HEAVY DUTY INTERLOCKING CONCRETE BLOCK PAVEMENTS AT THE PORT OF LYTTELTON

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SUMMARY

This paper covers the introduction of interlocking concrete block paving for heavy duty pavements at the Port of Lyttelton, New Zealand. Following the satisfactory performance of a trial area, interlocking concrete blocks were specified as an alternative to asphaltic concrete and eventually became the preferred option on a cost basis. The design, specification, construction, cost and performance of areas of heavy duty interlocking concrete block pavement are described. All heavy duty pavements used rectangular 200 mm x 100 mm x 100 mm blocks laid in herringbone pattern on 30 mm compacted thickness of bedding sand. Areas included 5435 m^2 of new construction laid by machine, and 2920 m^2 of overlay laid by hand to strengthen an existing asphaltic concrete pavement, allowing comparisons between hand and machine laying. The reasons for the choice of the size and shape of block, and the laying rates actually achieved, are given. NZS 3116: 1981, with minor additional requirements, was found to be a satisfactory basis for specifications for heavy duty pavements. The issue of long design lives for port structures, such as pavements, in relation to assessment of the economics of alternative forms of construction, is commented on. Conclusions are drawn from the experience with heavy duty interlocking concrete block pavement at the Port.

1 Introduction

Heavy duty pavements in port areas are subjected to arduous conditions throughout their lives. Although many potential problems can often be identified at the time of design, satisfactory technical solutions are not always available. Interlocking concrete block pavements (ICBP) appear to solve most of these potential problems and their use is therefore attractive in port areas.

The introduction of ICBP at the Port of Lyttelton was firstly on a trial basis and then later, as the performance of the trial area was acceptable, as an alternative to heavy duty asphaltic concrete and sometimes as a clear first choice. The trial area was subject to observation and testing over a 9 year period of intensive loading (results are given in reference (1)). Recent costs have shown that heavy duty ICBP is clearly lower in cost than asphaltic concrete and its long term performance appears better.

Usage of ICBP for heavy duty pavements at the Port of Lyttelton has included both hand laid and machine laid areas, and this has allowed comparison of laying methods. Also an area of relatively thin asphaltic concrete pavement was upgraded to container terminal standard by means of an overlay of interlocking concrete blocks. The design, construction and performance of these areas are described in this paper.

2 Background

The Port of Lyttelton (latitude 43° 37' S, longitude 172° 43' E) is situated in Lyttelton Harbour on the east coast of the South Island of New Zea-

land. It is the Port serving Christchurch (population 300,000), the largest city in the South Island, and has an annual tonnage of approximately 2.7 million tonnes, the largest of all South Island Ports. Regular services are maintained by cellular container vessels and roll-on roll-off vessels.

Up to September 1988, when the Lyttelton Port Company was established, the Lyttelton Harbour Board (LHB) was responsible for the construction and maintenance of all heavy duty pavements at the Port, including areas leased by stevedoring companies. For these pavements all design work, and supervision of construction and maintenance, was undertaken by the Board's engineering staff.

Much of the cargo handling area at the Port of Lyttelton is on reclaimed land overlying clays likely to be subject to further consolidation. Because of this, horizontal and vertical movements can occur on the reclamation surface and therefore flexible pavements have been preferred.

Asphaltic concrete pavements have been used for container handling areas at the Port since the late 1960's. This type of pavement has basic drawbacks as a heavy duty pavement, particularly in container handling areas. Drawbacks include vulnerability to hydraulic oil spillage from burst hoses on container handling machinery, and susceptibility to permanent deformation when corner castings of containers penetrate into the pavement surface. The largest area of asphaltic concrete was laid in the areas to be occupied by the Lyttelton Container Terminal and the redeveloped Union Co. Seacargo Terminal. Between 1976 and 1980 a total of 6.50 ha of asphaltic concrete pavement was constructed (4.86 ha in the Lyttelton Container Terminal). Reasons for using a structural asphaltic concrete layered pavement are given in reference 2. (Some areas, such as those around reefer pits and at railway sidings, were in fact paved with unreinforced concrete).

Because of the concerns over the future performance of the large areas of asphaltic concrete, and the failure in the mid 1970's of a considerable area in the Union Co. Seacargo Terminal (at its initial location), alternative forms of pavement construction to asphaltic concrete were investigated over the years. The alternatives considered included unreinforced concrete pavement, reinforced concrete, and ICBP. Some small areas of concrete pavement were laid within the Lyttelton Container Terminal where particular problems were expected with asphaltic concrete and the construction costs for these areas confirmed that overall costs per m^2 were comparable to those for asphaltic concrete (2).

In 1979 a small test area of 770 m^2 of ICBP was laid in a heavily trafficked area. Construction costs for this area were also comparable to those for asphaltic concrete (2). This test area performed satisfactorily (1), and gave confidence in specifying what was, at that time in New Zealand, a new form of construction for heavy duty pavements.

For subsequent heavy duty pavements involving large areas of new construction or overlay, alternative designs in asphaltic concrete and interlocking concrete block were prepared. Tenders were then called allowing prices on both designs as there was no clear cut evidence that costs would be significantly lower for any one type of construction, either on a first cost basis or on a whole of life basis. Only ICBP was specified for certain areas where special problems occurred. In all cases 200 mm x 100 mm x 100 mm rectangular blocks (200x100x100), laid in herringbone pattern on a 30 mm compacted depth of bedding sand (except at the test area), were specified, and were manufactured by Winstone (SI) Ltd at their Hornby plant to the requirements of NZS 3116s1981 (except for blocks ordered prior to 1981).

Publication of NZS 3116:1981 (3) meant that a recognized New Zealand standard specification was available for ICBP and, from 1981 on, specifications for ICBP at Lyttelton were based on this document. It was found that no additional requirements were needed for heavy duty pavements apart from tighter tolerances on final surface levels for the block course and tighter tolerances on final surface levels and grades for the subgrade. These tighter tolerances were a direct consequence of the relatively low surface grades used for large areas.

The various heavy duty pavements where interlocking concrete blocks were used are described below and in reference 1. The only occasion when heavy duty asphaltic concrete was cheaper than ICBP was in November 1980 for 2000 m^2 at the base of No. 7 Jetty. The design method, and specification, for this work (2) were similar to that for the later area west of No. 7 Jetty.

3 Area West of No. 7 Jetty

3.1 Background

In August 1985 tenders were called for 10,000 m^2 of heavy duty pavement to the west of No.7 Jetty. The specification for the work allowed for alternative construction above subgrade of either interlocking concrete blocks on 30 mm of bedding sand above 200 mm of uncrushed granular subbase; or 50 mm of asphaltic concrete wearing course, 100 mm of asphaltic concrete base layer, bitumen primer, 120 mm of crushed granular basecourse, and 130 mm of uncrushed subbase. Construction was with interlocking concrete blocks as tender prices were much lower. Surface grades were as low as 1:100.

The area is used to receive and deliver ISO containers, and to stockpile the containers prior to, and after, the vessels carrying them call at the Port of Lyttelton. Also considerable use is made in storing and marshalling trailers in connection with the coastal roll-on roll-off service of Pacifica Shipping. Heavy duty forklifts operate on the area.

The loading on the pavement is high, with the corner castings of the loaded ISO containers stacked two high applying a load of up to 150 kN over an area 164.5 mm x 149 mm (giving contact pressures of over 6.5 MPa), and the wheel loads of the forklifts being up to at least 450 kN, with tyre pressures of 830 kPa, Typical forklifts operating in the area are the Lees D65 and the Lees F55. The loading is distributed randomly over the paved area, with little definition of wheel paths, as the containers are block stacked, but not to a defined pattern.

3.2 Design

The subgrade material for the majority of the area consists of imported loess fill (from the hillside above Battery Point, to the east of the Port) which was compacted to 100% of the maximum dry density obtained in the NZ Standard Compaction Test (Test 14 of NZS 4402 Part 2P:1981 (4)). In some small areas volcanic fill, from LHB's Gollans Valley and Te Awaparahi Bay Quarries, was used. (Fill below the subgrade was compacted to 97% of the maximum dry density obtained in the NZ Standard Compaction Test.)

An extensive series of CBR tests on loess from Heathcote had been carried out by Blakeley (5). It was considered that the results of these tests could be used to derive a design CBR for the loess subgrade, even though Blakeley's tests were on loess from the northern side of the Port Hills whereas the loess for the subgrade was from the southern slopes. On the basis of Blakeley's tests a reasonable estimate of the 10 percentile value for the soaked CBR, for material compacted at optimum moisture content with

NZ Standard Compaction, was taken as 15 and this value was adopted as the design CM. At the time of construction of the Lyttelton Container Terminal pavement an extensive investigation had been carried out into the properties of volcanic fill and as a result a design CBR of 15 had been adopted for this material when used as a subgrade and compacted to 100% of the maximum dry density with NZ Standard Compaction. Thus a design CBR of 15 applied for all of the subgrade.

Pavement layer thickness design was by means of extrapolation off the design chart in IB 027 (6) with an estimate of 10^7 EDA for the traffic over the design life. This gave 100 mm thick blocks, 50 mm of bedding sand and 180 mm of subbase (330 mm cover thickness on subgrade) for a CBR of 15 and 10^7 EDA. The 50 mm of bedding sand was reduced by 20 mm and the subbase thickness increased by a corresponding amount to 200 mm. Results from the detector loop counts at the test area (1) indicated that the design figure of 10^7 EDA was of the correct order.

As a check the same cross section was obtained from the design chart proposed by Tait (7), with a subgrade design CBR of 15, and 20,000 repetitions of a 179.0 kN ESWL at 330 mm depth with 0.83 MPa tyre pressure. (The values of subbase thickness given by Tait were for 80 mm thick blocks. As 100 mm thick blocks were to be used, the subbase thickness value from Tait's chart was reduced by 40 mm following the approach used by Tait of taking the block thickness as equivalent to twice its thickness of subbase.)

The 20,000 repetitions of a 179.0 kN ESWL was consistent with operation of a Lees F55 forklift carrying containers (which has a 155 kN ESWL at 330 mm depth for the front axle with a 14.354 tonne container load, and a tyre pressure of 0.83 MPa) after allowing for:

- the anticipated container weight distribution (with an average container weight of 14.354 tonne),
- the predicted numbers of containers per year,
- the container handling forklifts currently in use at the Port, and
- the design life of the pavement.

3.3 Construction

The pavement above subgrade consists of a 200 mm thick sub base layer constructed from AP65 uncrushed graded Greywacke river gravel aggregate, a 30 mm AP 5 Cr 100 "crusher dust" (see Table 1) bedding layer (the Birdlings Flat sand (1), successfully used in the trial area, could no longer be obtained due to environmental restrictions), and block blocks laid to the requirements of NZS 3116-.1981. The perimeter of the area is either concrete walls or a reinforced concrete edge beam 400 mm x 325 mm deep with 4 longitudinal D12 bars. No intermediate abutments were provided as the area is not wider than 47 m in any place.

The only differences between the specification for the work and NZS 3116: 1981 were that:

- the requirement for an intermediate abutment when the area was wider than 30 m was dispensed with,
- the tolerances for the finished subgrade surface levels were decreased from +0, -20 mm, to +0, -15 mm,
- the tolerance for the finished subgrade surface grade was decreased from 15 mm from a 3 m straight edge to 12 mm from a 3 m straight edge, and
- the tolerances for the finished block surface levels were decreased from +10 mm, -10 mm, to +10mm, -0.

TABLE 1 - BEDDING SAND GRADINGS

Test Sieve Aperture mm	Percentage Passing Test Sieve		
	No 7 Nest Area (British Pavements)	CQ2 Shed Area (Isaacs)	NZS 3116:1981 Bedding Sand Limits
9.5			100
4.75	100	100	95 - 100
2.36	89	89	80 - 100
1.18	67	62	50 - 95
0.600	51	45	25 - 60
0.300	38	30	10 - 30
0.150	26	19	0-15
0.075	18	12	0-10

(The compressive strength required by NZS 3116:1981 is 40 MPa based on the block net surface area.)

100 mm thick blocks were chosen for the pavement, rather than the more readily available 80 mm thick blocks, on the basis of European practice at Container Terminals (where in some cases 120 mm thick blocks were known to be used), and the satisfactory performance of the test area. Also rectangular blocks were specified firstly as these were used in European container terminals and secondly as they had been shown at Lyttelton to allow ground movements without excessive damage to the blocks.

The contractor for the ICBP was British Pavements Limited, of Christchurch, who prepared the subgrade and supplied and laid the sub base and bedding sand. The concrete edge beam construction and the block laying were subcontracted to Kreisel Contracting Limited, of Christchurch, who developed a mechanical block laying machine for the work. This machine consisted of a hydraulically operated clamping mechanism attached to a 4 wheel "Swinger 140" loader. It was used to lift a layer of 54 blocks (stacked at the manufacturing plant in 1.0 m x 1.2 m layers, i.e. 60 blocks per layer, with 8 blocks in each 2 layers stacked vertical and 54 per layer stacked in herringbone pattern) off the pallet and place them into the final position on the bedding sand. A 4 man gang (including loader driver) laid the blocks at a rate of approximately 500 m^2 per day, with edge closures being fitted later. (The maximum placement rate was 691.2 m^2 per day and the overall rate was 360 m^2 per day including time lost due to wet weather but excluding edge closure fitting and joint sanding.)

Placing of bedding sand began on 1 October 1986. A total of 220 m^2 loose measure of bedding sand was supplied, giving an average loose thickness of approximately 40 mm, but some initial compaction was applied when laying with a paving machine and vibrating roller. Granular weedkiller was spread on the surface of the bedding sand with a seed spreader ("Shell Prefix" granules at 25 g/m^2). Defective blocks (either blocks broken by the block laying machine or "out of dimension tolerance" blocks) were identified after placing and replaced by hand. By 18 October the main block laying was complete and only edge closures remained to be done. After the joint sand was spread with the assistance of a drag broom, there was one pass of a plate vibrator and then a vibrating roller was used. A total area of 5435 m^2 of heavy duty ICBP was completed by November 1986, with work on the remainder being cancelled for financial reasons.

The only departure from the blocklaying procedure recommended in NZS 3116: 1981 was that the bedding sand was laid with a paving machine and given an initial roll. With the speed of mechanised laying it would have been difficult to lay the bedding sand immediately prior to block laying at a fast enough rate, and with the large area of sand surface exposed it was considered that some rolling was required to prevent loss by the high velocity winds that could occur.

The main drawback with the laying system used was that it was not as easy to identify "out of tolerance" blocks as with hand laying, where the block layer would quickly realize that a block was defective and place it to the side. The joint gaps were generally wider than with hand laying.

3.4 Performance

The final paved area has performed satisfactorily since completion in late 1986. After initial use additional joint sand was required but there have been no other problems with the interlocking concrete blocks, or stormwater drainage. Traffic volumes over the area are difficult to estimate as the area is used randomly by forklifts and other vehicles. The eastern part of the area is closer to the wharf and therefore receives more traffic than the western part.

4 Area formerly Occupied by Transit Shed CQ2

In 1985 LHB decided to demolish 36% of Transit Shed CQ2 to provide additional heavy duty paved area for the Lyttelton Container Terminal. This would involve loadings from straddle carriers (Clark Series 520 Model 245/136), heavy duty forklifts (Lees 055, F55 and 065) and ISO container corner castings. The existing floor inside the Shed consisted of 32 mm of asphaltic concrete over 70 mm of bituminous macadam on 100 mm of basecourse. This pavement was in reasonable condition but would have had a short life when subjected to container terminal loading. Therefore an overlay was required. Also the Lyttelton Container Terminal asphaltic concrete pavement had by then been subjected to approximately half of its design life loading and it was considered desirable to have a relatively small trial area of overlay using a method which could later be used for the main Terminal area.

Tenders were called allowing either asphaltic concrete (150 mm total thickness) or ICBP overlays. Construction of the overlay of 2920 m^2 was in ICBP as tender prices were much lower. An asphaltic plant mix was specified as a levelling course wherever levels had to be adjusted to suit the block paving. The bedding sand layer was then to be placed directly on the existing pavement surface, or on the levelling course, with a 400 mm x 325 mm reinforced concrete abutment where the ICBP was bounded by asphaltic concrete pavement. The width of block paving was 43.6 m but no intermediate abutment was provided even though the width exceeded that recommended in NZS 3116:1981. The specification for the work was similar to that for the area west of No. 7 Jetty. The existing surface grades of approximately 1 in 100 were maintained.

A sophisticated design approach for the overlay was not possible as the load history of the existing pavement was unknown. The existing asphaltic pavement gave 202 mm cover over the subgrade. With 30 mm compacted depth of bedding sand and 100 mm thick blocks laid over the existing pavement this gave an equivalent cover over the subgrade of a minimum of 432 mm (using Tait's factor of block thickness equivalent to twice the thickness of material above subgrade replaced (7)). As the existing Container Terminal asphaltic concrete pavement had 450 mm cover over the subgrade it was

considered that the overlay would produce a pavement with a similar life and strength.

The contractor for the ICBP was Seans Contracting, of Christchurch, who constructed the concrete edge beams and carried out the block laying. The levelling course was constructed by The Isaac Construction Co. Ltd, of Christchurch, who also supplied the bedding sand (see Table 1 for grading). Blocklaying commenced on 30 April 1986 and approximately 2565 m^2 was completed on 31 May 1986. The overall rate with a 4 man gang hand laying, and with a front end loader, was 85 m^2 per day and the rate would have been 100 m^2 per day if allowance was made for days not worked and relaying.

The bedding sand was screeded by hand to a loose depth of 40 mm, and granular weedkiller spread on the surface, before the blocks were placed by hand. Some initial difficulty was experienced in maintaining the correct alignment and joint width. This was found to be due to "out of tolerance" blocks and a small area had to be lifted and relaid. Once the problem was identified, and the blocklayers were made aware of the need to keep the joint spacing to the minimum, "out of tolerance blocks" were identified by the blocklayers before laying, and were put aside for replacement by the manufacturer.

Prior to completion of the work the LHB decided that the area should be kept outside the Lyttelton Container Terminal and used in conjunction with general cargo operations at Berth CQ2. This required alterations to the edge detail alongside the wharf and delayed completion of the pavement to a usable state until January 1987.

In 1987 it became necessary to lay a section of 11 kv cable below the south side of the ICBP area. The cable laying operation involved lifting and relaying an area of blocks approximately 6 m wide alongside the wharf. The trenching operation for the cable resulted in settlement of the backfill and the blocks again had to be lifted and relaid to restore acceptable grades. Little damage to individual blocks occurred and over 99% of the blocks were reused.

The final paved area has performed satisfactorily since completion in 1987. After initial use additional joint sand was required and there have been continuing problems with settlement in the area of the cable trench, requiring further lifting and relaying of the interlocking concrete blocks. No stormwater drainage problems have been experienced with the low surface grades except at the location of the cable trench.

In early 1990 the northern part of the area (approximately half) was incorporated in the Lyttelton Container Terminal as originally intended.

5 Miscellaneous Areas

Interlocking concrete blocks were used in several small areas where they had advantages. These areas included:

- CQ1 Transit Shed South Doorways (8), 9.9 m x 8 m each, 1986-87, laid by LHB and contractor.
- Between CQ2 Wharf and Transit Shed CQ2, 3.51 m x 117.5 m, 1986, laid by contractor.
- Fire Hydrant Surrounds (several), 4 m x 4 m, 1987-88, laid by LHB.
- Firefighting Pumping Points (2), 230 m^2 each, 1987-88, laid by LHB.
- No. 7 Jetty West Landing Ramp for Stem Ramps, 1.5 m x 17.5 m, 1988, laid by LHB.

6 Economics

In port areas it is debatable whether long design lives should be taken into account when assessing the economics of structures such as pavements. Cargo handling methods are apt to change rapidly, often making expensive long life structures redundant. Major changes in methods of cargo handling appear to be related to the design lives of vessels, which are from 12 to 20 years (14 years is typical for container vessels), and therefore it is often argued that facilities for a particular type of vessel should be written off over a period not exceeding 20 years. If this argument is accepted, then, in assessing the whole of life economics of ICBP, no account can be taken of the potential life of greater than 20 years for ICBP. ICBP must then be compared with asphaltic concrete, and other types of pavement, mainly on the basis of initial cost and likely repair cost, although block salvage value can be allowed for. (Similar arguments can be applied to both reinforced and unreinforced concrete pavements.)

At Lyttelton no account has been taken of the potentially longer life for ICBP, or salvage value, when comparing costs with asphaltic concrete pavements. However ICBP and asphaltic concrete pavement have been assessed to have similar tolerance to horizontal and vertical movements. Costs have been compared on a first cost basis when assessing project economics as no maintenance costs were available for ICBP.

7 Discussion and Conclusions

All heavy duty ICBPs at the Port of Lyttelton have been constructed from rectangular 200x100x100 blocks on a subgrade with a relatively high CBR (mostly 15). Therefore no comparisons can be made with other shapes of block, or conclusions drawn for other thicknesses.

Determination of an appropriate design CBR for the subgrade is probably the most crucial factor in ICBP pavement design and needs careful attention.

The relatively high subgrade CBR has meant that techniques such as cement stabilization have not been necessary and that use of lean mix concrete basecourses have been considered uneconomic. With the use of all granular layers below the blocks it was considered that the BPA Manual (8,9) design approach was not directly applicable as the manual was primarily derived for ICBP with lean mix concrete base.

The following conclusions can be drawn from the experience with interlocking concrete block heavy duty pavement at the Port of Lyttelton:

(a) Rectangular blocks are the preferred shape for heavy duty pavements. The advantages of rectangular blocks are seen to be-.

- less spalling at the top edges,
- robust and easy to handle (they can take limited abuse),
- it is easier to detect if the block is not the correct size (i.e. out of size and shape tolerance),
- observation of the joint gap can be used as a simple monitor of the out of tolerance of the block shape and size, and
- it is easier to stack rectangular blocks on pallets in the herringbone pattern for machine laying, especially where blocks need to be vertical.

(b) With the method of manufacture some blocks outside the size and shape tolerances are to be expected. Although some of these can be detected at the manufacturing plant high levels of inspection by the manufacturer are probably not economic. When laying blocks the blocklayers soon become able

to detect out of tolerance blocks, particularly if they have experienced difficulty with alignment, or maintaining the joint gap within specification (e.g. if they have had to relay an area rejected). The most economic method of inspection for out of tolerance blocks is probably by the blocklayer who is responsible for the finished surface quality, even though this does involve the manufacturer in the additional cost of removing defective blocks. (At Lyttelton 200x100x100 blocks were found on occasions to be 95 mm deep, 210 mm long and to have bulges on the sides. However the overall rejection rate was only of the order of 2%.) If this approach is followed the specified gap width becomes critical and should not be relaxed.

(c) For heavy duty pavements the importance of proper preparatory work before blocklaying cannot be overemphasized. Recognized standards for materials and construction must be followed for layers below the blockwork, and for the abutments, and to ensure this it is advisable that experienced reading contractors are employed. (Specifications for ICBP at Lyttelton were written to encourage experienced reading contractors to act as the main contractor and these contractors appeared to find no difficulty in working to interlocking concrete block standards.) ICBP is not an easy answer to poor preparation of the lower courses of heavy duty pavements. Problems which have occurred at Lyttelton have all been attributed to defects in the support layers or abutments, not to any defects in the blocks or laying. Special consideration needs to be given to compaction, and to potential escape routes for bedding sand, around fixtures such as manholes, fire hydrants, valve boxes, etc. Details incorporating geotextiles are likely to assist in ensuring that bedding sand is not removed by scouring.

(d) The thickness and shape of the block, and the thickness and properties of the underlying layers, appear to have been of more significance in the performance of the block pavements at Lyttelton than the grading of the bedding and joint sands. Very tight tolerances for the grading of bedding and joint sands are probably not necessary.

(e) NZS 3116:1981 is a satisfactory basis for specifications for the construction of heavy duty ICBP. For large areas with low grades stricter tolerances are both necessary and achievable. Some relaxations in the grading envelopes for bedding and joint sands may be possible. Placing of bedding sand by paving machine does not strictly comply with the usual requirement that bedding sand should not be compacted before blocklaying, and yet it appears to have resulted in a satisfactory pavement. For large areas where rapid blocklaying rates are occurring paving machine laying of bedding sand becomes very attractive economically.

(f) Machine laying of blocks using mechanical clamp arrangements on small front end loaders is practical and results in an acceptable pavement. The finished job is probably not quite as good as with hand laying by skilled operatives. In New Zealand machine laying is competitive economically with hand laying.

(g) Sanding of joints requires careful attention. Repeated applications of joint sand is necessary and needs to be continued for at least 3 months.

(h) Overlaying of existing asphaltic concrete pavement with interlocking concrete blocks can be carried out simply and rapidly. Levelling courses of asphaltic concrete should be applied prior to overlaying.

Interlocking concrete block pavements, with unbound granular layers below, have been successfully introduced as a heavy duty flexible pavement at the Port of Lyttelton and have performed satisfactorily under conditions of intensive loading.

9 References

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APPENDIX - COSTS FOR ICBP AREAS AT LYTTELTON

Area West of No. 7 Jetty (4th quarter 1985)

Bedding sand (supply and place)	$ 1.78 /m^2
Blocks (supply, lay, closures and fill joints)	$ 23.50 /m^2
Total Cost above subbase	$ 25.28 /m^2
Abutments	$ 27.50 /m

Ratio Asphaltic Concrete : Block cost (for full depth construction including subgrade preparation but excluding abutments) /m^2 1.85:1.00

Area Formerly Occupied by Transit Shed CO2 (2nd quarter 1986)

Bedding sand (supply)	$ 1.60 /m^2
Blocks (supply and transport)	$ 17.00 /m^2
Laying (place bedding and blocks, closures and fill joints)	$ 4.28 /m^2
Total Cost above asphalt	$ 22.88 /m^2
Abutments	$ 35.00 /m

Ratio Asphaltic Concrete : Block cost (for full depth construction including abutments) 1.87:1.00

Area between Transit Shed CO2 and Wharf CO2 (October 1986)

Supply and lay bedding sand and blocks	$ 31.50 /m^2

Note: Unit rates shown were tender prices. Actual costs were identical apart from cost increases due to inflation.