledge is available when planning to use recycled materials for the first time, experience is lacking when one wishes to reuse materials for a second time, i.e. materials that have been recycled once. Nevertheless, this lack of knowledge about the second life of a product is common to innovations.

In light of all this, recycling is now an option that must be carefully considered due to its competitiveness in terms of overall costs, its performance potential, and its contribution to sustainable development.

3. THE IMPACT OF ROAD WORKS

The report from Technical Committee 4.3 on this subject summarizes the solutions that are available for reducing the impact of construction, rehabilitation, and maintenance work on road users (travelling public and road workers) and adjacent properties (businesses, homeowners). This information includes methods for improving worker safety, mitigation measures that apply to immediate surroundings of the worksite, and actions taken to diminish the impact of construction activities on traffic flow.

A survey was conducted in order to obtain documentation pertaining to requirements, regulations, guides, and best and trade practices for reducing the impact of construction, rehabilitation, and maintenance activities. Road authorities were also asked to describe their requirements and the approaches that they adopted in order to ensure compliance. A key section of the survey covered innovations for reducing this impact, how the innovations were introduced, who was responsible for their

The key findings of the survey were as follows:

- Most design and construction innovations are driven by the need to maintain traffic flow.
- At the present time, the interest in methods for reducing the impact of road works on safety, pollution, and vibrations is lukewarm, and varies from country to country.
- As a general rule, developing and emerging countries are less concerned about the impact of construction work on users and the environment. The survey results indicate that these issues are more prominent in developed countries and urban centres.
- Cooperation among all of the stakeholders (road authorities, general public, and businesses) is necessary in order to foster the emergence of innovations.

The impact of construction work sometimes extends beyond the immediate vicinity of the site. Road works on pavement can result in users taking detours, and the resulting traffic can have an impact on the neighbourhood in terms of noise, vibrations, and potential safety problems caused by heavier traffic in residential or commercial zones.

Various methods for mitigating the impact of road works have been tried, and are now in use in many countries:

- *To reduce noise*: regulations that establish maximum levels on noise, design and construction methods, shortening construction time by means of appropriate techniques (e.g.: prefab slabs, warm asphalt), or bonuses/penalties tied to construction delays.
- *To cut down on pollution*: retention ponds, the use of dust suppressors or emission control measures, monitoring of contamination risks, control of construction materials, proper storage and handling of hazardous materials, and recycling and processing of materials at or near the worksite.
- *To improve safety*: information campaign for the public, police surveillance, advance warning signs of construction, escort vehicles, speed displays and radar to reduce speed, clear distinction between regular traffic lanes and those that are reserved for construction equipment, barriers to restrict access, sidewalks and temporary bridges as a detour for pedestrian traffic, brightly coloured garments to identify workers, the use of crash cushions, proper lighting for night work, pavement markers.
- *To diminish vibrations*: other means of transporting materials, adapted construction techniques, control of vehicle speed, type of materials and equipment used for construction, and monetary compensation for installing additional soundproofing.
- *To improve mobility during construction work*: communication plan for the public, promotion of public transit, construction when traffic is light (weekends, nights, lane rental, etc.), detours, temporary lanes for extra traffic, longer lasting pavements to minimize the frequency of maintenance, the use of alternative means of transporting construction materials (rail or waterways), fast-drying concrete, prefabricated concrete slabs, thin surfacings.

While these innovations for reducing the impact of worksites are already in use, many obstacles restrict access to new technological advances. Many of these innovations originate in the private sector, but are contingent upon client demands. Road authorities are not free to deal exclusively with one contractor or supplier. In addition, they often focus on the lowest bidder for the level of quality that is determined in advance.

As a general rule, businesses only invest in solutions that increase their profit margin or market share. Therefore, the fact that they cannot cash in on the specific advantages, or that the client cannot pay them, is a barrier to innovative development.

The best option for innovation lies in giving private enterprise the freedom to make choices. In light of this, the criteria for awarding contracts must be consistent for more than one project, so that the firm can be certain that its investment will pay off.

For example, performance specifications can leave the contractor free to deploy innovations. However, the performance criteria must correspond to known, measurable standards. For the contractor, this means attaining these criteria at the lowest cost, and having to exercise creativity. Another means of stimulating innovation is to give the contractor the freedom to determine the work schedule, based on restrictions that are determined in advance, such as lane rental or bid prices that take into account both the work to be done and the construction delay.

In this context, in their role as regulators, agency and government decision-makers have a number of instruments for directing market trends. In order to increase profit margins, private enterprise must then be creative within the established requirements.

4. OVERCOMING THE OBSTACLES TO TECHNOLOGICAL PROGRESS

TC 4.3’s work in 2004-2007 provides examples of techniques or processes at various stages of development in the innovation life cycle.

In the case of long life pavements, their potential is being proven because this area of interest has shifted from the conceptual phase to feasibility demonstrations. The resulting knowledge remains to be incorporated into design methods and procedures that demonstrate the economic value of these pavements and justify them.

With respect to recycling and the use of alternative materials, they have reached a more advanced stage of development and implementation, because many road authorities are already practising these methods. However, the use of recycled and alternative materials for pavement construction has not yet attained its full potential, and has not achieved credibility in many countries. Therefore, more work is required in order for the technological progress that has been made to gain full recognition.

In terms of reducing the impact of road works, a number of techniques are already in practice. This area has reached a stage that can be described as “mature” compared to the first two. However, the fact remains that many of the innovations identified, whether in management methods or construction techniques, can produce considerable benefits when it comes to reducing the impact on users, and of course, on neighbouring residents.

Once an innovation has been thoroughly mastered, it culminates in standardization. Standards must not be perceived as obstacles to innovation, bur rather as the outcome of the process. Standards reflect the state of the art, as determined by consensus. They enable the client to clearly state objectives in terms of expected results. Contractors and suppliers can then refer to them in order to clearly define the goal that the client wishes to attain.

A few specific methods can be considered in order to encourage innovation, such as testing performance specifications. However, in meeting these specifications, innovations must have reached a very advanced stage of development or evolution before being used, due to the guarantees associated with this type of contract. Competition, the competencies of each party, and sound risk-sharing are also preconditions for the use of performance specifications.

Many other means of a more general nature can be adopted by countries that are interested in stimulating technological progress in pavements, regardless of the development stage of a particular innovation. Here are a few examples of potential forms of action:

- Properly manage commonly used techniques and tools, or in other words, tightly control design standards and construction quality, with a view to building longer lasting pavements and planning the reuse and recycling of materials from existing pavements and existing structures.
- Adopt laws, regulations, and contractual requirements that foster the emergence of innovations and their market launch so that they remain competitive after introduction.
- Keep clients well informed, and make them aware of the progress made and the advantages and disadvantages of adopting new techniques or processes. This is the highest priority action which should be taken.
- Document product characteristics, conditions of use, and the performance achieved, in order to allow the innovation to gain solid credibility and improve acceptance.
- Identify the key factors that provide the best guarantee of success and that are the most significant in terms of performance.
- Treat innovation as an investment rather than an expense. In this respect, consider whole life costs, and not just upfront costs, in order to accurately assess the full potential of an innovation.
- Take into consideration the contribution that an innovation will make to sustainable development and indirect costs in terms of reducing impact on users and neighbouring residents.

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DRAFT CONCLUSIONS

Regardless of the developmental stage that a technique has attained, the need to innovate remains an inescapable objective, because today's society demands fewer nuisances, less risk, greater mobility for all, and increased sustainable development. It is also increasingly impatient in terms of having its expectations satisfied. The innovation process must not only come up with the right answers, but it must strive to meet the stated need and deliver the solution quickly.

In order to stimulate technological progress, creativity must be allowed to express itself, both among clients, who must establish conditions that are conducive to innovation; and among contractors, suppliers, and researchers, where innovations originate. A market based on healthy competition and balanced supply and demand must be accessible, or accessibility must be created with the help of road authorities in order to facilitate the introduction of innovations

In order to stimulate progress in the realm of pavements, the client must be properly informed, and designers must be provided with technical tools so that the innovation is used properly and remains fully credible.

The aim of technological progress is not simply to help reduce the direct costs incurred by a road authority or a contractor. The contributions to sustainable development and to reducing the impact on users are also very important benefits.

Countries stand to gain from sharing international experiences pertaining to progress in design and construction of pavements in order to ensure the harmonization and improvement of techniques and specifications. PIARC and its network of experts is a prime forum for producing a thorough and objective assessment that can serve as a reference.