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Pavement performance revisited

The first pavement design manual specifically targeted at the port industry was the British Ports Association's publication entitled *The Structural Design of Heavy Duty Pavements for Ports and Other Industries*. This manual is commonly found on the shelves of port consultants, terminal operators, shipping line managers and port engineers around the world, and has been used to design numerous projects in all types of environment. Initially published in 1982 and updated in 1987 and 1996, this guide presented three pavement options including pavement quality concrete and asphalt or concrete block surfaced cement stabilised base. Cement stabilised base has proven to be a highly rut resistant material with good load spreading properties. A subsequent revision to the manual's concepts changed the base material in the asphalt and concrete block options to wet lean concrete, partly reflecting changes in some highway design practice. However, this wet concrete material has not found as much favour in the port sector as the semi-dry cement stabilised base option.

Cement stabilised base for heavy duty pavements is produced from aggregates, cementitious materials and water. The aggregates can be processed concrete aggregates or natural sand and gravel mixtures. The cementitious materials are typically portland cement, and occasionally other pozzolanic materials.

Specifications for these materials can be found in the UK Highway Agency's *Standard Specifications for Highway Works, Series 800* (and BS EN 14227).

Cement bound materials are hardly ever seriously considered to comprise an entire pavement section from bottom to top to provide a wearing surface for port traffic.

There is such as system that has been used regularly outside of the ports industry but rarely within it.

This material is known as Roller Compacted Concrete (RCC).

RCC – A SERIOUS OPTION

What is it, and why should it be considered for port pavements? The answer to this is addressed in this article owing to the serious commercial advantages this system has over other more traditional pavements.

Like all other industries the port industry is led by the need to implement a financially driven approach to its capital expenditure and as pavements comprise a significant proportion of any capital costs related to new or renovation projects any large savings in paving procurement must be worth considering.

In the 1970s the logging industries in Canada and New Zealand were in need of economical pavements capable of supporting their log handling equipment. This equipment had wheel loads similar to modern container handling equipment. The solution that became commonplace was roller compacted concrete. This material is a stronger version of cement bound aggregate as used for base courses in other pavements. As it is also used for the construction of dam cores in the Americas there were several contractors capable of undertaking these projects.

The first use of roller compacted concrete in a port container terminal was at the Conley Marine Terminal in Boston, which was constructed in 1986. Although this pavement has only experienced minor surface issues, there was little additional use of un-surfaced roller compacted concrete in other ports during the following 15 years, despite its use in other industries.

However, over the course of the last five years there has been greatly renewed interest in RCC, particularly in the UK and the Americas. RCC pavements have been constructed in ports on the east and west coasts of the UK and on the east coast of the States. Other projects are currently in design on the US Gulf Coast, the west coast of Canada and north coast of Europe. This renewed interest can be attributed to three important features Firstly, roller compacted concrete has become more cost competitive, typically being 10 to 20 per cent less than pavement quality concrete and concrete block surfaced pavements, and comparable with almost all asphalt surfaced pavements. Secondly, roller compacted concrete can be constructed in a short time period by virtue of the limited number of construction components. Finally, roller compacted concrete has proven to be a low maintenance pavement option in heavy load applications.

RCC EXPLAINED

RCC is a semi-dry, zero slump, high-strength concrete comprising aggregate, water and cementitious materials (Portland cement by itself or with pulverized-fuel ash or ground granulated blast-furnace slag). Mixture proportions are similar to conventional concrete with the exception of the water content which is lower. The water content is based upon optimum moisture content so as to achieve the maximum possible density. The mix is designed using flexural strength and compressive strength. Because of the low water-cement ratio, RCC typically has higher strengths than conventional concrete. Common design flexural strengths are in the range of 4.5 MPa to 7.0 MPa with comparative compressive strengths in the range of 35 MPa to 60 MPa.

RCC is mixed in a continuous mixing plant with the materials proportional by mass. Mixing and hauling must be performed quickly with close quality control. When used as a pavement, it is constructed with conventional and modified asphalt paving equipment. The mixture is placed in single or double layers each up to 250mm thick. Vibratory compaction by rolling must follow quickly and not cause damage to the surface or the edges of the layer. This is followed by pneumatic-tyre rollers to close up the surface. Cold joints should be planned carefully. Curing, following placement and compaction, is critical to achieve the desired flexural strength. This can be achieved by applying a sprayed curing membrane or by spraying with water for seven days.

Design of RCC pavement follows a similar procedure to conventional concrete in considering subgrade properties, RCC flexural strength, equipment loadings and repetitions. Most engineering properties are similar to conventional concrete, however, fatigue characteristics differ from those of conventional concrete paving mixtures. Based upon a compilation of US testing and research, RCC has a slightly higher ratio of flexural to compressive strengths than Portland cement concrete. However, the fatigue life of RCC has been found to be less for the same ratio of applied stress to ultimate stress. Reinforcement to control shrinkage and temperature cracking is not required. Movement joints with dowel bars are not required, and joint sealing is not undertaken.

The premier characteristics of RCC and its overall rating compared to other pavement surface materials are highlighted in Table 1. The Rating Scale is as follows: 1 = lowest, 5 = highest value of characteristic.

Table 1: RCC its Premier Characteristics and Overall Rating Compared to Other Systems

Characteristic	Concrete Blocks	Aggregate Surfacing	Hot Rolled Asphalt	Bituminous Macadam	Pavement Quality Concrete	Roller Compacted Concrete
Resistance to Rutting (Channelised Traffic)	4	1	2	3	5	5
Resistance to Point Loads (Stacking)	4	1	2	3	5	5
Resistance to Scraping (Bulk Storage)	3	1	3	2	5	5
Accommodates Ground Movement	5	5	4	4	2	4
Construction Costs	3	5	3	3	1	4
Construction Time	3	5	4	4	2	4
Maintenance Costs	5	2	3	3	3	4
All Weather Surface	5	2	5	5	5	5
Oil Spill and Leachate Resistance	4	1	2	2	4	5
Temperature Gain/Loss	3	4	2	2	4	4
Reflectivity	4	2	2	2	5	4
Movement/Creep	3	3	2	1	5	5
Cold Weather Resistance	3	2	4	4	4	4
Hot Weather	4	4	3	3	4	4
White Lining	4	1	5	5	4	4
Tyre Damage	3	1	2	2	5	4
Track work	1	5	4	4	3	2
Skid/Slip	4	2	4	4	4	4
Aesthetics	5	1	3	3	3	2
SUMMATION	70	48	59	59	73	77

In the United Kingdom, RCC installations include composting yards, warehouse floors, sludge farms and marine terminals as indicated in Table 2.

Table 2: RCC Installations in the UK

Projects in UK	Year	Thickness (mm)	Area (hectare)
Green Waste Facility, Little Bushywarren Copse, Basingstoke, Hampshire	2004	200	4.0
Waste Recycling Centre, Caythorpe, North Grantham, Lincolnshire	2004	200	1.6
Stoke Bardolph Sewage Treatment Works	2003	170	2.7
Wanlip Sewerage Treatment Works	2003	180	4.0
Baston Fenn Concrete Products Stockyard	2003	200	2.6
Immingham Bulk Storage Terminal	2002	200	2.6
Liverpool Port	2001	300	2.2

In North America, RCC pavements have been successfully used in intermodal rail terminals, aircraft parking areas, logging yards, coal yards, military facilities and container terminals as indicated in Table 3.

Table 3: RCC Applications in North America

Projects in North America	Year	Thickness (mm)	Area (hectare)
Virginia Port Authority	2004	300-450	4.65
Pier 300 Port of Los Angeles, Los Angeles, California	1998	430	3.34
Canadian National Railway Intermodal Yard, Calgary, Alberta	1997	355-405	7.27
Wood chips storage area, Edmonton, Alberta	1992	250	11.7
Motor park hardstands, Ft Bliss, Texas	1987	205	7.35
Koch Industries coke pad, Joliet, Illinois	1986	255 & 355	0.93
Massachusetts Port Authority Conley Terminal, Boston, Massachusetts	1986	455	6.35
Western Farmers coal yard, Hugo, Oklahoma	1986	330	3.13
Tracked vehicle hardstand, Ft Lewis, Washington	1986	215	1.31
BN Rennick Yard Intermodal Terminal, Denver, Colorado	1986	380 & 510	11.37
Portland Airport aircraft parking, Portland, Oregon	1985	355	3.43
Port of Tacoma North Intermodal Yard, Tacoma, Washington	1985	305 & 430	2.93
North plant ready-mix yard, Colorado Springs, Colorado	1985	205	1.00
Port of Tacoma South Intermodal Yard, Houston, Texas	1985	460	4.43
Tank Hardstand, Ft Hood, Texas	1984	255	1.64
Coal storage area, British Columbia	1982	225	19.00