Structural design of block pavements for ports

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Introduction

The use of concrete block paving for ports is becoming accepted throughout the world. The relatively low cost of construction and maintenance of concrete block paving makes it an attractive proposition to the port engineer. However, there is as yet no method whereby the port engineer can specify the strength and thickness of the layers of the pavement to provide a specified design life. From a study of the performance of pavements constructed from various materials in many ports and by using established theoretical load – deformation relationships, the authors have developed a method whereby port engineers can design concrete block pavements rationally. The method presented in this paper can be used to produce a series of pavement designs for specific operating and subgrade conditions. In recognition of the fact that each design situation is a special case, the authors have formulated the design method in a way which preserves the engineers' freedom to specify sub-base and base material types and thicknesses in the pavement.

Definition of requirements

There are four primary requirements for a pavement:

1. Low cost of construction.
2. Low maintenance costs.
3. High reliability.
4. Known design life.

Although no material meets all of these requirements perfectly, it is believed by the authors that a concrete block surfacing with a cement bound base is the best solution available today.

A successful design must take the following parameters into account:

- port layout and operation
- future uses and development
- type of trafficking (vehicle speeds; wheel loadings; number of loadings)
- static loading (point loads; impact loading)
- surface pollution (hydraulic oil; de-icing salts)
- strength of subgrade
- anticipated settlement (short term; long term)
- climate
- availability of local materials

This list is by no means exhaustive.

With so many design parameters it is virtually impossible to put forward a comprehensive design method which would cover all plausible conditions; the graphical and tabular presentation required would be formidable.

This paper describes the development and use of a series of design charts which have been derived from a basic design philosophy; each chart covers a particular subgrade CBR value and sub-base thickness. It has not been possible to include a full set of charts in this paper due to the large number of variables and the limited space available. However, since all the data is generated and plotted by computer, different design situations can be accommodated readily by varying the input. The data presented should be regarded as typical rather than comprehensive.

Pavement design and analysis methods

Pavement design has been, indeed still is, empirical. The variability of the materials making up the pavement structure has, until recently, made it difficult to develop a suitable analytical design philosophy. However, the wide use of computers has brought a semi-analytical approach to highway design in the past few years, and this has also made it possible to extend the empirical design rules beyond their original bounds of development to include motorways and industrial pavements.

The most successful of these analysis techniques has been the multi-layer elastic model. Several programs of varying degrees of complexity have been developed, and this work uses a simplified analytical technique developed by Ullidtz and Peattie[1]. This has been adopted because of its speed of execution, particularly when several hundred pavement structures are being analysed, as is the case for each design chart.

The pavement model is shown in Figure 1. The contact area between the tyre and the pavement is assumed to be circular with a contact stress equal to the tyre pressure. The analysis program gives the vertical stress and strain, and the radial strain at each interface. Two design criteria have been established and generally applied to pavements:

1. Fatigue cracking of base material.
2. Progressive vertical deformation of the subgrade.

Thus the two design parameters in the structure are the tensile radial strain at the bottom of the bound layer and the compressive vertical strain at the top of the subgrade. Relationships have been developed between these two strains and the design life, ie number of load repetitions to failure of the pavement.

Thus with computer analysis it is possible to establish these critical strains for a whole range of pavement structures and plot the results as a design chart. The design charts are positioned on a single sheet for ease of interpretation and three examples

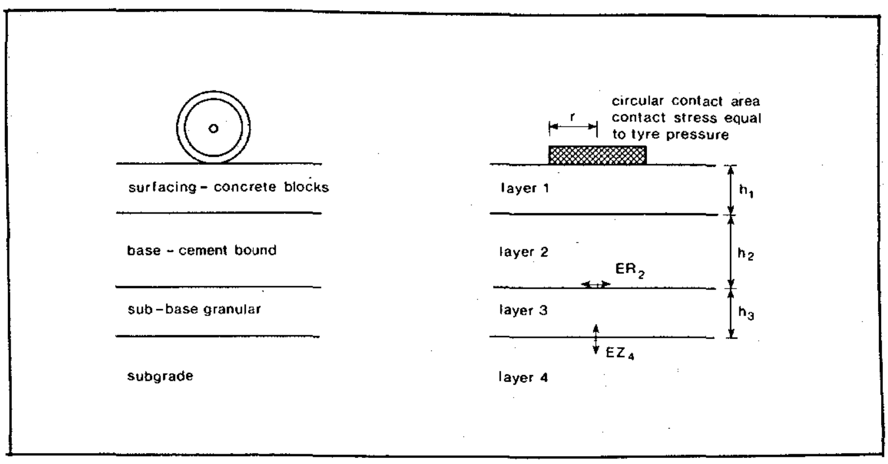


Figure 1: The pavement model. ER_2 is the critical strain in the base. EZ_4 is the critical compressive strain in the sub-base.

re given in this paper, Figures 2, 3 nd 4.

For each chart the following variables are held constant:

Surfacing (material type – 80 mm thick concrete blocks)
Base (material type – cement bound material)
Subbase (material type, granular; thickness; elastic modulus)
Subgrade (CBR – California Bearing Ratio)

The variables for each chart are:

Base (thickness; elastic modulus)
Loading (magnitude of loading)

On each chart an example line has been drawn showing how the graphs are related:

(i) The strength of the basecourse, ie. its elastic modulus, is the starting point on the ordinate of the bottom graph. Project horizontally to the intercept of the curve representing base thickness and then vertically to the centre graph.

(ii) This graph has two ordinate

igure 2: ubgrade CBR 5%.

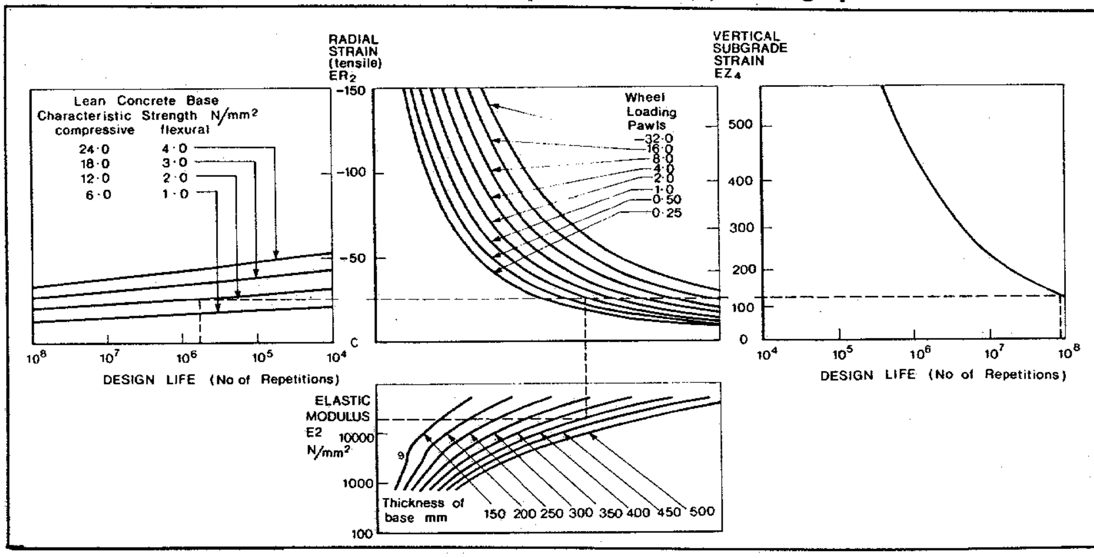
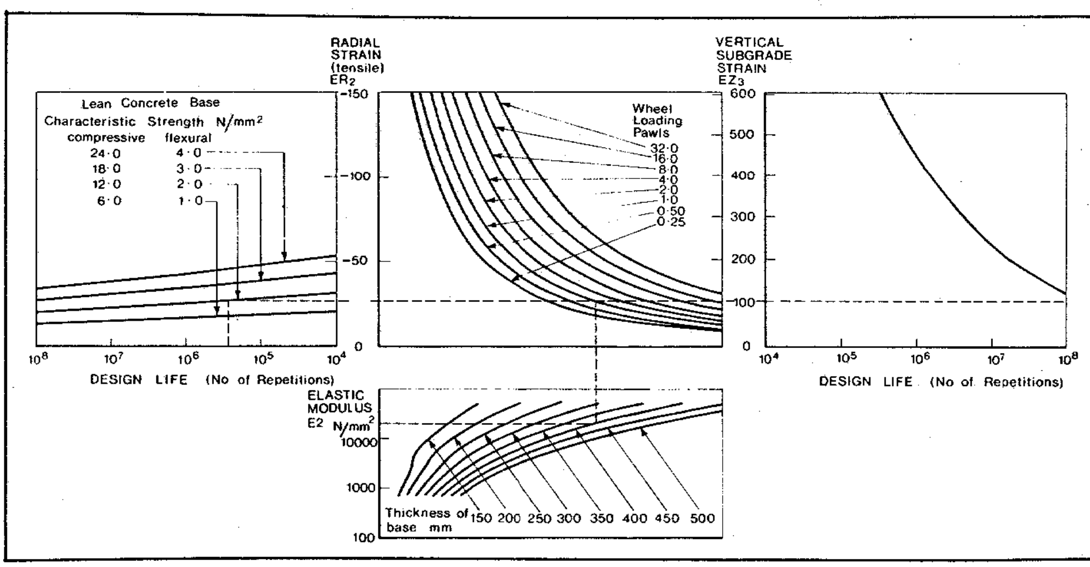
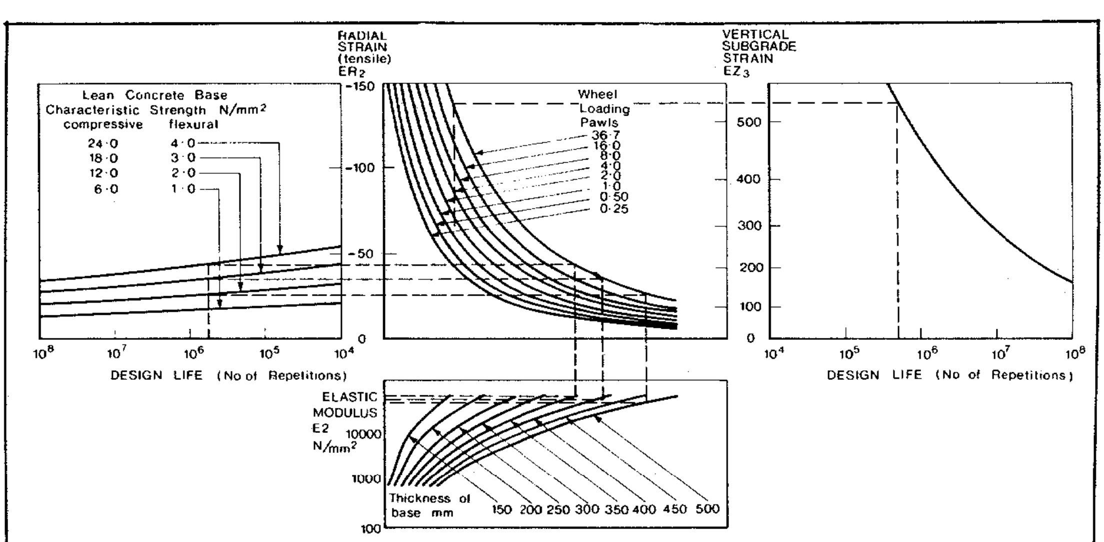


Figure 3: Subgrade CBR 10%.



igure 4: Subgrade CBR 20%.



scales; the one on the left is the tensile radial strain at the bottom of the bound layer and the right hand scale is the compressive vertical strain at the surface of the subgrade (both are scaled in microstrain). Unlike highway design, where there is a statutory maximum axle load for pavements in port areas the maximum load is variable. Hence the central graph has a series of curves representing the magnitudes of loading, which are given in Port Area Wheel Loads increasing in multiples of two.

(iii) The two outer graphs represent the fatigue characteristics of the pavement base, on the left, and the subgrade, on the right. Thus projecting horizontally across both outer graphs and descending to the abscissae gives the anticipated design life for each constraint. The actual design life is the lower of the two values.

The assessment of the vehicle loading is an important part of the design procedure. A survey of the loading characteristics of container handling vehicles made by the authors[2] was first published in 1979, and subsequently updated[3] in 1980. The wheel loading is characterised in terms of the Port Area Wheel Load, or PAWL, which is defined as a 12 tonne wheel load with a damaging factor of unity. The complete theory is not presented in this paper, but Table 1 gives typical values for handling equipment in common use.

The design charts given in this paper cover a range of subgrade strengths, CBR's of 5, 10, and 20%, with a surfacing of 80 mm concrete blocks.

Table 2 gives typical values for the elastic moduli of various base materials necessary for the input in (i)[4]. These are intended for use as a guide; if possible the true values should be established from laboratory tests since they are dependent on the characteristics of locally available materials.

Performance of paving materials

Since no universal pavement recommendations or design methods have been proposed over the years, a whole range of different construction techniques has been developed, largely through trial and error. Despite the diversity most structures can be divided into one of six broad categories, as shown in Figure 5.

There are two principal elements in a pavement:

Surfacing. Must be of a high durability and strength to resist the severe surface loads and high contact stresses.

Base. The principal structural component of the pavement which

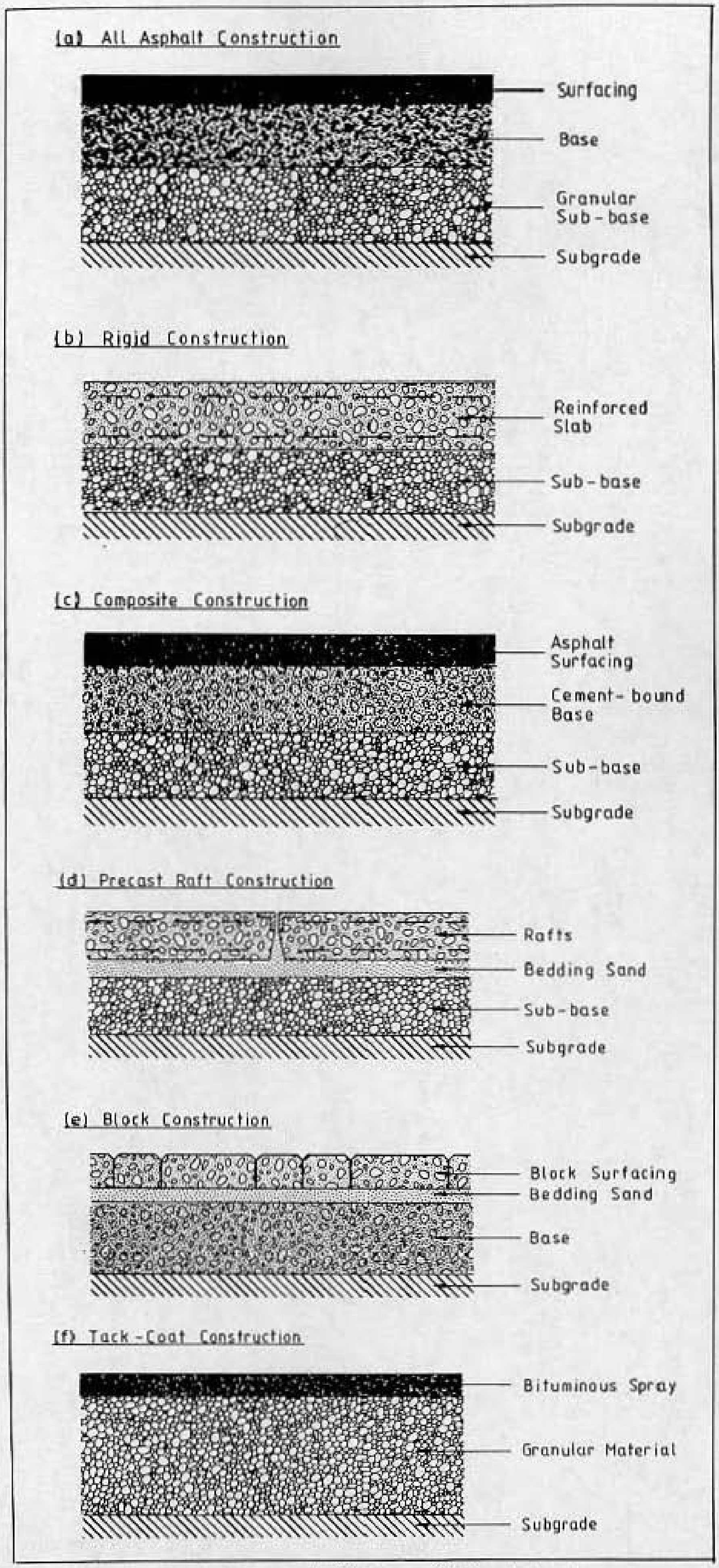


Figure 5: Pavement constructions generally fall into one of six broad categories.

Table 1: Typical Pawl values for handling equipment in common use.

Type of vehicle	PAWL ratings		
	unladen	average laden	most damaging wheel load
Road trailer	0.00	0.02	0.02
20 ft terminal trailer			
1 x 20 ft containers	0.01	0.10	0.14
2 x 20 ft containers	0.01	0.94	1.56
40 ft terminal trailer			
1 x 40 ft container	0.01	0.05	0.02
2 x 20 ft containers	0.01	0.26	0.18
2 x 40 ft containers	0.01	0.39	0.25
4 x 20 ft containers	0.01	2.62	2.01
Front lift trucks			
23.5 t capacity	0.80	10.0	15.0
28.0 t capacity	1.05	11.0	17.5
37.0 t capacity	5.0	20.0	35.0
Straddle carriers			
4 wheels	0.60	3.00	2.06
8 wheels	0.80	1.40	0.60

Table 2: Typical values for the elastic moduli of various base materials.

	Compressive Strength N/mm^2	Flexural Strength N/mm^2	Elastic Modulus N/mm^2
Lean concrete	6	1	27,000
	12	2	35,000
	18	3	42,000
	24	4	48,000
Cement Bound Granular Material	3	0.5	15,000
	6	1.0	17,000
	9	1.5	20,000
	12	2.0	22,000
Soil Cement	2.5	0.5	3- 7,000
	5.0	1.0	5-11,000

spreads the load so the subgrade is not overstressed.

A secondary element is the SUB-BASE which is provided where the pavement is constructed over a weak subgrade to give extra strength at low cost and to provide a good working surface for subsequent construction.

Ideally, each component is selected for its suitability and the combinations shown in Figure 5 are by no means comprehensive. The performance of the various materials available is now discussed in detail.

Asphaltic Materials

Asphaltic materials have been used extensively for both highway and aircraft pavements and their application to industrial paving seemed logical. However, three characteristics of the asphaltic mix have resulted in an overall poor performance in port applications:

1. The stiffness, or strength, of a bituminous material decreases as the temperature rises.

2. The stiffness of a bituminous mix decreases as the loading time decreases; i.e. the slower the vehicle the lower the strength.

3. Surface oil pollution slowly dissolves the bituminous binder, leaving it more susceptible to scuff and frost attack.

ASPHALT AS A SURFACING MATERIAL

Hot rolled asphalt, similar to that used in the UK for highway pavements, is generally too soft to carry the large wheel loads, high contact stresses and low vehicle speeds associated with container handling areas. For low speeds, a typical mix stiffness for a 100 Pen. bitumen mix is approximately 2300 N/mm^2, compared to 7000 N/mm^2 used in highway design calculations where the speed is nearer 80 km/hr. This is reflected directly by rutting and indentation, particularly in the summer months, see Figures 6 and 7.

The durability of asphalt surfacing can be greatly improved if a high stone content and a low penetration bitumen is used. In this case the mix stiffness is more likely to be 4500 N/mm^2 (50 Pen. bitumen, 55-65% stone content), and this gives much greater durability against indentation, rutting and oil damage. However, the stiffer mixes generally

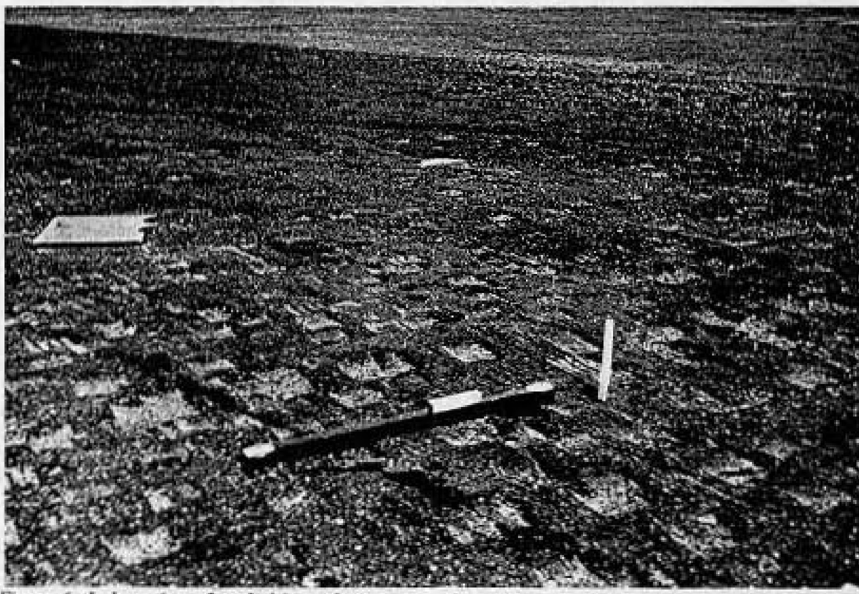


Figure 6: Indentation of asphaltic surfacing.

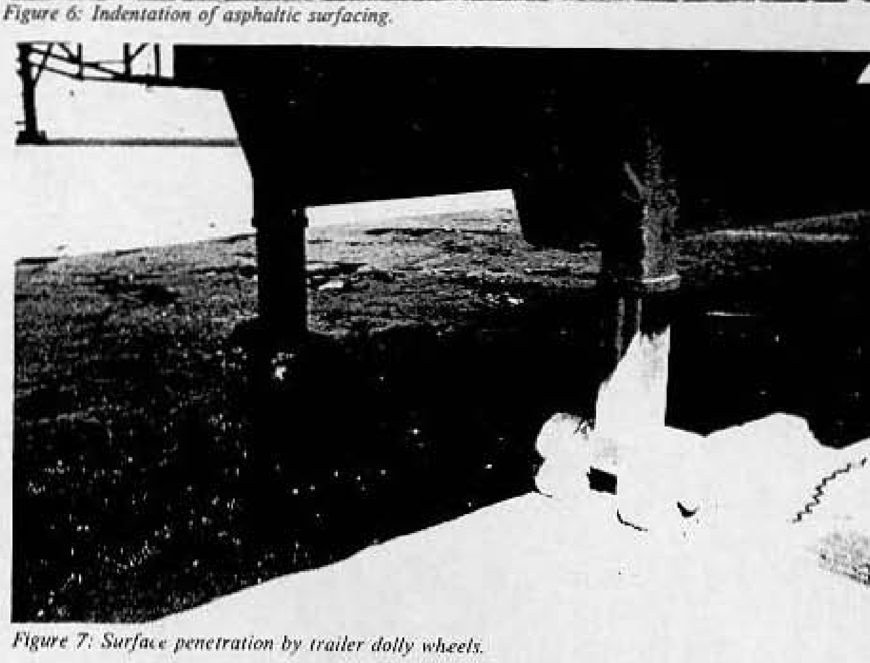


Figure 7: Surface penetration by trailer dolly wheels.

exhibit poorer fatigue characteristics and are more prone to structural cracking. Also low binder contents are more susceptible to surface damage from severe tyre screwing. Fatigue cracking, as will be seen shortly, can be overcome by the use of a cement bound base.

Although an asphaltic pavement is considered to be flexible, excessive differential settlement will lead to cracking and subsequent breakdown of the bound layer. The surface can be patched easily, but this is rarely satisfactory as pneumatic tyres rapidly pull the new material out. In large settlement areas, therefore, asphaltic surfacing is often rejected in favour of a more durable material.

ASPHALT AS A BASE COURSE MATERIAL

In view of the low stiffness and the poor fatigue characteristics, bitumen bound bases have not been used widely. A notable exception is in Denmark, where there is a well established asphalt industry, and two construction techniques have been used. The first, Figure 8, was based on highway design methods with modified thicknesses to accommodate the increased loading. The structure's pertormance was not completely satisfactory and when a further area was laid the specification was changed to that shown in Figure 9, this proved to be satisfactory. The difference in performance can be explained when the two structures are analysed. The two critical strains in the first structure are much greater than those in the second. It was also found that the latter was quicker, easier and less expensive to construct.

Another port using an all asphaltic construction, this time in the UK, has experienced very severe problems with critical pavement damage. An analysis of the structure in Figure 10 clearly shows why; both the critical strains are very high and well above the material's ultimate strain.

The performance of these three structures should be contrasted with that of a composite structure, ie asphaltic surfacing over a lean mix concrete base, Figure 11. Here, with a high strength base, the tensile strain in the asphalt is very low and may become compressive in some structures; the critical strain is then that at the base of the cement bound layer. The vertical subgrade strain is also very low. It is generally found that this form of construction gives a much more durable pavement.

Two of the structures given above have used a wet mix macadam as the base material; this has also been used under a concrete block surfacing for an industrial pavement in the UK. It is a relatively weak material being almost analagous to soil cement but

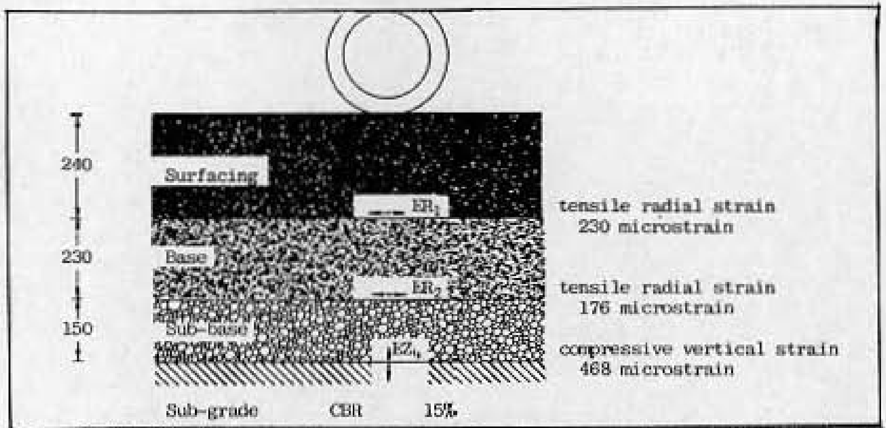


Figure 8: Original pavement specification in Denmark. Wheel loading: 1 Pawl. Construction: 40 mm asphalt concrete wearing course (100 pen); 200 mm asphalt base course (100 pen); 230 mm Macadam base; 150 mm mechanically stabilised gravel.

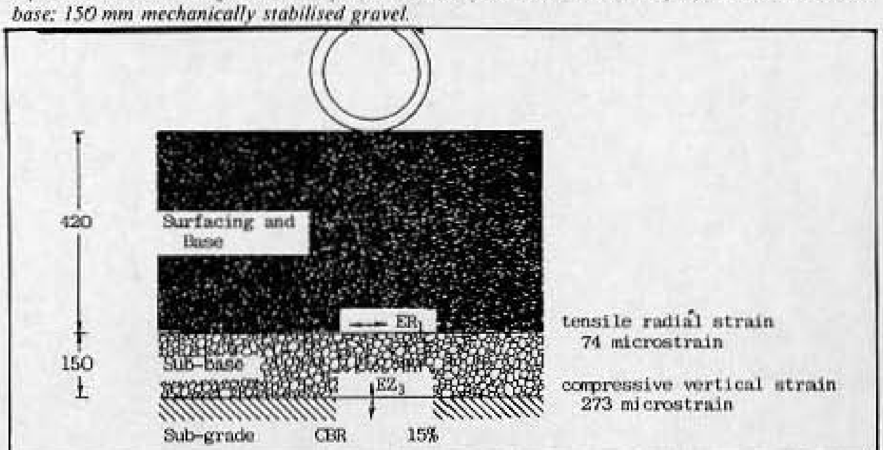


Figure 9: Modified pavement specification in Denmark. Wheel loading, 1 Pawl. Construction: 40 mm ashphalt wearing course (100 pen); 80 mm asphalt base course; 300 mm asphalt base; 150 mm mechanically stabilised gravel.

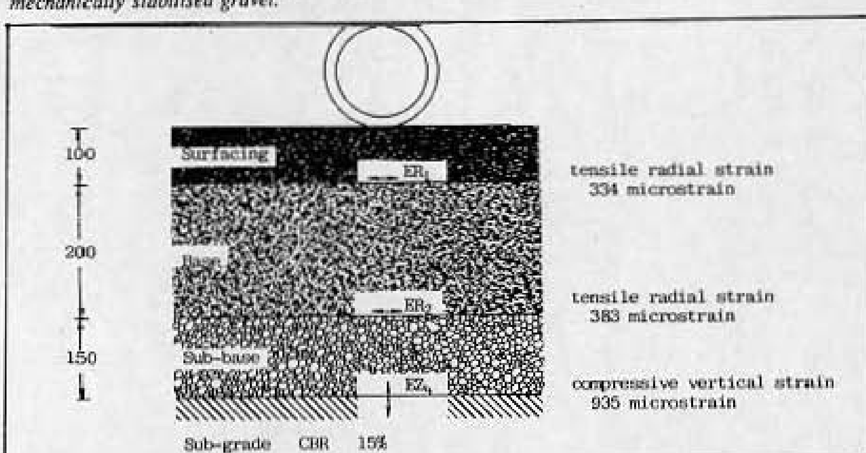


Figure 10: Typical all-asphalt paving. Wheel loading, 1 Pawl. Construction: 100 mm asphalt wearing course and dense bitumen macadam base course: 200 mm wet mix macadam base; 150 mm Type 2 granular sub-base.

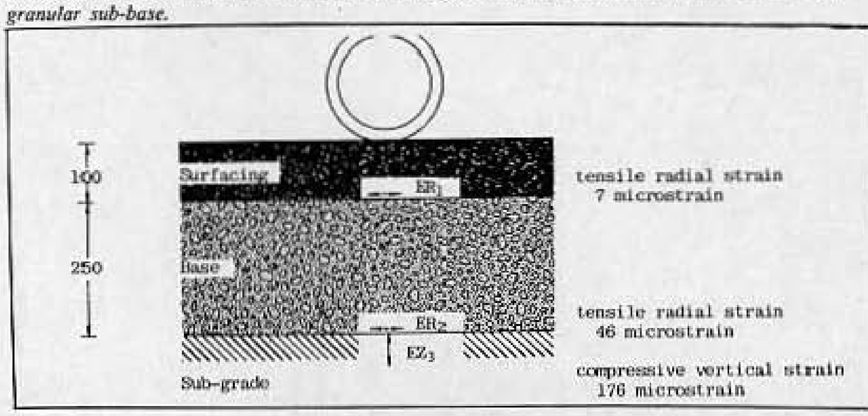


Figure 11: Typical cement-bound base pavement. Wheel loading, 1 Pawl. Construction: 100 mm high stone content asphalt wearing and base course; 250 mm lean mix concrete.

is claimed to be more tolerant to subgrade settlement. However the performance in the structures analysed in this paper does not seem to justify the higher cost of use, although the performance under block paving has yet to be proved.

Traditionally, asphaltic materials have been one of the most economical forms of paving, but the recent increases in the cost of oil based products has, in the UK at least, made it comparable to other more expensive surfacing materials, e.g. concrete blocks. In some European countries, where the alternatives are better established and less expensive, asphalt no longer has an initial cost advantage.

SPECIAL ASPHALT MIXES

It is possible to improve the surface durability of asphalt with a cement based grout. This is available under a number of trade names, but all use essentially the same technique. A surface layer of approximately 40 mm thickness of open textured, bitumen coated aggregate (no fines) is laid. Into this is rolled/vibrated a resin cement grout which is left to harden, it takes around 28 days to develop it's full strength.

The final stiffness of the surfacing is high, about 12,000 N/mm^2, and gives much greater resistance to surface loads. However, high strength, or semi-rigid, surfacings are very susceptible to cracking due to the high tensile stresses developed under loading. The strength of the supporting base material is critical, and the manufacturers have carried out design research based on the multilayer elastic model.

Since the material is not as flexible as a true asphalt, experience has shown that, under conditions of modest differential settlement, surface cracking will occur whereas a traditional asphalt mix would roll out. However these cracks are fine and widely spaced and do not affect the overall integrity of the pavement.

An alternative to cement resin is an epoxy asphalt mix. These special mixes are highly resistant to oil attack which makes them highly suited for maintenance areas etc. Construction has to be fast and efficient as the thermosetting mix hardens in about 90 minutes. Its use in port areas is not very widespread and where it is used it is restricted to heavily polluted areas such as loading bays.

Both these methods give increased durability, but at a higher cost of construction. This makes the adoption of these materials for extensive parking and operating areas unlikely on the grounds of cost.

Rigid pavement construction

An in-situ concrete pavement provides a very durable surface that can withstand high contact stresses, and gives an excellent riding quality. There are, however, two problems which make the use of rigid pavement construction impracticable:

1. Subgrade settlement cannot be accommodated without excessive cracking.
2. Some provision for thermal expansion/contraction must be made.

In the older port developments concrete paving was commonly used, either unreinforced or with a single layer of mesh reinforcement and regular expansion joints. Reinforced concrete is adequate for all but the heaviest of loading providing the site is not prone to settlement. Unfortunately this is rarely the case in a modern development and if a concrete structure is laid cracking must be expected.

Unreinforced concrete is completely unsuitable, and even at sites where extensive top and bottom steel reinforcement have been used problems with cracking have not been overcome. Regular expansion joints are necessary, but these are expensive to install and form inherent weaknesses within the structure; cracking usually manifests itself across the corners and along the joints, see Figure 12.

The problem associated with expansion joints can be overcome with a continuously reinforced pavement. Here sufficient reinforcement is included to distribute the stresses evenly through the concrete. Thus instead of large cracks developing at intervals of 5 to 7 metres, transverse cracking is fine and closely spaced, 1 to 2 metres. In view of the increased steel reinforcement needed the cost of construction is high and it is still prone to subgrade settlement.

In general rigid construction is viable only in established areas where settlement is negligible and access to underground services is not required, or where an extremely hard and impact resistant surface is specified. Should rehabilitation be necessary costs will be high as it is virtually impossible to construct an overlay and the whole structure has to be broken out.

A hard concrete surface is ideal and the necessary flexibility can be achieved by using a precast concrete surfacing material which can be relaid as settlement takes place.

Precast concrete rafts

Precast concrete surfacing offer several advantages

1. Good quality control in manufacture.
2. Full strength achieved in off-site curing.
3. Little plant needed for laying.
4. Immediate trafficking.
5. Easy relaying as settlement takes place.

Rafts, or slabs, are generally 2 metres square, reinforced and usually have a protective steel angle surround. Some do not have the angle but provide a chamfer around the top edge instead, this is to prevent spalling of the concrete under local stress concentrations. Various thicknesses are available but the heavy duty 150 mm thick slabs are recommended. Few requirements on the suitability of the underlaying subgrade are made, providing it is well compacted and free draining. The slabs are bedded on a layer of compacted coarse sand, the only plant required is a front lift truck and laying is straightforward.

Although the required preparation of the subgrade is minimal, and of low cost, the cost of the rafts themselves is high. This is aggravated by the large size of the units, weighing around 1.25 tonnes, and haulage is expensive. This can be overcome in very large and remote areas by setting up a manufacturing plant on site.

The high cost of construction has, unfortunately, not been reflected by a good performance record in the Port environment. The principle problem seems to be settlement of the subgrade. Uneven settlement leads to steps developing between adjacent units and pumping. This has to be rectified as quickly as possible as surface water and rocking washes out the supporting sand, aggravating the problem.

The units are large and, being greater than the trackwidth of the handling vehicles, very large hogging bending moments are induced in the rafts. If the supporting subgrade has settled, this can cause cracking across the corners. The problems of hogging and high wheel loads make the precast rafts unsuitable for use in areas operated by rubber tyred terminal trailers.

Not all experience with the rafts has been bad, some ports find it an ideal form of construction and use it extensively. However, overall costs are significantly greater than the alternative precast concrete surfacing, concrete blocks.

Concrete block surfacing

Concrete blocks offer the same advantages as the raft system, a highly durable and hard surface, but they also possess the flexibility associated with asphaltic construction. The individual units are small, 100 mm by 200 mm, and providing they have sufficient thickness tensile cracking does not occur. Since the structure is already "cracked" the urfacing can accommodate xtensive deformation without amage.

The blocks are laid by hand on a lyer of screeded but uncompacted and. The surface is vibrated to give he final profile and this forces the and up into the joints, so converting he individual units into a omogeneous surfacing. Since the locks are made of high quality conrete the surface durability is xcellent, it can withstand the very arsh loading from trailer dolley wheels without any problems, Figure 13. Also, once the blocks have been ocked together with the sand, i.e. "interlock", the strength of the surface layer is high and thus a large elastic modulus is used in the design chart.

Several thicknesses of block are available, 100 mm thick have been used in some ports but the thinner 80 mm blocks are more common and performance has been perfectly satisfactory. Construction is obviously labour intensive but in large open areas, such as a port, high laying rates can be achieved with several men working on each face, placing blocks two at a time. The initial cost of construction may be slightly higher than an asphaltic construction, but existing block pavements have required little maintenance. The overall costs, therefore, are lower.

Although this form of surfacing is very tolerant to surface deformation the provision of a structural base is essential for extremely heavy loading. In some areas, such as lorry parks, where there is a very strong subgrade of gravel or fill, the blocks have been used successfully with a granular base. Here the resulting surface undulation is of minor importance, but this is unlikely to be suitable for container stacking and fast operation. The usual construction is a base of lean mix concrete.

At some smaller ports the rapid development of large parking areas does not take place. The original finger piers were constructed with miscellaneous fill and left to consolidate over the years. With recent development the quay-sides have been cleared and the docks partially backfilled with rubble to give a straight quayside. Differential settlement occurs and in this situation a concrete block surfacing makes an ideal surfacing material. If the backfill is stable, ie largely building rubble, there is usually no reason to provide a base at all. Surface water will drain through the backfill and if settlement around any soft spots becomes excessive, the blocks can be lifted and relaid in a few hours. This makes for one of the most cost effective forms of paving available for Port areas.


Figure 12: Cracking of in-situ concrete construction.

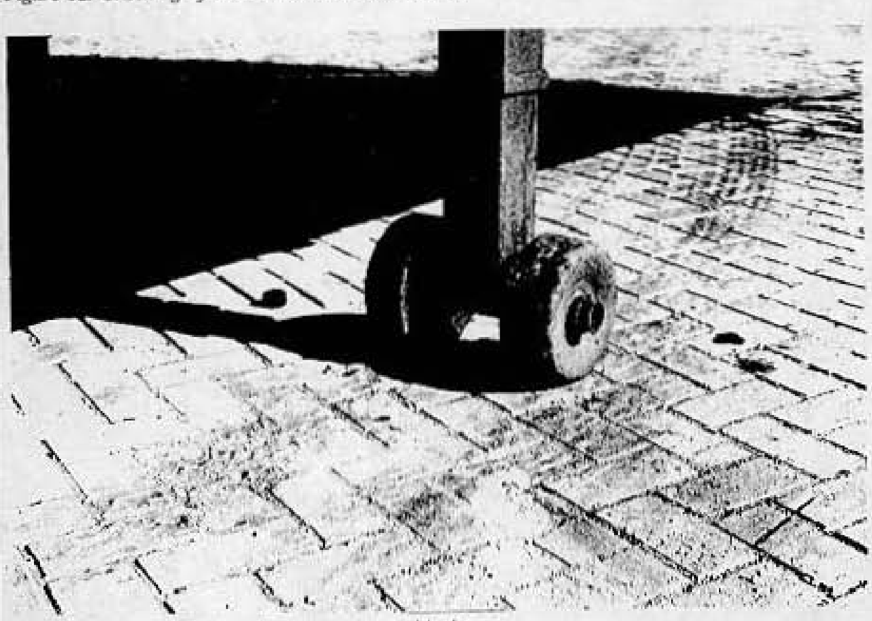


Figure 13: Trailer dolley wheels on concrete blocks.

Cement bound base materials

Cement bound base materials are the most successful form of construction. It has already been shown that the high stiffness of the material largely elminates the tensile strains within the surfacing, the tensile strength of the cementitious material is the design criterion. Cement bound materials are usually divided into three broad groups:

rolled dry lean concrete

cement bound granular material
stabilised soil cement

Generally the cement content increases down the group, whereas the aggregate changes from a graded concrete aggregate down to natural soil. This division of the cement bound materials is generally regarded as unsatisfactory due to the variability within each group, characteristic strengths and cost of construction follow no single rule and laboratory testing is the only satisfactory form of selection and specification.

Which, if any, of these materials is the most suitable depends on materials and plant available; soil stabilisation of a sandy gravel subgrade can be significantly less expensive than lean concrete, despite the greater thickness and higher cement content required.

The materials can be mixed in-situ or batched; they can be tipped, levelled and rolled easily. All cement bound materials require a curing period to develop full strength, but this rarely causes a delay as the surfacing can be laid during this time. It is generally recognised that the higher the strength the better, although this aggravates problems of shrinkage cracking. Lean concrete is generally regarded as a non-flexible

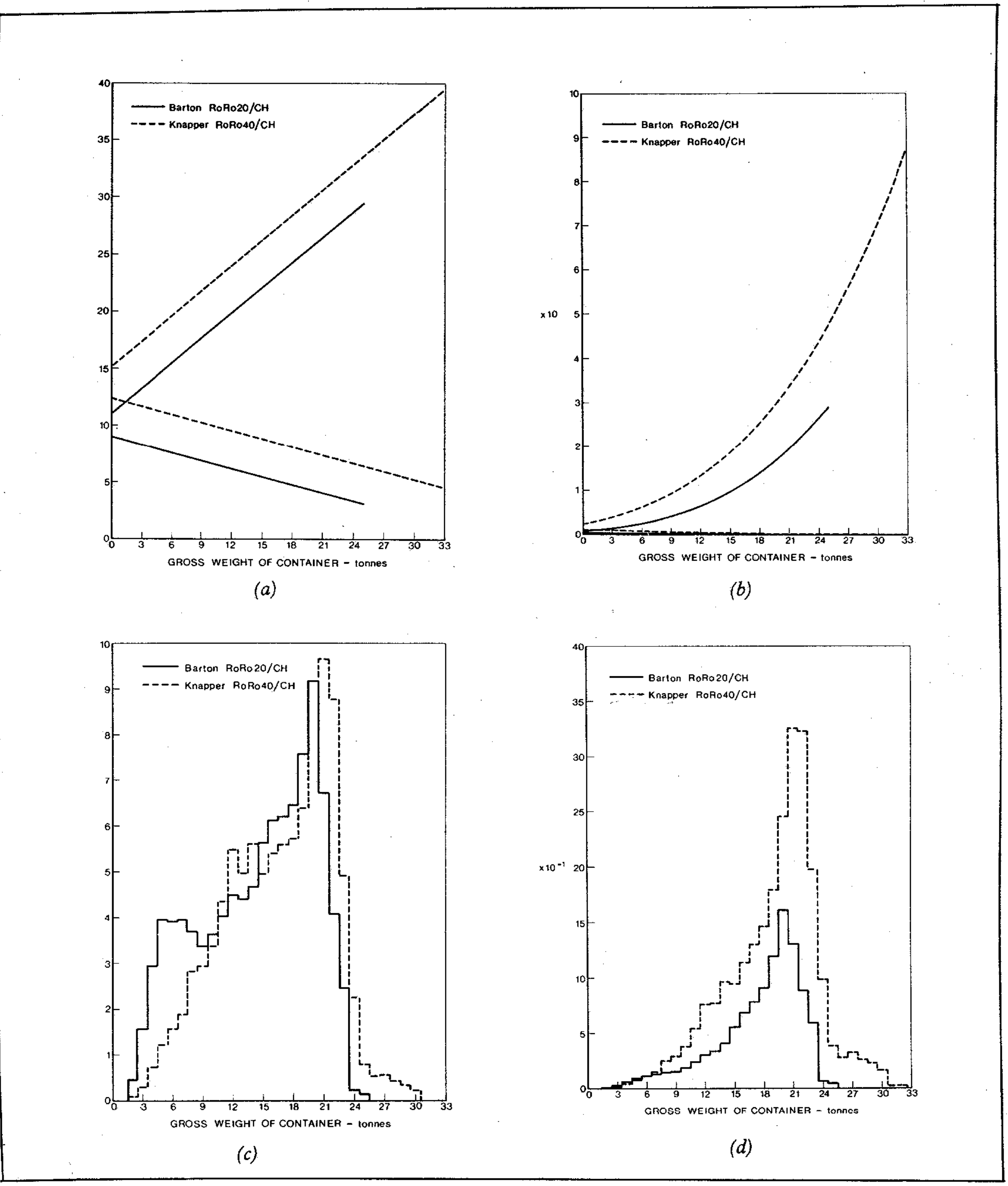


Figure 14: Graphs of wheel loads (a); damaging factors (b); frequency distribution of weight (c); and proportional damaging power (d).

material, but it has proved to be sufficiently flexible to follow site settlement to a remarkable degree. In areas of settlement, an angular aggregate will give better durability as frictional interlock across cracks is very high.

Design example

The use of the design charts is best explained by a simple example. It is proposed to construct a roadway between the ship's loading ramp and the container stacking area. It is anticipated that 600 x 20 ft units will be unloaded and driven along this roadway per ship, with two ships per week. These will be handled by 3 similar front lift trucks, Barton RoRo/20CH, the vehicles returning on the opposite side of the roadway with a container for export. In two years' time there is expected to be a 50% increase in throughput, when 40 ft containers will be introduced. It is planned to operate two larger FLTs, Knapper RoRo/40CH, to handle these and they will spend about 80% of their time on the 40 ft units.

The subgrade is a reasonably well graded sand/gravel, no substantial settlement is anticipated, CBR 20%. Design life 15 years.

The basic dimensions of the two FLTs are given in Table 3. The damaging powers are found from the series of four graphs shown in Figure 14 (a) to (d). These give the axle loads (a) and relative damaging power (b) for both axles against the weight of the container. The distribution of the container weights for each truck is given in (c), thus multiplying (b) by (c) gives the proportional distribution of the damaging powers, (d). From this it is clear that the most critical loading condition is a 22 tonne container carried by the Knapper, this is the design load which, from (b), is equal to a PAWL rating of 36.7. Also, the area under the histograms in (d) represents the total number of PAWLs per 100 movements, hence the average rating can be calculated. These load ratings are included in Table 3.

It is assumed imports equal exports, thus the outward and return pavements are identical.

In the first two years:

Vehicle movements:

Barton 20 = 2 x 600 x 52 x 2
= 124,800

Throughput after 1982 will be 900 containers per ship divided into:

60% Barton 20
40% Knapper 40

Vehicle movements:

Barton 20 = 2 x 900 x 0.60 x 52 x 13
= 730,080
Knapper 40 = 2 x 900 x 0.40 x 52 x 13
= 486,720

Thus, total loading:

Barton 20 = 854,880 movements
Knapper 40 = 486,720 movements

To establish the total number of PAWLs the pavement has to carry, multiply by the respective average PAWL rating for the trucks.

Total No. PAWLs
= 854,880 x 10.77 + 486,720 x 24.56
= 21.16 million

For the design, a single wheel load is adopted. This is assumed to be the most damaging wheel load for the whole load spectrum, 36.7 PAWLs in this case.

Design wheel load
= 36.7 PAWLs

Design life required
= 21.16 / 36.7 million
= 0.58 million repetitions

Referring to the design chart for a subgrade CBR of 20%, Figure 4, it is clear that for this design the vertical subgrade strain on the right hand side is not critical. On the left, a line is drawn vertically from the required design life, 0.58 million, to intersect all curves. From each intersection, a line is drawn horizontally to the centre graph, the next intersection being taken at the design PAWL rating (36.7 PAWLs). From here drop vertically to the bottom graph.

Here the starting point is the abscissa, the elastic modulus of the base. This is taken from the data in Table 1. The design thickness is found from the intersection of the elastic modulus with the relevant line from above. Care must be taken to correlate the correct base modulus with the characteristic strength used in the first graph.

The following designs for the base course are obtained:

Compressive strength (N/mm^2)	Elastic modulus (N/mm^2)	Thickness required (mm)
24	48000	350
18	42000	400
12	35000	500

From another design chart it is found that if a 150 mm granular subbase, Type 1 material, is used, then the base thicknesses can be reduced to 300, 350 and 500 mm respectively. It can be seen that for a given operational situation, the charts can be used to produce a series of designs permitting the engineer to choose the one he favours. It would be wrong to remove this choice from the engineer whose local experience must always be the final mediator in selecting a form of construction.

TABLE 3: Load ratings

Model	Barton RoRo20/CH	Knapper RoRo10/CH
Lifting capacity (tonnes)	24.000	37.500
Unladen Wt., including toplift (tonnes)	40.000	55.000
Wheel base (m)	4.750	5.250
Lifting centre (m)	2.250	2.500
Unladen axle loads (tonnes)		
Front	22.000	30.250
Rear	18.000	24.750
Tyre pressures (N/mm^2)	0.8	0.8
Proportion of 20 ft/40 ft boxes handled	100/0	20/80
Unladen PAWL rating	1.06	3.50
Most damaging PAWL rating	19.45	36.70
Average PAWL rating	10.77	24.56

References

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