July 2006

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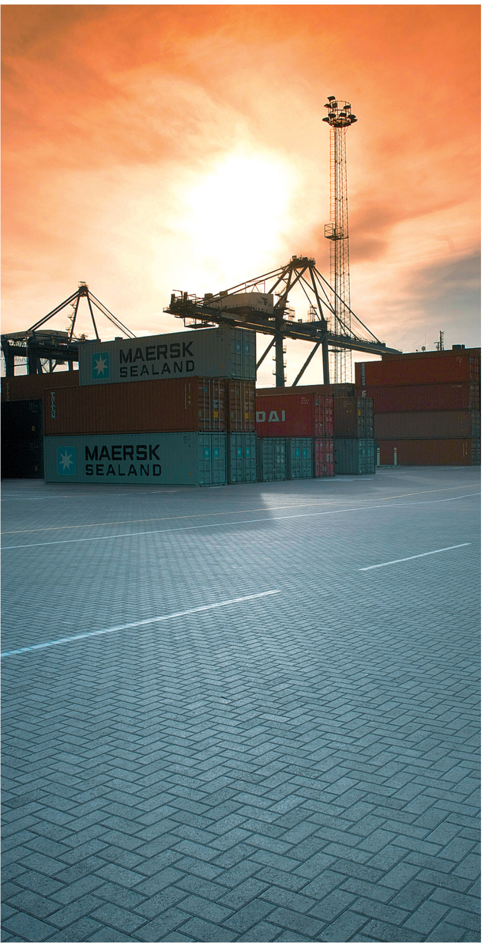
the costs of paving



COMPARATIVE INITIAL CONSTRUCTION AND WHOLE LIFE COST ANALYSES FOR PAVEMENTS

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THE PRECAST CONCRETE PAVING AND KERB ASSOCIATION

www.paving.org.uk

Background

Concrete block paving has been used widely in the UK for over 30 years on diverse project types ranging from footpaths to container terminals. One of the most exciting recent developments is the use of this technology for permeable pavements, offering major environmental benefits acknowledged by planning guidance, regulations and environmental regulators.

However, the potential cost advantages of concrete block permeable pavements (CBPP) are less well understood and to address this Interpave has commissioned Scott Wilson to carry out independent, comparative cost research of various pavement types including CBPP used in different applications and ground conditions. This document summarises the results of that research, which is available in full on the Interpave website www.paving.org.uk. In addition, supporting information and drawings can be inspected at the Interpave offices. The research is intended to provide paving designers with initial guidance only and individual projects should be subjected to specific feasibility and costing studies.

METHODOLOGY

The research project was carried out in two stages, commencing with investigation and comparison of pavement and drainage construction requirements and their initial construction costs. Where possible Scott Wilson used projects where they were originally appointed as designers to give realistic and accurate designs reflecting local topography and drainage requirements. These projects were then redesigned using various pavement types and a range of different ground conditions (expressed in terms of California Bearing Ratio values, or CBRs). The pavement types considered for each pavement application are summarised in the table below.

Over 250 different cases were considered and designs were undertaken in accordance with current British Standards and/or other appropriate design methods and guides. The same on-site drainage systems were used for each impermeable pavement type but redesigned to suit each type of CBPP, with no drainage costs for System A. For a variety of application types, initial costs per square metre have been plotted in the graphs that follow for each pavement type related to a range of CBR values.

Whole Life Cost (WLC) analysis is a useful tool for an asset owner or operator to establish the most appropriate design and maintenance solution for a given asset. The second stage of this research project involves WLC of three of the previously assessed pavement types applied to four applications identified in red in the table. The applications were chosen to represent markets suitable for block paving and where its value may not be fully recognised. In each case, two alternative subgrade conditions were considered: a 3% CBR value representing a fairly poor quality of subgrade and 6% for a reasonable quality.

Each pavement application has different maintenance requirements driven by their different needs. These factors are termed ‘maintenance instigators’ and the maintenance strategies needed to meet these requirements (for each of the pavement type and application combinations) have been documented. Costings for the maintenance strategies over a typical 40 year life have been combined with the initial construction costs from the first stage to calculate the WLCs. Pavement user costs were not accounted for as these do not affect the service owner/operator. It is important to note that the initial construction cost would not be duplicated if the asset was still in service after 40 years as the maintenance strategies are designed to return the asset to its ‘as built’ condition after 40 years service.

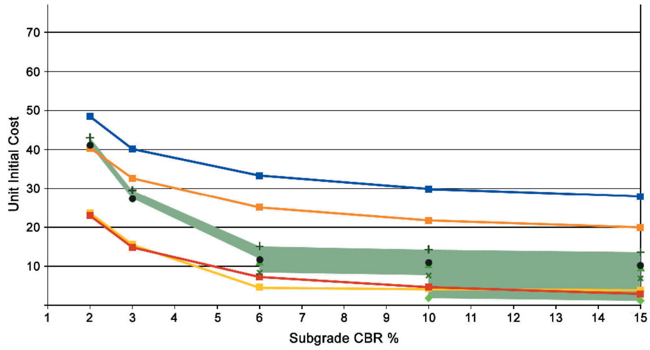
Pavement type (surfacing)

Pavement application	Concrete Block Paving	Concrete Flags	Asphalt	RC Concrete	PQ Concrete	Permeable Pavements		
						System A*	System B*	System C*
Pedestrian Footpath	✓	✓	✓	✓		✓	✓	✓
Domestic Driveway	✓	✓	✓	✓		✓	✓	✓
Municipal Mall/Plaza	✓	✓	✓	✓		✓	✓	✓
Supermarkets and other Car Parks	✓	✓	✓✓	✓	✓✓	✓	✓	✓✓
Estate Road – Housing	✓		✓✓	✓	✓✓	✓	✓	✓✓
Estate Road – Industrial	✓		✓✓	✓	✓✓	✓	✓	✓✓
Parking for Warehouses	✓		✓✓	✓	✓✓	✓	✓	✓✓
Container Yards	✓		✓	✓	✓			
Airport Airside Pavements	✓		✓	✓	✓			

Note: * System A for subgrade CBR values only greater than 10% * System B for subgrade CBR values only greater than 6% * System C for subgrade CBR values from 2 to 6%
System A CBPP allows full infiltration of water to the ground, System B partial infiltration and System C full containment and transfer to piped drainage.

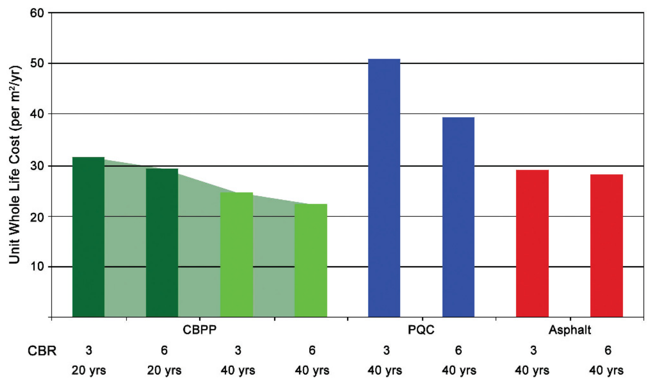
»Applications

Supermarkets and other Car Parks – In terms of initial cost, impermeable concrete block paving closely follows asphalt. Where ground conditions allow, System A CBPP offers the lowest cost solution.

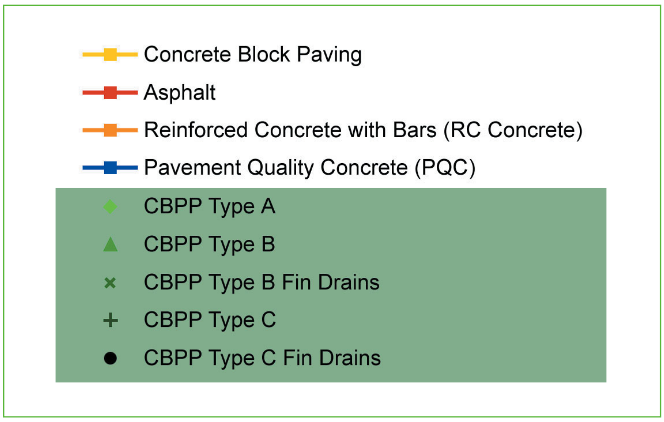


National supermarket chains are acutely sensitive to the appearance of stores. As a result there is a need to maintain the 'cosmetics' of the car park, resulting in a more onerous maintenance schedule than that usually required to service purely utilitarian functions. Most supermarkets will require any major maintenance to be undertaken during off peak hours, usually at night, allowing customers to park (and shop) at peak times. For the same reasons, any maintenance perceived as time consuming or requiring a long 'curing' duration is likely to be viewed unfavourably.

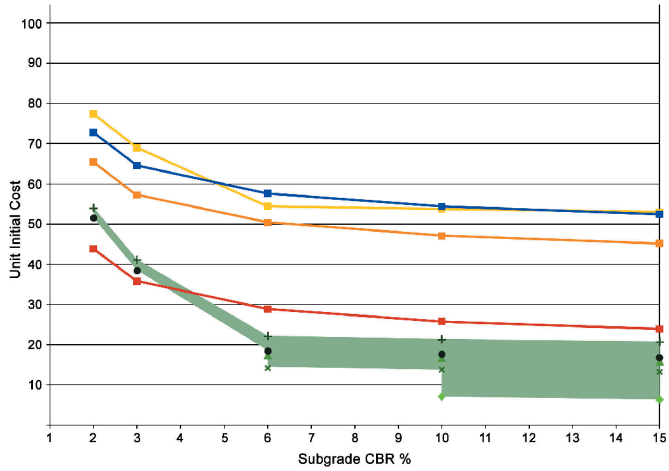
Owner/operators will be more concerned with WLC than initial costs and here the difference between CBPP (System C) and asphalt is minimal, with Systems A or B offering potential cost savings.



Block paving at a supermarket after more than 20 years service

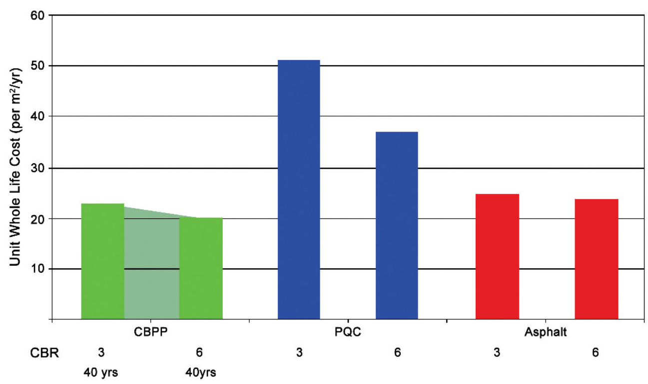


Estate Roads – Housing – Initial costs for all types of CBPP are lower than asphalt for CBR values as low as 4% with no more than a 10% extra for lower CBR values.

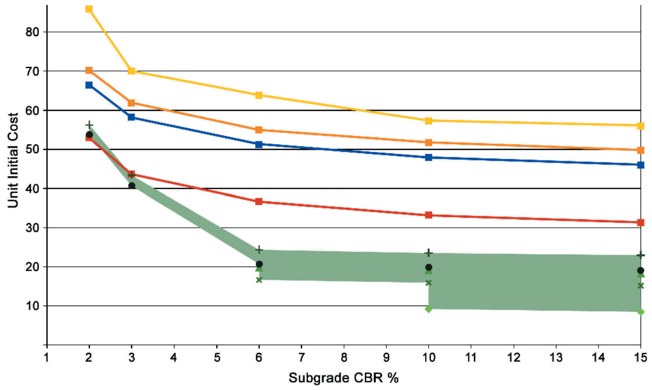


The majority of vehicles on a housing estate distribution road are domestic, transmitting a relatively low load to the surface. The traffic flows obviously depend on the size of the housing estate but would generally be classed as low. Housing developers place great importance on aesthetics, as market research suggests that it is the 'overall feel' which helps secure sales. Other research has demonstrated the popularity of concrete block paving with the public, adding 'kerb appeal' to developments.

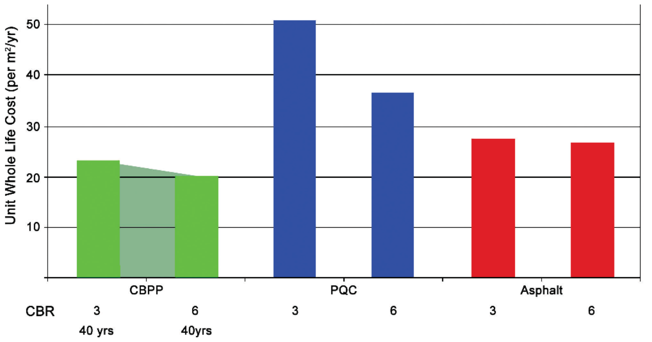
CBPP (System C) offer the lowest WLCs at CBR values of both 3% and 6%, while offering the well-recognised visual attractions of block paving. Highway authorities adopting such roads will be particularly interested by maintenance costs and WLCs benefits of CBPP.



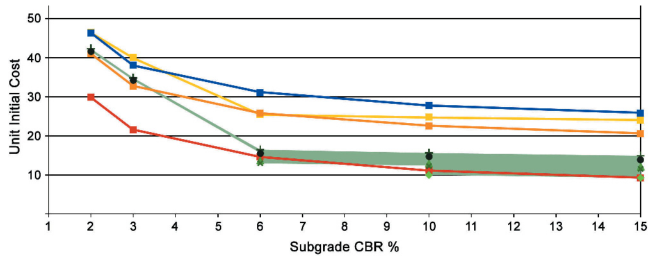
Estate Roads – Industrial – Initial costs for all types of CBPP are substantially lower than asphalt for CBR values of 4% or more, becoming similar for the lower values.



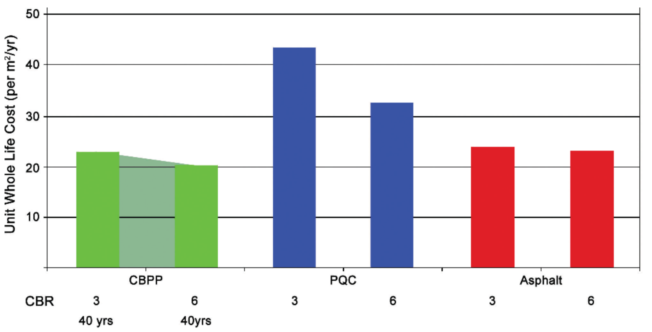
The loading regime on an industrial estate distribution road can be relatively severe, with a high proportion of heavy good vehicles. So, maintenance and WLCs are important, with CBPP (System C) offering the lowest WLC.



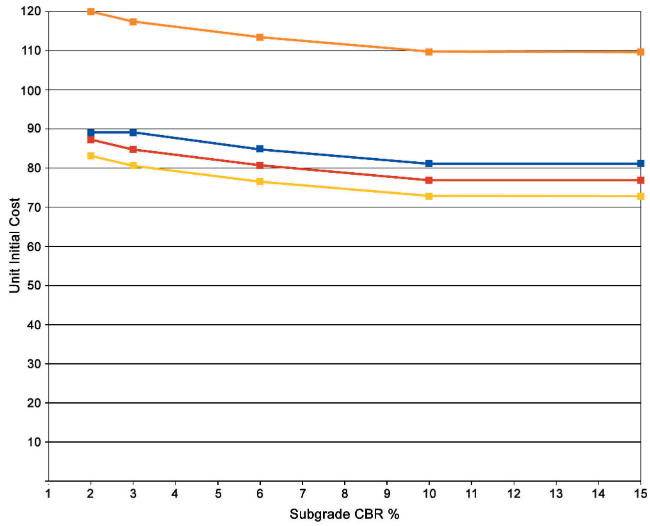
Parking for Warehouses – Initial costs for all types of CBPP closely follow asphalt for CBR values of 6% or more.



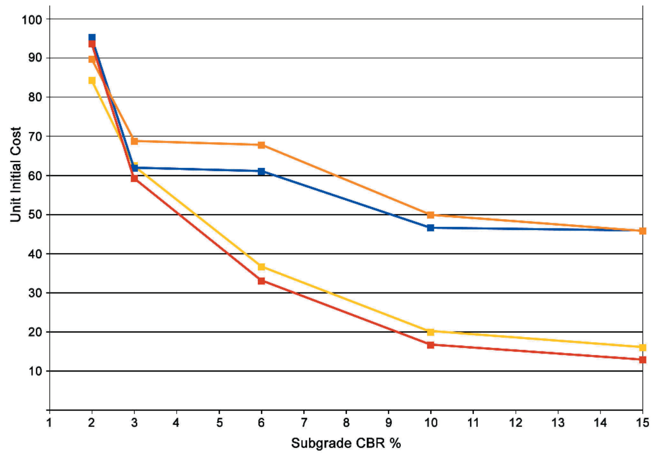
The maintenance strategy for a warehouse distribution centre is focused on maintaining the structural integrity of the pavement. The aesthetics of the surface are a low priority with the pavement serving a purely utilitarian purpose. The loading regime for a busy warehouse distribution centre is particularly onerous. The advent of 'super size' tyres on articulated heavy goods vehicles have increased the point loads which the pavements are subjected to and this compounds the rate of 'damage' to the pavement. WLC will be a major issue for owner/operators and CBPP (System C) offers the lowest cost with potential further savings where Systems A and B can be used.



Container Yards – considered from an initial cost perspective only. Costs of impermeable concrete block paving are slightly lower than both asphalt and PQ concrete for all CBR values with reinforced concrete substantially higher.



Airport Airside Pavements – considered from an initial cost perspective only. Costs of impermeable concrete block paving follow those for asphalt and are substantially lower than those for reinforced or PQ concrete until very low CBR values are reached.



A 21 year old block-paved aircraft stand after some 400,000 aircraft movements

Key Findings

The first stage of the research shows that, where ground conditions allow, System A CBPP provides the lowest initial costs in all cases. With low CBR values, the situation varies from one application to another (as shown) but Systems B and C are shown to be competitive in all cases.

> "where it can be used, System A concrete block permeable pavements provide the lowest initial costs in all cases"

The second stage of the costing exercise has shown the concrete block permeable pavements proved the most cost effective paving solution for all four application types. It is important to note that the most expensive CBPP option, System C, has been used in this analysis. Systems A and B would allow for further significant reductions in WLCs. In addition, the design lives for permeable paving used in this analysis have intentionally been extremely conservative and thus form the upper boundary of WLCs which could be expected in practice.

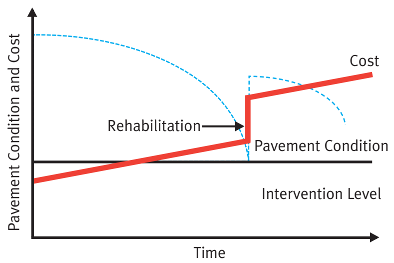
> "the concrete block permeable pavements proved the most cost effective paving solution over 40 years"

CBPPs also have significant environmental advantages when compared to asphalt and unreinforced concrete as a key Sustainable Drainage System (SUDS) technique and with an inherent capability for reuse when maintained.

Whole Life Costs for Pavements

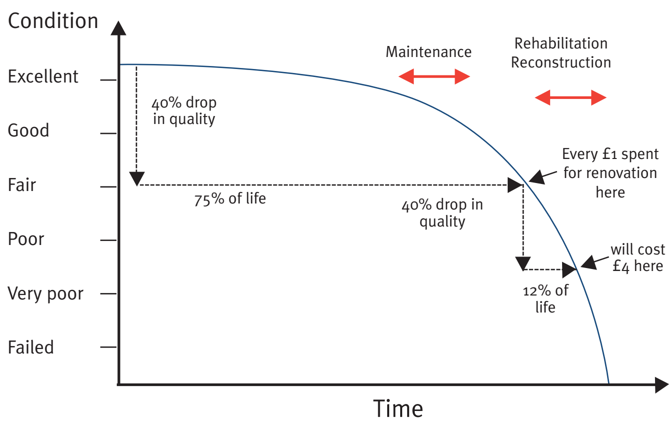
There have been several studies (Shahin et al, 1990; Zimmerman et al, 2000) undertaken which detail the appropriate intervention junctures to maintain the structural integrity of the pavement at minimum financial cost to the asset owner. A schematic diagram showing the road maintenance costs and condition against time is given below.

Schematic Representation of Rehabilitation costs and Intervention Levels for a Road



It can be seen that once the condition of the road reaches an 'intervention' level it becomes necessary to spend money on rehabilitation treatment and thus improve the condition of the pavement. The importance of timely maintenance and reconstruction to protect against 'expensive' work being required at a slightly later point in time was highlighted by Shahin et al (1990), as shown below. This shows that if maintenance is left for an extra 12% of its life, a 40% drop in road condition occurs, resulting in a factor of four increase in maintenance costs. Hence it is important to undertake maintenance works before the occurrence of serious structural damage.

Physical Factors Affecting Pavement Deterioration Rate



INFLUENCING FACTORS

Vehicle-pavement interaction is dependent on vehicle weight, the number of axle loadings and the spacing within the axle group. Pavement impacts are also influenced by vehicle suspension, tyre pressure and tyre type, although these are secondary effects. Over time, the accumulated strains (the pavement deformation from all the axle loads) deteriorate the pavement structure, eventually resulting in cracking of both rigid and flexible pavements, with permanent deformation or rutting in flexible pavements. Fatigue or fatigue cracking is caused by repeated loadings and the heavier the loads, the fewer number of repetitions required to reach the same condition of cracking.

A series of empirical tests undertaken in the 1950s suggested that a 'fourth power law' relationship exists between axle load and road 'damage' i.e. doubling the axle load would increase pavement damage by a factor of 16. One of the reasons that damage to the road accelerates after a certain time can be attributed to a concept called 'spatial repeatability', which assumes that particular locations will be damaged significantly more than others. The reasons behind the development of these specific 'damage locations' are complex, but are in part due to the excitation of the modal response of the vehicles (the frequency and amplitude of vertical motion) and irregularities in the road surface (which can cause a 'bouncing effect').
In addition to the vehicle-pavement interaction the other primary factors affecting pavement durability are pavement design, material quality, subgrade conditions, weather conditions and, importantly, construction quality.

LIFE EXPECTANCY

Flexible pavements are generally expected to serve from 10 to 20 years, depending on traffic conditions and construction, before major rehabilitation is required. In contrast, rigid pavements may serve up to 40 years. However, when flexible pavements require major rehabilitation, the work is generally less expensive and quicker to perform than for rigid pavements. Block paving is not routinely used for major road applications in the UK, so there is a dearth of information relating to its performance. However, commonsense suggests that its behaviour is between that of a rigid pavement (concrete) and that of a flexible pavement (asphalt). Reports have confirmed that in 'town centre' roads, block paving can perform with minimal maintenance for in excess of 20 years (Walsh, 2004) and on residential roads for in excess of 40 years.

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