

COMPARATIVE INITIAL CONSTRUCTION AND WHOLE LIFE COST ANALYSES FOR VARIOUS PAVEMENT AND DRAINAGE OPTIONS

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SUMMARY

This paper summarises investigative work undertaken by Interpave, "The UK Precast Concrete Paving and Kerb Association" in determining Initial Construction Costs (ICC) and Whole Life Costs (WLC) for a range of different pavement types, applications and sub grade and drainage conditions.

This work was undertaken in two stages; the first to establish accurate Initial Construction Costs and the second to develop Whole Life Costs based upon the Initial Construction Costs and establishing the design life maintenance costs.

Where possible, Interpave's Consultant Engineers engaged to undertake this work, used data from actual projects to which they were the appointed designers, as opposed to undertaking theoretical designs. This approach was chosen to give more realistic and accurate designs and costings, taking into account typical topography and local drainage requirements.

Due to time and cost restraints it was decided not to develop all the pavement applications into Whole Life Costs. Certain applications were considered, comparing concrete block permeable pavements (CBPP), in situ concrete and asphalt pavements.

CBPP were specifically chosen as they represent the largest potential market growth area in the United Kingdom at present.

1. INTRODUCTION

Precast concrete paving has been used widely in the UK for over 30 years on diverse project types ranging from footpaths to container terminals. To the author's knowledge there has not been a comprehensive cost exercise undertaken to establish accurate Initial Construction Costs (ICC) and Whole Life Costs (WLC) comparing concrete block and flag pavements with equivalent in-situ concrete and asphalt pavements, including drainage costs. In particular, the potential cost advantages of CBPPs are less well understood. In the UK CBPPs are organised into three systems to simplify description:

System A – full infiltration of water to the subgrade

System B – partial infiltration with some additional drainage to other devices

System C – full containment of water by impermeable membrane

1.1 Scope of the Research

In 2003 Interpave engaged Consulting Engineers, Scott Wilson, to undertake a research project to determine a comprehensive array of ICCs and WLCs. This project was carried out in two stages, commencing with investigation and comparison of pavement and drainage construction requirements and to determine accurate ICCs. The extent of pavements under consideration ranged from pedestrian pavements to aircraft pavements, using different surfacing materials and pavement structures with subgrade Californian Bearing Ratio (CBR) values of 2, 3, 6, 10, and 15%.

After the ICCs were determined the second stage of this project involved developing WLCs from the ICCs. WLC analysis is a useful tool for an asset owner or operator to establish the most appropriate design solution and maintenance regime for a given asset, however, it is important to understand the client's or owner's perspective as ICCs or WLCs may be of greater relevance and to ensure that the ICCs are accurate.

Table 1 summarises the pavement applications and types considered for ICC (shown in blue) and WLC (in red).

Table 1 Summary of Pavement Applications, Pavement Types Investigated

| Pavement application | Concrete Block Paving | Concrete Flags | Asphalt | RC Concrete | PQC | 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 | ✓ | | ✓ | ✓ | ✓ | | | |

Key:

- ✓ – considered for ICC
- ✓ – considered for WLC

Notes:

- Sub grade values investigated 2, 3, 6, 10 and 15
- * 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%.

1.2 Constraints on Research

Ideally it would have been desirable to apply WLCs to all the applications identified in the ICCs, but this was not feasible due cost and time constraints. Therefore WLCs of permeable pavements, in-situ concrete and asphalt applied was determined for four different applications with sub grade CBR values of 3% and 6%.

These applications were chosen as they represent markets considered to have the greatest potential for Concrete Block Permeable Pavements (CBPP). Permeable Pavement System C was chosen for the WLC exercise as it is the most expensive option representing the worst case cost scenario.

2. INITIAL CONSTRUCTION COSTS

2.1 Methodology

Where possible, Scott Wilson based this work on projects to which they were originally appointed as the designers, as they had access to the original site investigation and design data. This approach was chosen to give more realistic and accurate designs taking into account typical topography and local drainage requirements.

As these pavement and drainage designs were specific to the original project and based upon certain subgrade soil conditions, it was necessary to redesign these pavements in the various pavement types under review within a range of various CBR values. A total 256 different scenarios were considered in this exercise. Designs and re-designs were undertaken in accordance with current British Standards and/or appropriate design guides.

The redesigns, in most cases, consider the alternative of CBPP instead of the conventional impermeable pavements and associated surface water drainage system originally used. In these re-designed projects the drainage and other associated details have been designed to reflect the use of CBPP. It should be noted that the costs associated with impervious pavements are based upon the use of conventional drainage, the same drainage design being used for all of the impervious pavements, regardless of the pavement type.

2.2 Schemes Reviewed

- Small Car Parking scheme – 0.35ha
- Housing/Light Industrial Access Road scheme – 0.5ha
- ‘Outlet’ Retail Car Parking scheme – 5ha
- Car Storage Compound scheme – 10ha
- Airport Airside Apron scheme – 2.5ha
- Dockside container terminal – 26ha

All of these schemes except the small car park were originally designed as conventional impermeable pavements.

2.3 Costing Basis

Scott Wilson engaged quantity surveyors to undertake the costing exercise based upon the re- designs. No allowance was made for overheads and profit and costs were current at the 4th quarter of 2004. CBPP was not considered for either container yards (although there are successful examples in other countries) or airport pavements in this work and the relevant costings exclude drainage elements in these two applications.

It should be noted that the use of drainage pipes with less than 900mm cover is not normal practice for pavements that carry vehicles. As an alternative, a geocomposite fin drain can be used, laid either directly on the prepared formation for System B, or directly on the impermeable membrane for System C. These systems were costed separately.

2.4 Key Findings

The ICCs for various subgrade CBR values in the different pavement applications have been plotted in the graphs that follow.

2.4.1 Supermarkets and Other Car Parks

For car parks subjected to cars only, the cost of an asphalt and concrete block pavement (CBP) are the cheapest option and the costs are comparable, except when the subgrade CBR value is 10% or greater, then CBPP System A is the cheapest option.

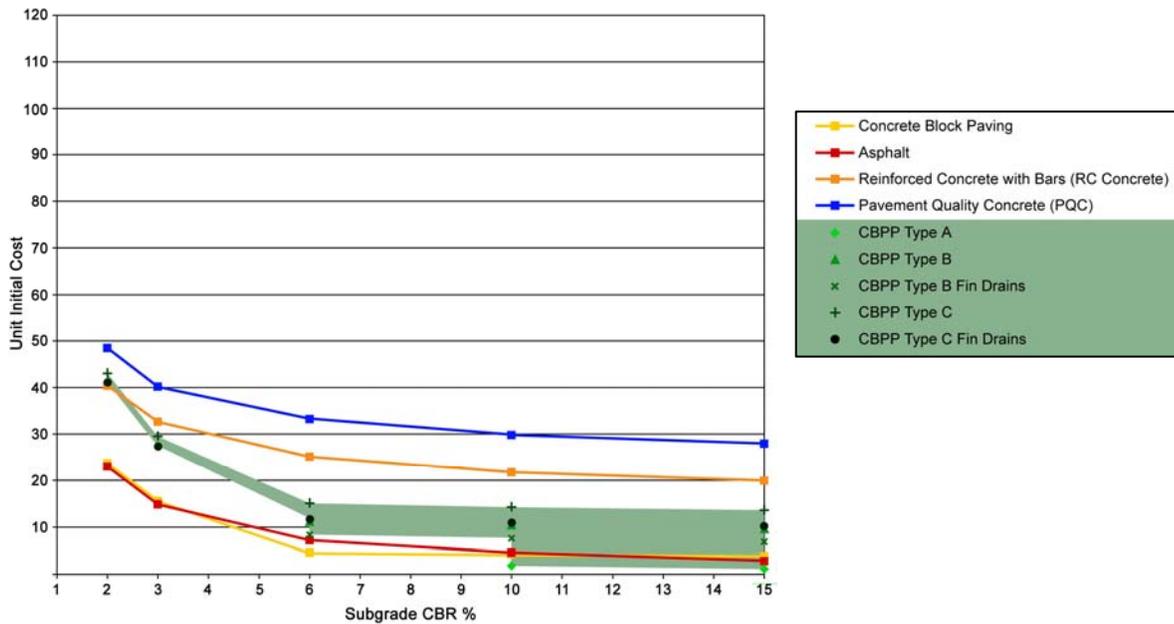


Figure 1. Supermarkets and Other Car Parks: ICC

2.4.2 Parking for Warehouses

For parking areas subjected to commercial vehicle trafficking, CBP is not competitive with any other pavement options, however, when the sub grade CBR value is to 6% or greater, then permeable pavements become comparable.

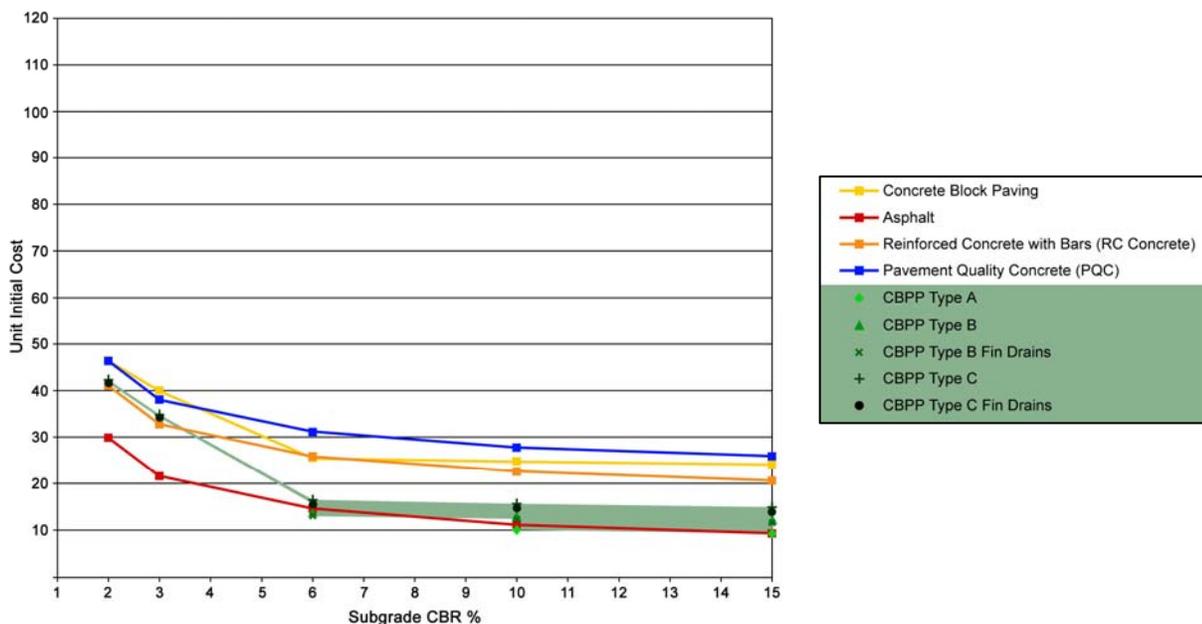


Figure 2. Parking for Warehouses: ICC

2.4.3 Estate Road - Housing

For housing estate roads with the subgrade CBR values of 3.5% or greater, all types of permeable pavements are the cheapest option.

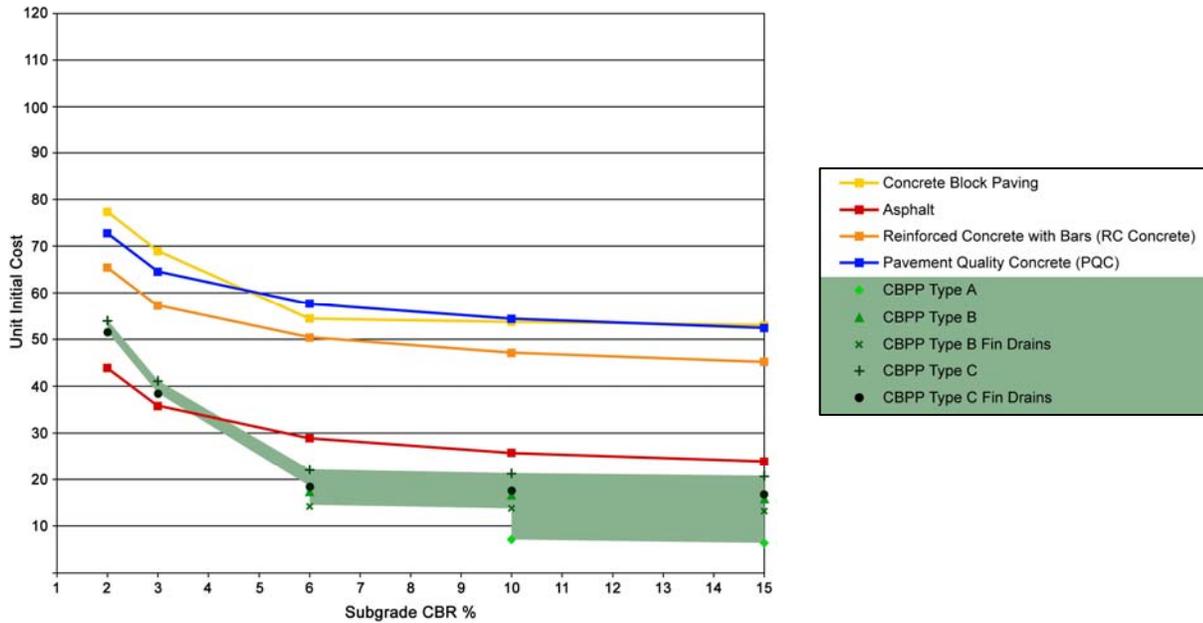


Figure 3. Estate Road - Housing: ICC

2.4.4 Estate Road - Industrial

For estate roads where the traffic loading increases allowing for commercial and light industrial traffic, permeable pavements are the most cost-effective options for all subgrade CBR values.

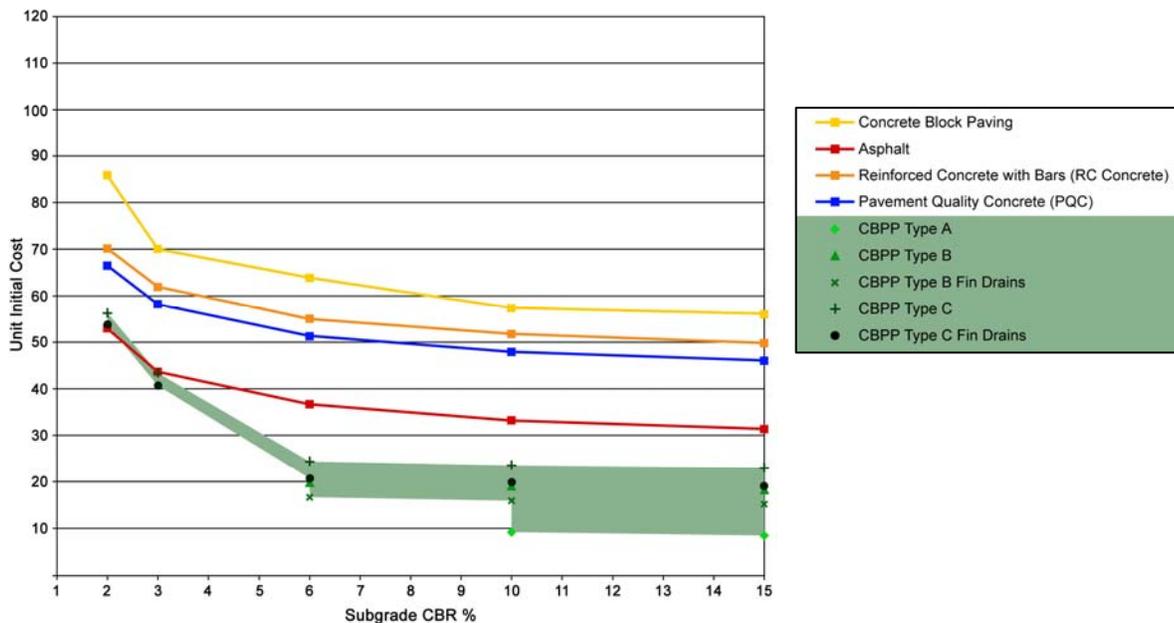


Figure 4. Estate Road - Industrial: ICC

2.4.5 Container Yards

Concrete block paving proves to be the most cost-effective option for all subgrade CBR values.

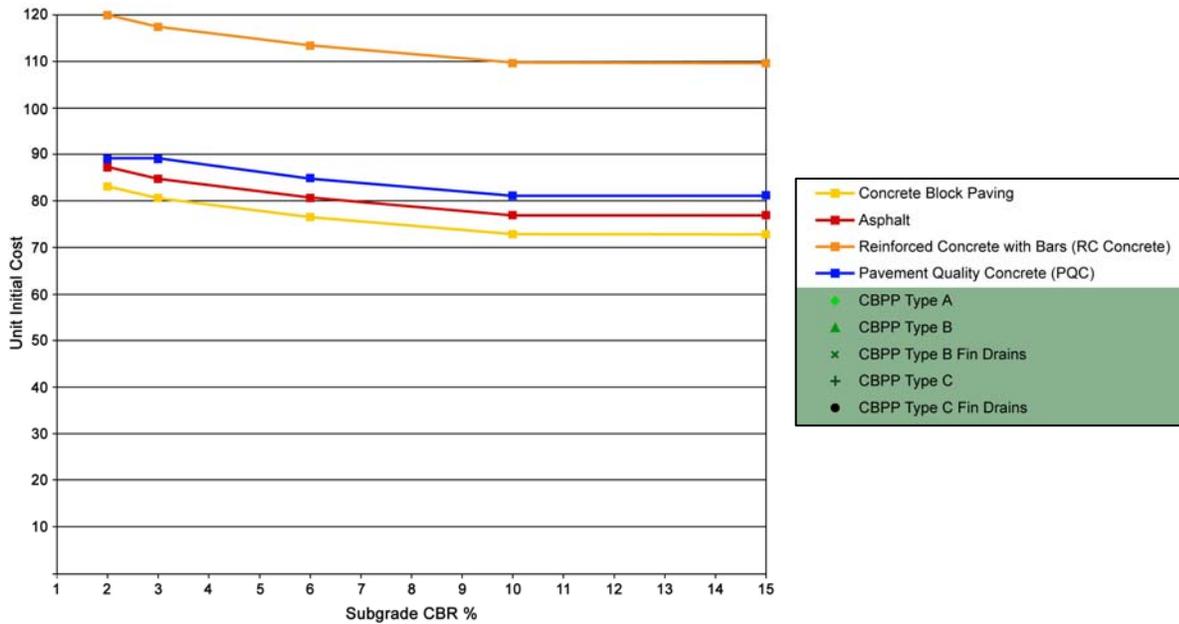


Figure 5. Container Yards - Dredging: ICC

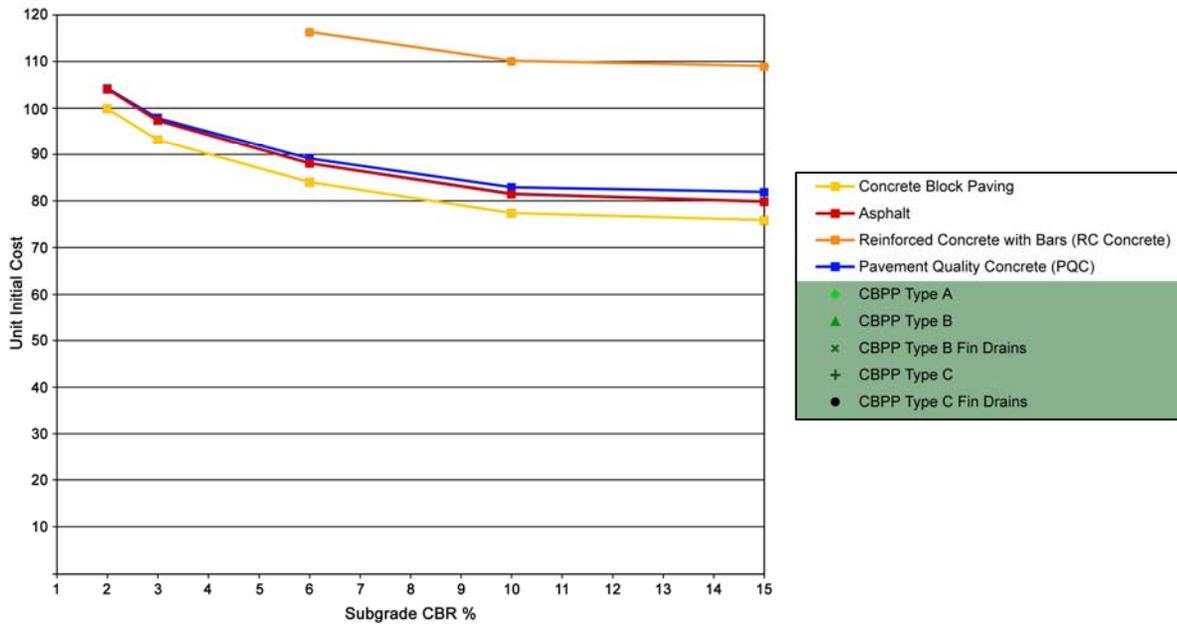


Figure 6. Container Yards - Excavation: ICC

2.4.6 Airport Airside Pavements

Concrete block and asphalt pavements are cost compatible for all subgrade CBR values.

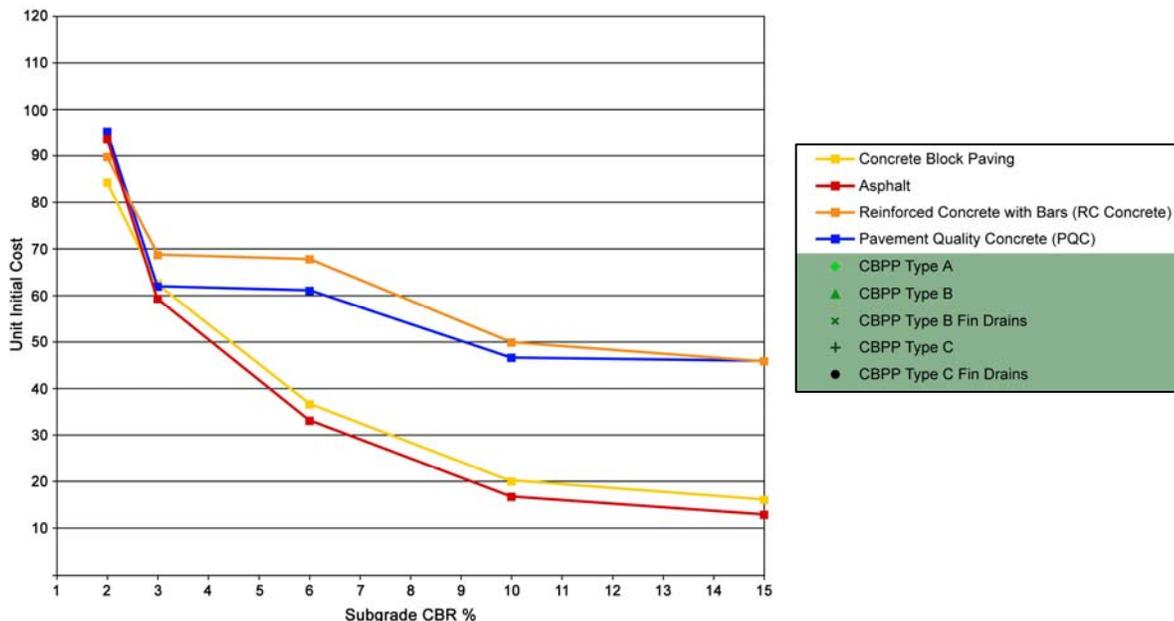


Figure 7. Airport Airside Pavements: ICC

3. WHOLE LIFE COSTS

3.1 Methodology

The second stage of this research project involved WLC of three of the previously assessed pavement types applied to four applications identified in red in Table 1. Certain applications were considered, comparing concrete block permeable pavements (CBPP), in situ concrete and asphalt pavements. CBPP were specifically chosen as they represent the largest potential market growth area in the United Kingdom at present. In each case, two alternative subgrade conditions were considered: a CBR value of 3% representing a fairly poor quality of subgrade and a value of 6% for a reasonable quality.

3.2 Maintenance Considerations

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 ICCs 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 ICC 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.

3.3 Key Findings

This second stage of the costing exercise has shown that the CBPPs 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 which requires an impermeable membrane, 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. CBPPs also have significant environmental advantages when compared to asphalt and in-situ concrete as a key Sustainable

Drainage System (SUDS) technique.

3.3.1 Supermarkets and Other Car Parks

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 ICC and here the difference between CBPP (System C) and asphalt is minimal, with Systems A or B offering potential cost savings.

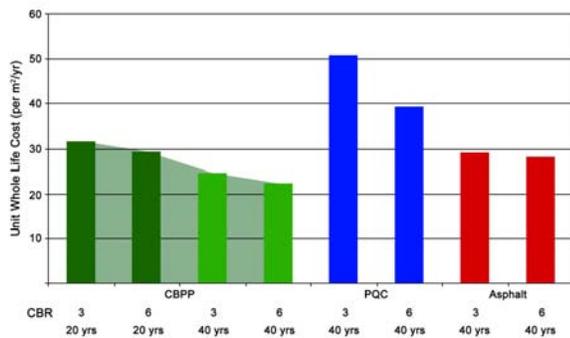


Figure 8. Supermarkets and Other Car Parks: WLC

3.3.2 Parking for Warehouses

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 has 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.

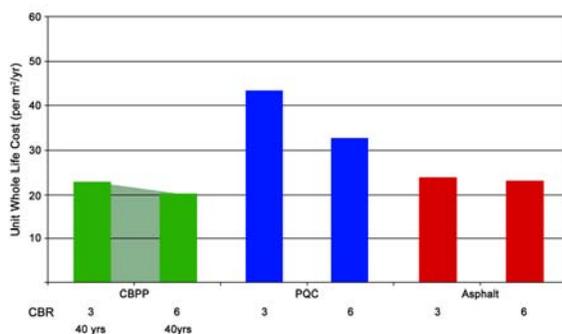


Figure 9. Parking for Warehouses: WLC

3.3.3 Estate Road – Housing

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’ that helps secure sales. Other research has demonstrated the popularity of concrete block paving with the public, adding ‘kerb appeal’ to developments. CBPP (System C) offers

the lowest WLC at CBR values of both 3 and 6, while offering the well-recognised visual attractions of block paving. Highway authorities ‘adopting’ (i.e. taking ownership of and responsibility for) such roads will be particularly interested in maintenance costs and WLC benefits of CBPP.

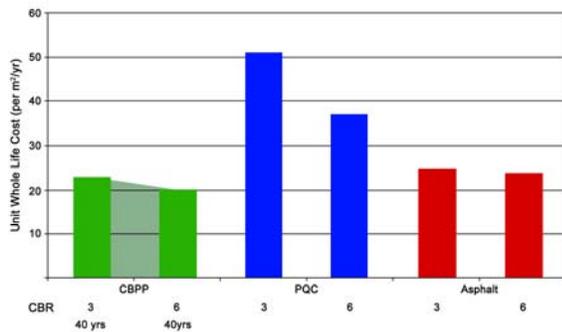


Figure 10. Estate Road – Housing: WLC

3.3.4 Estate Road - Industrial

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.

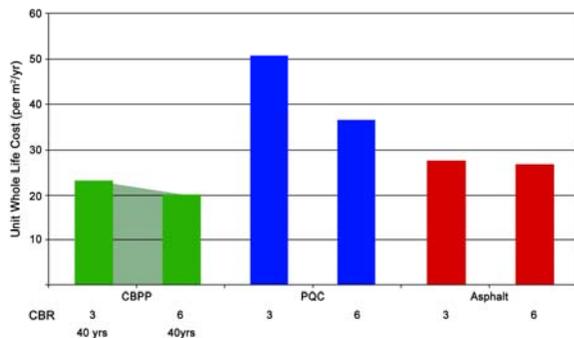


Figure 11. Estate Road – Industrial: WLC

4. CONCLUSIONS

Whilst the topography of a development area has a bearing on the design levels of a site, the creation of suitable falls to large areas of carriageway, parking, or storage play a major part in determining the ground profile adopted. This then dictates the amount of excavation or imported material necessary. The use of permeable paving is therefore best considered at the earliest stage of any design, as this will be the time when the maximum cost benefits will be derived.

The drainage of large areas of impermeable surface – which in the case of estate roads, for example, could include not only the carriageway, but also any footpaths or domestic driveways – can cause major problems for the designer and developer of new projects, particularly concerning the matter of satisfying the design criteria set out by the Local Authorities and regulators, such as agreeing storm water discharge rates. Again, early consideration should be given to the use of concrete block permeable paving, to minimise the additional measures necessary to comply with these requirements,

whether simply discharging to a watercourse or undertaking further surface water management using Sustainable Drainage Systems (SUDS).

It is advisable to undertake ICC at the feasibility of a project to accurately predict the costs taking into account all the factors specific to this particular project.

The complete ICC and WLC reports are available on the Interpave web site www.paving.org.uk

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