A REVIEW OF CONCRETE BLOCK PAVEMENTS AT PORTS IN THE UK

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SUMMARY

The paper examines the performance of concrete block paving at seven port areas in which the pavement is trafficked either by container handling plant or by Roll-on/Roll-off traffic. These pavements are between twelve and three years old and they have been subjected to various degrees of maintenance. The following sites are described:

(a) Poole Harbour (1975)  (b) Dover Harbour (1976)  (c) Port of Sunderland (1980)
(g) Russell Davies Limited, Felixstowe (1985)

In each case, the pavement construction materials are described and the type of loading is quantified. The level of maintenance carried out during the life of the pavement is shown and the maintenance costs are stated as a cost per annum per square metre. In cases where maintenance has been significantly high or low, the particular reasons for this are discussed. It is concluded that concrete block paving is particularly suitable for port applications and in the great majority of sites, the material has performed well. It is also concluded that maintenance costs are low or zero.

1. INTRODUCTION

The first substantial area of concrete block paving to be constructed in a port in the UK was Phase 1 of the Freight Ferry Terminal at the Port of Poole in 1976. This comprised an area of 18,000m² at a time when the UK output of concrete block paving was 450,000m² per annum. Since then, concrete blocks have been used in over 20 UK ports and the material has become the orthodox surfacing material for heavy duty pavements. Because of this, there is now sufficient data available to allow conclusions to be drawn regarding the long term maintenance requirements of concrete block paving. Much of the data in this paper was obtained during visits to each of the ports mentioned during July 1987. Before this data is presented, a brief account of the introduction of concrete blocks to UK ports is provided and the reasons why port engineers adopted the material are discussed.

2. INTRODUCTION OF CONCRETE BLOCK PAVING TO UK PORTS

In the Netherlands and West Germany, a concrete block paving industry developed during the 1950's and the 1960's. In the Netherlands, concrete blocks replaced paving brick and in West Germany, they had replaced granite setts. Britain had replaced nearly all of its brick and setts roads with asphalt during the period 1920 - 1960 so that there was no small sized unit which concrete blocks could replace in the UK. For this reason, the material was not introduced to the UK until the late 1960's, 20 years after it became available in the Netherlands and West Germany (it had been used before the Second World War in Belgium, but not in important quantities). During the period 1968 - 1972, four UK companies introduced a shaped concrete block, two shapes were licenced from West German organisations, one was an imitation of one of those and the forth was a "castellated" shape developed in the UK. They were being marketed as a decorative surfacing material and combined annual production was less than 100,000m².

![FIGURE 1: THE SHAPES OF CONCRETE BLOCKS MANUFACTURED IN UK IN 1972](image-url)

A change in the perception of concrete block paving occurred in the UK in 1973 when the Cement and Concrete Association initiated a development programme which resulted in design methods becoming available for many categories of pavement, although Cement and Concrete Association specifically avoided developing design methods for port pavements. The Cement and Concrete Association's technical programme was supported by a promotional campaign which brought the material to the attention of UK highway pavement specifiers.
g the early 1970s port engineers were still having to address their paving problems, which were becoming acute following the introduction of container handling equipment. Ports had roads and hardstandings for highway loadings of up to 12t, whereas front line trucks were then introduced with axle loads of 70t. Discussions between manufacturers, who envisaged that ports could become a major new market, and port engineers lead to the initial contracts at Poole.

An important factor contributing to the growth of concrete block paving in ports was the publication of the British Ports Association (BPA) heavy duty pavement design manual in 1983. This developed from the port engineers' concern mentioned above and is of particular relevance to the block paving industry as it became (and still is) the only pavement design manual in the world which considered concrete block paving similar status to rigid concrete and asphalt. Most other concrete block paving design procedures were developed by the industry as a promotional ploy, whereas the BPA manual was produced by the ports themselves.

A second important factor was the success of the areas of concrete block paving at the Container Terminal (ECT) in Rotterdam. The combination of technical innovation and efficient publicity had brought the benefits of concrete block to the attention of UK engineers, many of whom had visited ECT, specifically to observe their paving solutions.

An interesting factor in the use of concrete block paving by ports has been the witch from shaped pavers to rectangular ones. Between 1973 and 1987, the UK block paving market changed from being 100% shaped to 80% rectangular. Public authorities often resisted the introduction of block paving during the mid-1970's for fear of being linked to one manufacturer. The standard 100mm x 200mm rectangular block has become the predominant material. The only exception to this is in those ports where blocks were introduced prior to rectangles becoming widely available. In order to avoid creating a patchwork quilt those ports have continued with their original shapes (e.g. Poole and Dover) whereas newer projects have usually employed rectangles (e.g. Tilbury, Exxtor).

3. PORT OF POOLE

The Freight Ferry Terminal at the Port of Poole, on the south coast of England was the first large UK industrial area to be surfaced with concrete block paving. Phase 1, comprising 18000m² was completed in 1976. Between 1979 and 1982 a further 7500m² was constructed and 22500m² was constructed during 1985. Resulting in an total area of 48000m². The area is trafficked by 70000 commercial vehicles per annum and by ferry passenger and importation car traffic.

The site was reclaimed from Poole Harbour just prior to construction. The reclamation work comprised the pumping of dredged sand fill which was then consolidated hydraulically. This material developed negligible settlement. The pavement construction comprised 150mm well-graded limestone granular base material, 50mm laying course sand and 80mm blocks.

After 12 years trafficking, the pavement remains in good condition and has settled uniformly by approximately 30mm. This has lead to the need for some remedial laying on reseeded sand around gulleys, manholes and inspection chambers. The cost of this work, expressed in terms of unit area of pavement, is negligible and the pavement can be considered to be maintenance free.

In an experimental area, the 150mm base was omitted. Owing to layout changes this was trafficked less heavily than anticipated but additional settlement has occurred and the signs are that this would not be satisfactory under heavy use.

An area of concrete block paving has been constructed at the Port's general cargo area, New Quay, on land which was reclaimed over 50 years ago, using uncontrolled fill material. In this area, concrete block paving has been laid over either 300mm or 150mm granular base material, directly over the fill. The traffic comprises regular 25t capacity fork lift trucks, having a laden front axle load of 53t.

The area was completed in 1978 and 25% has been relaid. Of the remainder, there is deformation up to 150mm and most of the blocks are cracked and spalled. Approximately 75% of the area would require remedial work to bring the area to good condition.

A third area of concrete block paving was constructed at Bulwark Quay in 1979 over an area used to handle steel strip. The blocks suffered impact damage and were overlaid with a 50mm single course of hot rolled asphalt. There is no evidence of crack propagation through the asphalt.

From Poole Harbour, the following conclusions can be drawn:

a. Relatively thin granular bases are suitable over hydraulically placed fill material for Ro/Ro traffic. Maintenance is confined to resetting gulleys and other hard products.

b. Care should be taken with heavy fork lift trucks over uncontrolled fill. The use of granular base material will lead to high levels of maintenance with the majority of blocks requiring replacement within 10 years.
c. 50mm thickness hot rolled asphalt can be used to overlay abraded block paving.

4. DOVER HARBOUR BOARD

There are several significant areas of concrete block paving at Dover. They are as follows and are shown in Figure 2.

<table>
<thead>
<tr>
<th>Name</th>
<th>Size (m²)</th>
<th>Construction</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import Freight Area Phase 1</td>
<td>40,000</td>
<td>280mm lean concrete</td>
<td>1977</td>
</tr>
<tr>
<td>Nos. 5 &amp; 6 Berths</td>
<td>27,000</td>
<td>280mm lean concrete</td>
<td>1979</td>
</tr>
<tr>
<td>Camber Reclamation</td>
<td>40,000</td>
<td>250mm lean concrete 300mm shale</td>
<td>1984</td>
</tr>
<tr>
<td>Import Freight Terminal Phase 2</td>
<td>50,000</td>
<td>400mm blastfurnace slag</td>
<td>1985</td>
</tr>
<tr>
<td>Berth No. 3</td>
<td>8,000</td>
<td>300mm lean concrete</td>
<td>1987</td>
</tr>
</tbody>
</table>

A further 50,000m² is being constructed during 1987 to be commissioned in 1988.

Each of the sites is on reclaimed land within the Eastern Docks complex and is subject to Ro/Ro traffic. The reclaimation material comprises Goodwin Sand. This is a single sized fine sand pumped ashore and won from sandbanks in the Straights of Dover. It is consolidated hydraulically and develops a little long term settlement. It settles by up to 50mm during the first 12 months after placing and then by one or two millimetres per year.

The Dover Harbour Board engineer has undertaken several trials during the last 12 years. In one, a moisture susceptible base material was used. The pavement failed immedately and the base material was rejected. In a further trial, stabilised limestone was used in place of lean concrete. It was discontinued for two reasons: firstly, the material had been laid in 4 metre wide strips and the joints exhibited significant deterioration. Secondly, the material showed no cost benefit when compared with lean concrete.

Perhaps the most interesting trial at Dover was the omission of a base, the block paving being constructed directly over imported single sized sand fill. This trial performed satisfactorily and the possibility remains of progressing this further.

All of the areas with the exception of Phase 2 of the Import Freight Terminal used a similar block, a "wiggly brick" type of unit. Phase 2 used a block comprising three hexagons joined by grooves in the surface to give the impression of three independent hexagons. The other major difference between this section and the others is the use of an unstabilised base instead of lean concrete. During an inspection in July 1987, it was evident that none of these hexagon blocks had cracked whereas in some locations the original shape had cracked. The Author considers that this difference in shape has lead to the reduced occurrence of cracking.

The major conclusion to be drawn from Dover is that pavement maintenance has been almost eliminated since the introduction of concrete block paving. Prior to 1977, pavement maintenance (reinforced concrete and asphalt) had been a major item of spending. The engineer responsible for the paving considers that concrete block paving has been a major positive factor in reducing surface costs at the Eastern Docks, Dover. In each section, there has been no first cost premium required. None of the areas appears to be approaching serviceability failure and the port is intending to continue with the material.

5. PORT OF SUNDERLAND

The South Foreshore Container Park at Sunderland Port Authority was constructed during 1980 and opened for container handling in 1981. The area is used for the storage of 40ft and 20ft laden containers which are delivered and retrieved by highway trailers. Containers are lifted by a Clark Y800D front lift truck applying a front axle load of 90,000kg. The site comprised a redundant shipyard which had been demolished to ground level. The subgrade comprised compact ballast with a CBR of 20%. In some areas, existing concrete slabs were broken and the pavement was constructed directly over either the ballast or the broken slabs. The pavement comprises 200mm granular material, 300mm lean concrete, 50mm sharp sand and 80mm blocks.

The park has an area of 22,000 m² and was the first pavement to be designed by the British Ports Association heavy duty pavement design method. Because of this, it was the subject of a monitoring exercise over a three year period during which surface deformation was measured. Five areas were selected, each subjected to a different type of loading and the details of these areas shown in Table 1.

<table>
<thead>
<tr>
<th>Area Description</th>
<th>Type of Use</th>
<th>Size (m)</th>
<th>Number of points monitored</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Little used (control)</td>
<td>5 x 5</td>
<td>144</td>
</tr>
<tr>
<td>B</td>
<td>Front lift trucks with light loads</td>
<td>6.4 x 6.4</td>
<td>225</td>
</tr>
<tr>
<td>C</td>
<td>Highway trailer turning</td>
<td>12.0 x 12.0</td>
<td>225</td>
</tr>
<tr>
<td>E</td>
<td>Container corner castings</td>
<td>5 x 2.25</td>
<td>72</td>
</tr>
<tr>
<td>G</td>
<td>Front lift trucks with heavy loads</td>
<td>6.4 x 6.4</td>
<td>225</td>
</tr>
</tbody>
</table>

TABLE 1: AREAS MONITORED AT SUNDERLAND CONTAINER PARK.
Figure 3 to 7 show isometric projections of pavement deformation after a period of 20 months use. Table 2 shows the maximum and typical deformation in each case.

<table>
<thead>
<tr>
<th>Area Designation</th>
<th>Maximum Deformation (mm)</th>
<th>Typical Deformation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>E</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>G</td>
<td>6</td>
<td>4</td>
</tr>
</tbody>
</table>

**TABLE 2.**

Table 2 shows that significant deformation has occurred only in areas E and G i.e. at corner casting locations and where heavily laden front lift trucks run. Typically, container castings have indented the pavement by 12mm which is the amount by which corner castings project beneath the container underside. Area G is the one subjected to the pavement’s full design load and it can be seen that a deformation of 4mm has occurred typically over a period of 20 months.

It is concluded from this monitoring exercise that heavy duty concrete block pavements can be expected to settle in loaded areas by a few millimetres per year. This settlement has not lead to any maintenance requirement and the pavement has been wholly maintenance free. It is also concluded that where heavy containers are stored, concrete block paving will form depressions beneath the container corner castings. These corner castings project 12mm below the container underside, although manufacturing tolerances bring this figure to 20mm or more in some cases. Therefore, depressions up to 25mm can be expected in local areas. These depressions have no adverse effect on the pavement and appear to result from the lateral migration and degradation of the laying course sand. A further effect of container storage is the development of “star” cracking as shown in Figure 8. This has occurred when containers have been dropped onto the pavement. The cracks emanate from a point and run towards perimeter recesses. It is postulated that this occurs only in blocks which include recesses. It does not appear to lead to further degradation of the surface.

The conclusions from Sunderland can be summarised as follows. On a very heavily loaded pavement, some local surface damage may occur but providing a cement stabilised base is used as the major structural component, there should be no regular maintenance required. The pavement has now been in service for six years, although during the last two years, loading has been light.

6. PORTSMOUTH HARBOUR FERRY TERMINAL

The traditional fill material in the Portsmouth district is chalk. It was used to reclaim land from the sea for the first stage of the development of the cross channel ferry terminal. To prevent frost heave in the chalk, the pavement construction chosen was 500mm thick, made up of 40mm hot rolled asphalt on 60mm dense bituminous macadam and 250mm lean mix concrete on 150mm granular sub base.

Later phases of the development saw changes in both the reclamation material and the surfacing. Ballast-as-dredged from the sea replaced the chalk, and the 100mm bituminous material was replaced by concrete block paving. After experimenting in 1984 with various permutations of base and sub-base types, including no base and sub-base at all, a large area has since been constructed comprising 80mm blocks on 50mm laying course sand directly on the ballast-as-dredged.

A feature of this site is the construction of 6m wide granular fill islands with precast concrete kerb perimeters. Following a fatality accident, the port authority was required to construct these islands to prevent back out parking trailers from touching each other. The 250mm high kerbs are glued to the block paving surface. Sometimes, kerbs are dislodged by trailers and a lower 200mm kerb is gradually replacing the 250mm units.

During 1986, it was observed that blocks were cracking and spalling on those parts of the area subjected to severe trailer wheel loads. An 80m2 trial was constructed in the worst area in which 100mm x 200mm British Standard rectangular blocks replaced the previous "wiggly brick" unit. Both types were of similar concrete thickness and position of area. Also similar construction materials and methods were adopted. The trial area showed cracking whilst the non-rectangular blocks continue to crack.

From Portsmouth Harbour, the following conclusion can be drawn:

a. A stabilised roadbase is unnecessary on well consolidated fill sites subject to normal highway and Ro/Ro traffic.

b. A change in block shape, all other parameters remaining constant, can have a significant influence on block cracking. The rectangular block is less susceptible to cracking than blocks of the shape used.

It is interesting to consider that in some...
countries, national recommendations issued by concrete masonry promotional bodies suggest the use of "wiggly brick" type blocks for this application and consider that rectangular blocks be not used. The Author considers that such recommendations are at variance with the observed performance of concrete block paving.

7. PORT OF BLYTH

Three types of concrete block pavements have been constructed at South Harbour, Blyth, UK. In December 1983 a general cargo storage area was constructed using 80mm thick concrete blocks on 50mm sand over 450mm thickness of granular base material. The subgrade comprises fill material of variable density. This area has settled uniformly by up to 30mm over a period of four years. This is a result of settlement of the fill material. Two further areas were constructed on the same fill material. The first was subjected to 12t capacity front lift trucks applying individual wheel loads of 12t. This comprised blocks and sand over 300mm thickness of lean concrete. The third area was similar but was trafficked by highway vehicle and the lean concrete thickness was reduced to 250mm. Neither of the stabilised base pavements has settled. The conclusion to be drawn from Blyth is that for industrial areas on fill sites, either granular or stabilised bases may be specified. With granular bases, settlement can be expected, although this should not be excessive. It should be noted that none of the areas at Blyth are subjected to severely channelised traffic and most of the loads are those which are associated with a Ro/Ro operation.

There has been no maintenance spending at Blyth. The settlement is regarded as acceptable and no plans are in hand to relay the blocks.

8. TILBURY CONTAINER SERVICES

A pavement comprising 100mm asphalt over 250mm lean concrete on sand fill had been constructed surrounding a straddle carrier maintenance workshop. Much of the asphalt was degrading owing to the spillage of mineral oil from a fleet of 13 straddle carriers. In 1985, an area of 9,000m2 was overlain with 80mm thick concrete block paving laid on 50mm thickness of sharp sand.

After two years, the pavement remained in excellent condition and no maintenance spending had been undertaken. The eight wheeled straddle carriers have individual wheel loads of 6,000kg in their unladen configuration, which is the usual situation in the maintenance area and apply individual wheel loads of up to 10,000kg. In some places, these loads will have been amplified when straddle carriers turn or brake. Turning can increase loads on the outer wheels by 30% and braking can increase front wheel load 25%.

From this application, it can be concluded that flexible pavements in which the surface has degraded can be overlain with concrete blocks and that the result was pavement should be maintenance free, even in very heavy load situations. It is also concluded that concrete block paving is suitable in locations where severe spillage occurs.

9. RUSSELL DAVIES LIMITED, FELIXSTOWE

A 16,000m2 container storage yard has been constructed in 1979 using 200mm thick reinforced concrete over a granular sub-base on clay subgrade with a CBR of 3%. By 1983 the concrete had cracked and spalled to such a degree that much of the pavement was unserviceable as shown in Figure 9.

The remedial scheme comprising a concrete block overlay was undertaken in 1983. The kerbs and drainage were raised by 130mm and 80mm blocks were laid over 50mm sharp sand. Prior to this, approximately 12% of the existing slabs were renewed, mainly because spalling had become so severe that slab thickness would have been too variable. Also, corner cracking had lead to some of the slabs rocking and pumping the sub-base material to the surface.

Strips of filter fabric were laid over the joints prior to sand screening in order to prevent sand from entering the joints. The overlay area is shown in Figure 10.

When the overlay pavement had been in service for 12 months, it was observed that block settlement had taken place along the line of a few of the joints in one corner of the yard. The blocks were removed and it was found that much of the laying course sand had disappeared over those joints. The remainder of the sand was replaced to reveal the filter fabric which had been placed over the joint to prevent sand loss. The material had degraded to the consistency of horse hair and chemical tests were undertaken to verify that the material was the filter fabric originally specified. The tests confirmed that it was the specified non-woven melded fabric.

An investigation into the degradation of the filter fabric confirmed that the affected area had a high water table and the material had been moist permanently. The traffic loads had caused the sharp laying course sand to abrade the material and this had lead to the loss of bond between individual fibres.

Remedial work comprised relaying the lines of blocks and substituting polythene for the filter fabric. This appears to operate satisfactorily.
From this project, it is concluded that spelplated concrete pavements can be overlain with concrete block paving but special care should be taken at joints. In particular, the ability of filter fabric to maintain its integrity beneath laying course sand should be established positively. In the absence of any other data, it can be assumed that in areas of high water table, filter fabric should not be used to prevent the ingress of laying course sand into rigid concrete joints below.

Owing to the ease and speed with which concrete block paving can be taken up and replaced, the remedial work was undertaken at little cost and inconvenience. Approximately 50m2 was relaid during a period of one weekend by eight men. Most of the time was taken in removing and cleaning the blocks. The blocks which were removed were rectangular with 3m wide spacers. In order to facilitate relaying, new rectangular blocks of similar size, but without spacers were installed. The remainder of the area has been maintenance free, other than replacing broken blocks when containers have been dropped accidentally.

10. Trinity Terminal, Felixstowe

The largest single UK port block paving project is the Trinity Terminal, Felixstowe which was constructed 1985 and 1986 and includes 150,000m2 of concrete block paving. Pavement construction comprised the in-situ cement stabilisation of 400mm thickness of as-dredged ballast, with 100mm thick rectangular concrete blocks, 200mm x 100mm in plan dimensions on 500mm thickness of sharp sand. The pavement is subject to individual wheel loads of up to 64,000kg applied by rubber tyred gantry cranes. Multiple wheeled gantry cranes were developed to permit free movement over the entire pavement. Previously, the port’s rubber tyred gantry cranes had been confined to runway beams with container stored on asphalt paving.

As yet, there is no quantitative data available regarding maintenance costs. This project demonstrates that rubber tyred gantry cranes can run freely over concrete block paving.

11. CONCLUSION

a) In Ro/No areas, where the subgrade comprises controlled fill, concrete block paving can be laid directly over the fill. This will lead to differential settlement between the paving and fixed structures and some maintenance will be required at these locations. However expressed as an annual cost per square metre of paving, these costs are minimal. A figure of £ 0-04 /m2 /annum is suggested as the maintenance expenditure to be allowed for this type of pavement. Usually, hydraulically placed fill material is suitable but in cases where the material has insufficient shear strength, a granular sub-base may be provided. Typically 200mm - 300mm thickness of such material will suffice and the maintenance spending is as stated above.

b) For pavements constructed over fine grained material (clay usually), a stabilised base is usually required both for Ro/No traffic and for the heavier loads associated with container handling. If a granular base is used there is the likelihood that both deflexion and deformation will occur at the surface. Deformation will lead to rutting and ponding, which will allow water to percolate through the surface and weaken the granular material. Excessive deflexion will lead to block spalling and breakage. It is considered that a granular base over fine grained soils will have an unacceptably high maintenance requirement.

A cement or bitumen stabilised base acts to strengthen the pavement and prevent the ingress of moisture in the subgrade. Experience indicates that pavements with a correctly designed stabilised base should have a zero maintenance requirement over a life of 25 years or more.

c) Concrete block paving can be overlain with bituminous material and the block pattern does not reflect through the asphalt. Only one example of this technique has been undertaken at a British port and so far, it has required zero maintenance.

d) For pavements on stabilised bases, the type of block used does not affect the performance of the pavement. Experience at Portsmouth Harbour indicates that there may be differences where pavements are constructed with granular bases. In particular, rectangular blocks have performed satisfactorily in all cases whereas cracking has occurred with profiled blocks.

e) When existing concrete pavements are overlain, care needs to be taken to ensure that laying course sand does not enter the joints. This can be achieved by a combination of filter fabric, joint sealant and polythene.

Local depression of concrete blocks along joints has occurred on some sites leading to ponding and spalling. Remedial work is relatively simple and inexpensive when expressed as a unit cost for the total area of paving.
Concrete block paving is suitable in areas of substantial oil spillage. At Tilbury, concrete blocks have become covered in oil dropped by straddle carriers and this has not adversely affected the concrete. Indeed the oil repels moisture and reduces the ingress of water into the laying course sand.

The overlain area at Poole was damaged by impact owing to heavy setting down of steel coil weighing 25t. Blocks were shattered but no great loss of thickness occurred. The overlay was carried out as soon as areas started to loose their integrity.

At several sites, blocks had been removed to gain access to utilities. In all cases, it had proved more difficult to reinstate than had been anticipated. Invariably, the last few blocks would not fit and part blocks had been inserted. In one situation, painted blocks had been removed and it had been impossible to reinstate the original pattern, with the result illustrated in Figure 11.

At one port, the engineer felt that the introduction of concrete block paving has been the most important construction innovation for 20 years. It has virtually eliminated the need for pavement maintenance which had been a major item of spending prior to the introduction of concrete blocks. Previously unreinforced concrete slabs had been used commonly and the maintenance requirement had been substantial.

**SUMMARY**

Each of the projects described in this paper has been in service for several years and some have been in service for over 10 years. Added together the pavements described have an area of 350,000 m² and have been subjected to total use of 1,700,000m² - years. In view of this low level of maintenance spending has been surprising. Where maintenance has been required it has been possible in each case to identify a specific fault. Often, this has been a question of pavement detailing at kerbs, manholes, gullies and similar constructions. Overlain pavements have performed satisfactorily and concrete block paving can be considered as a suitable pavement overlay material.

**REFERENCES**


Further information regarding the sites described in this paper can be obtained as listed below:

1. **Port of Poole**
   Poole Harbour Commissioners
   Harbour Office
   Town Quays
   Poole
   Dorset
   BH15 1HG
   Contact: Mr R Appleton (Chief Engineer)
   Tel: 44 202 685261

2. **Dover Harbour Board**
   Harbour House
   Dover
   CT1 9BU
   Contact: Mr J Gerrard (Director of Engineering)
   Tel: 44 304 240400

3. **Port of Sunderland**
   Port of Sunderland Authority
   Barrack Road
   Sunderland
   Tyne and Wear
   Contact: Mr R Stapleton
   Tel: 44 90 5140411

4. **Portsmouth Harbour Ferry Terminal**
   Portsmouth City Council
   Civic Office
   Guildhall Square
   Portsmouth
   Hants
   Contact: Mr C A Maber
   Tel: 44 705 822251

5. **Port of Blyth**
   Blyth Harbour Commissioners
   79 Bridge Street
   Blyth
   Northumberland
   NE24 2AW
   Contact: Mr I Robertshaw (Chief Engineer)
   Tel: 44 670 352066
Figure 3

Permanent deformation of control section of pavement at SUNDERLAND CONTAINER PARK after 20 months use. Note the random movement.

Figure 4

Permanent deformation of pavement trafficked by lightly loaded front lift trucks at SUNDERLAND CONTAINER PARK after 20 months use. The pavement has settled uniformly by 1mm.
Figure 5
Permanent deformation of pavement trafficked by highway trailers turning at SUNDERLAND CONTAINER PARK after 20 months use. The pavement has settled uniformly by less than 1mm.

Figure 6
Permanent deformation of pavement beneath corner castings at SUNDERLAND CONTAINER PARK after 20 months use. Settlement of up to 24mm has occurred.
Figure 7

Permanent deformation of pavement trafficked by heavy laden front lift trucks at SUNDERLAND CONTAINER PARK after 20 months use. The pavement has settled by up to 6 mm.

Figure 8

'Stor' cracking resulting from the impact of container corner castings.
Pattern of cracking in reinforced concrete slabs at RUSSELL DAVIES, FELIXSTOWE.
Approximately 12% of the existing concrete was replaced with new reinforced concrete and the whole was overlain with concrete block paving.

Completed concrete block overlay at RUSSELL DAVIES, FELIXSTOWE.
Figure 11

Painted blocks demarking a pedestrian route through a RO-RO area were not reinstated in their original position.