MECHANICALLY LAID, SPECIFICALLY DESIGNED, CONCRETE PAVERS FOR EXTREMELY ABRASIVE CONDITIONS IN NEW ZEALAND

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ABSTRACT

The New Zealand concrete paver market is enjoying increased volume in the specialized market of heavy-duty pavements. This paper serves to demonstrate the suitability of specifically designed concrete pavers for the extremely harsh logging industry in New Zealand, and how well suited mechanical-laying is in these extreme commercial applications.

The logging industry uses some heavy-duty plant to process the timber. One of these is the Wagner logstacker, which can induce single axle loads of up to 100 tonnes. The paving is exposed to various types of wear including the screwing action of the jockey wheels on the logstacker, the payloader's steel buckets scraping up logs; the sweeping up of the bark on the pavers using logs; the offloading of logs by tipper truck. The logging industry has installed concrete paving to stop attrition rates of 25mm per month of Asphalt Concrete Pavements.

The sizes of pavers that are currently installed in high wear areas are predominantly 100mm thick, but can increase to 120mm thick weighing 5.1Kg each. These thicknesses are made to satisfy the very high attrition rates (3mm wear per year) and a life expectancy of 10 years. A currently active project that was installed approximately 10 years ago utilising 100mm pavers have worn down 30mm and are still functional at 70mm thick.

In production-type environments it is critical to be able to install the pavers with the minimal amount of downtime or disruption. Mechanical laying is very well suited to installing heavy pavers at high installation rates of 850m2 – 1000m2 per day with one machine. Mechanical layers install approximately 1m2 of paving at a time, which can weigh up to 300kg.

The combination of the availability of good, hard aggregates and Technical Production Engineers is achieving the required abrasive resistant paver, which is outperforming the more conventional AC Pavements. Mechanical installation is ensuring good production rates and consistency of installation. It is proving to be a saving to the industry with reduced worker-fatigue, hence the vibrant & increasing market. This paper and presentation is a great advertisement for the concrete paving industry and validates that paving is well suited to do even more than the normal container yard, wharf or distribution centres completed in 80mm pavers.

1. KINLEITH LOG YARD TOKOROA, NEW ZEALAND

1.1 Background

It has been perceived that in general specifications for industrial grade pavers have often been excessive when related to actual pavement performance.

The purpose of this paper is to outline the performance of the pavers used in the Kinleith Log yard. This is considered to be an aggressive environment and is understood to be the first site in New Zealand where this type of paving system has been used.

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1.2 Kinleith Situation

The Kinleith Pulp and Paper mill, located in the South Waikato is operated by Carter Holt Harvey Pulp & Paper and processes approximately 1M tonnes of pulpwood per annum. Adjacent to the pulp mill is the Kinleith Log yard operated by Carter Holt Harvey Forests. This yard processes around 3M tonne of wood per annum. In addition to the pulpwood are the saw logs and veneers. Veneers are processed at the Plymill also adjacent to the log yard. Saw logs are used at local mills nearby, or exported via Mount Maunganui mainly using the rail connection.

Incoming wood arrives on truck from the forest. It should be noted that this wood comes mainly via the private roading network where gross weights are typically 60 to 70 tonnes with axles around 10 tonnes. Incoming wood is weighed at one of the weighbridges and then forwarded either for direct consumption or placed into storage for future use, processing in some way or export.

Wagner logstackers are used for unloading and stockpiling wood at various locations in the yard, while rubber tyred loaders are often used for loading wood out.

Historically the pavement systems used, particularly at the log ends were high maintenance items. There are two log ends at the pulp mill; these are basically the feed points. Following high maintenance costs at the log ends; an alternative to the traditional asphaltic concrete was sought. This resulted in earlier use of industrial pavers in New Zealand.

1.3 Pavement Loadings



Figure 1.



Figure 2.

1.4 Wagner Logstackers

The log stackers can achieve single axle loadings of up to 100 tonnes however with most of the logs currently arriving in a semi-processed form this type of loading is currently rarely achieved. Observations indicate that the unloaded rear jockey wheel on the stackers is likely to create the most wear on the pavement. In the unloaded state these are typically in excess of 30 tonnes and with power steering the wheels can be rotated on the spot.

Traditional pavement design methods require all the traffic movements to be converted into an assessed number of Equivalent Standard Axles. There are however a number of things that requires clear definition and understanding for this system to work.

These are:

- Varying tyre pressures.
- Different wheel sizes
- Different configurations and associated interaction with the pavement e.g. screwing action of stacker jockey wheels braking forces etc.
- Varying vehicle speed.

- In a large yard vehicles are rarely confined to "one channel". There are obviously high use areas but some areas have logs parked on them for six months at a time.
- Some excessive loads are outside the normal range.
- Suitability of construction materials i.e. bedding sand

The number of assessed Equivalent Standard Axles is then used in a pavement "wear" model to arrive at an appropriate pavement thickness to protect weaker layers at depth.

Observations at the yard however indicate that there is more than just the passage of rubber tyres imposing loadings on the yard. I have already mentioned the screwing actions of the stackers jockey wheel.

Others include:
- Log loaders and stackers have tynes or tusks designed to slide under logs. Invariably times arise when these tynes are forced downwards.
- Scrapping action of equipment picking up debris or bin wood from the yard.
- Impact loadings from falling logs.
- Equipment running over logs.

Along with the additional loadings is the operating environment. The use of mobile plant in this type of operation results in leaks of oil and hydraulic fluid. Also tannic acids leach from bark and debris accumulation in the yard. So the yard is subjected to not only the various physical loadings mentioned, but also varying chemical conditions.

2. OTHER FACTORS

2.1 Original Ground Conditions

The Kinleith site is underlain with a rhyolite basement material and was then overlain by varying layers of ash and pumice. The pumice and rhyolite form excellent subgrade material while the ash is a disaster. It is variable in depth and strength, very weak and prone to settlement.

Roller compacted concrete was tried at the site about the time pavers were first used. It is understood that this was also a first in New Zealand. It failed. There was much discussion/argument about why, conformance with specifications and the like. It did not work, so someone lost out. On excavating out failed sections several years later, it was observed that the failed sections directly correlated with ash as opposed rhyolite subgrade material. The correlation was that close, that I can confidently state that this was the prime reason for the failure.

Industrial pavers are a flexible pavement system and can therefore accommodate a degree of settlement that rigid pavement systems cannot tolerate. They therefore can perform in situations where other systems are prone to failure.

2.2 Underground Services

The Kinleith site has evolved over time. There are a significant number of underground services at the site. Some have become redundant over time. Services include high voltage underground power cables, high-pressure steam, water, effluent, telecom cables, gas, storm water and the like. One cannot predict when some of these may require servicing, upgrading or relocating for a new development or similar.

Industrial pavers have performed well in this situation as no cutting of existing pavement is required and the same pavers can be reinstated when underground services are accessed.

3. WEAR RATES

How does one accommodate the additional loadings identified above? The end result of the aggressive operating environment is that pavements at Kinleith have been identified as wearing out by attrition of the surface layers.

In the unbound rail siding yard the attrition rate is about 300mm of aggregate per year. On the "channelled" feed to the number three log end attrition rates of asphaltic concrete were found to be 300mm per year, primarily due to the screwing action of the stackers jockey wheel. Over a ten-year period this would be 3 metres!

Industrial pavers at the dry drum feed have had two lots of maintenance over the last ten years. This has involved removing existing industrial pavers, topping up with a shallow top course aggregate and relaying new pavers in a relatively discrete area. The majority of the yard has remained untouched. In the area where incoming trucks are unloaded the industrial pavers have not been touched. These are now very loose and currently require replacement. On removing insitu pavers, it was observed that they had shed 30mm over the ten-year period. In this area it can be safely stated that the pavers have worn down at 3mm per year. It would be interesting to know what the wear rate on AC would have been over a corresponding period.



Figure 3. 100mm paver after 10 years now measures 70mm thick.

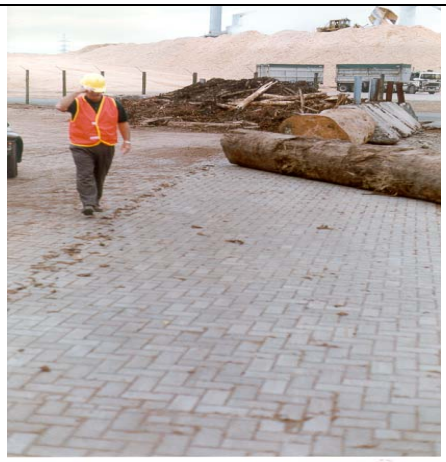

Figure 4. Logs are used to sweep up the bark.

Attrition from the surface layers does not seem to be a feature in conventional pavement design. In the Kinleith situation, it is totally appropriate that this is considered and I would suggest that it should be a factor used at other industrial sites similar to Kinleith.

4. MAINTENANCE

Industrial pavers have been found to be easy to maintain. Areas that have become worn down, loose or out of shape can be readily lifted and replaced with new blocks. This has happened in a small area under the highest loadings twice in the last 10 years at Kinleith. The majority of the yard has remained in excellent condition with no maintenance dollars being spent. No effort at cleaning off the yard and spreading sand over the pavers has been made. Overall maintenance costs have therefore been very low.

5. CONFINEMENT BEAMS

These add significantly to the cost of the paving option. They are, in essence, a rigid pavement operating along side a flexible one.

If they are to be designed to carry 100 tonne axle loads they need to be of some size. I understand that in previous designs, confinement beams have been required at frequent intervals. This may rule out industrial pavers as an option when compared with other pavement options. Lateral movement of industrial pavers at the Kinleith site has only been rarely observed. It has not led to pavement failure. Areas of 6,000 to 8,000 m2 have been completed at the site with confinement beams kept to the perimeter. A confinement beam that is flexible in the vertical plane but stable in the horizontal direction would be of benefit.

In one application at the yard that is lightly trafficked pavers have been placed against cut asphaltic concrete and have performed well to date.

6. BINWOOD YARD

The Binwood Yard is an area set aside, normally for short logs that are transported by high-sided dumpers. This wood is delivered to the yard by end dumping from the trucks. There is a significant impact loading. There is also a scrapping action, as a large bucket picks up the wood.

When asked to design a pavement for this yard I was frankly uncertain as to what to use. Due to the performance of the industrial pavers in other yards at the site they were selected with a question mark as to how they would perform in this situation, particularly due to impact damage from logs being end tipped onto the yard. Basically they have worked extremely well. The only defect in the yard occurred where a stormwater trench was inadequately compacted and some settlement occurred. The industrial pavers being a flexible system have accommodated this. A surface depression on the old trench line can now be observed but the yard continues to operate satisfactorily.

7. PAVER SPECIFICATIONS

Construction of the industrial pavers has generally conformed to NZS 3116:1991. This specification requires a 6.0MPa Flexural Tensile Strength with no single paver below 5.5MPa. The Standard Deviation does not exceed 1MPa. It is my understanding that recent specifications have sought higher tensile strength in pavers. In brief the pavers that have worn down to 70mm have not readily failed by cracking and segregation and secondly the impact loading from logs falling end on to pavers in the Binwood Yard have not caused any sign of pavement distress. I would have thought that if the tensile strength of pavers were their “Achilles heel” then both of these situations would have demonstrated it. They have not. It would therefore seem to me that seeking a higher tensile strength in pavers is based on a desire as opposed a practicality.

One might also question the sense of going for higher compressive strengths when the underlying pavement layers are typically a factor of 10 or less, however compressive strength may have some bearing on abrasive resistance which in my view should be the key consideration.

“The Structural Design of Heavy Duty Pavements for Ports and Other Industries” a British Ports Publication, recommends that pavers of 80mm be used in all situations. In the very high use areas where attrition is significant then 80mm is not enough for a reasonable design life. In some discrete applications I would recommend 120mm. This does not mean that new yards should have a blanket specification of 120mm either.

8. CONCLUSIONS

The industrial pavers as specified at the Kinleith Logyard have performed very well in an aggressive environment. Attrition rates from the pavement surface is often under rated by designers.

In essence once a pavement has been designed there needs to be consideration as to how the yard is to perform in the longer term. In the very high use areas in the future I would be inclined to use deeper pavers. There has been a lack of long-term performance information in New Zealand. I understand from personal comments that this has led designers to often over specify criteria in relation to block manufacture, confinement beam spacing and the like. Kinleith experience has been that a lower standard of specification works well. Industrial pavers can cost more initially than other pavement systems but long-term performance including wear, maintenance and practicality issues results in significant savings. For the future, a confinement beam that is flexible in the vertical plane would be beneficial.

9. CARTER HOLT HARVEY LVL PLANT

9.1 Background

Carter Holt Harvey's new NZ$ 132 million wood processing plant at Marsden Point near Whangarei in New Zealand is a high tech continuous press Laminated Veneer Lumber Plant is the biggest in the Southern Hemisphere and one of only four in the world. The LVL process turns wood fibre of variable quality into light and strong, engineered product. Due to the nature of the handling machinery of the logs high attrition rates were designed for wear of 3mm per year with a design life of 20 years.

9.2 Design Standards

The paving block heavy pavement has been designed using a mechanistic analysis approach based on the CIRCLY software programme with a modified subgrade failure criteria for heavily loaded pavements. The CIRCLY programme calculates displacements, strains and stresses at specific points throughout the pavement structure by analysing multiple circular loads on a layered elastic structure (both isotropic and anisotropic) using integral transform techniques.

The paving block pavement design was also checked against the British Ports Association manual, 'The Structural Design of Heavy Duty Pavements for Ports and Other Industries', and the software package 'Lockpave' of the Concrete Masonry Association of Australia Limited.

10. DESIGN PARAMETERS

The different elements of design are:

10.1 Construction and Maintenance Considerations

The log-handling yard is subjected to heavy loading from log loader turning and loading/unloading movements. Due to Carter Holt Harvey's experience at other log yard facilities they have a preference for the use of pavement blocks rather than AC for the surface layer in heavy-duty pavement areas. Paving blocks of 120 mm thickness have been used in heavy-duty pavement areas.

Due to constraints in site grading and *varying pavement loadings* paving blocks, concrete pavement, and asphalt have been used. Paving blocks have been used in heavy-duty pavement log handling areas of 2% or greater surface gradients. Concrete pavement has been used in localised heavy-duty pavement areas, e.g. ramps and fuelling areas. Asphalt has been used in non-heavy duty pavement areas.

10.2 Subgrade Evaluation

Equivalent California Bearing Ratio (CBR) values derived from scala penetrometer readings were used to evaluate the subgrade conditions. For design purposes a subgrade CBR = 4 was used. A value of 5 was used for field quality control.

10.3 Pavement Materials

Pavement materials considered were paving blocks, asphalt and concrete pavement (surfacing), cemented material and unbound granular material (pavement layers). For the mechanistic design procedure, pavement materials are characterised by their elastic parameters.

10.4 Pavement Design Life

Traffic types and loadings (number of axle passes, axle loadings and axle configurations) used for pavement design were:

- 'Typical log truck' gross laden 44 tonnes, pay load up to 28 tonnes with loaded axle loads of 6 to 7.5 tonnes
- WA320 loader, operating weight 13 tonne, and a 2 to 5 tonne lift, giving a total weight of 15 to 18 tonnes. Loaded weight distributions vary from 9.4 tonne front axle and 5.6 tonne rear axle for the 2 tonne load, to a 14.7 tonne front axle and 3.3 tonne rear axle for the tonne load
- WA470 loader, operating weight 23 tonnes, 16 tonne lift, total weight 39 tonnes with loaded weight distribution of 38 tonne front axle and 1 tonne rear axle.
- H45D Linde forklift with a 6.5 tonne tare and a 4.5 tonne load (9.8 tonne loaded front axle and 1.2 tonne rear axle)

An appropriate dynamic load factor of 1.4 for heavy-duty pavement yards was used for log loader loads (being the greater of 1.4 for cornering and 1.3 for breaking, British Ports Association, The Structural Design of Heavy Duty Pavements for Ports and Other Industries)

10.5 Log Yard – Pavement Type 1

- Logging truck and trailer units, 300,000 for 20 year life
- WA470 loader, 1,000,000 trips with 16 tonne pay load for 20 year life

10.6 Log Conditioning Yard – Pavement Type 2

- 4,100,000 loader trips for 20 year life
- 90% with WA320 loader, that is 3,700,000 trips, and
- 10% with WA 470 loader (with 5 tonne pay load), that is 400,000 trips

Table 3. Pavement Design.

Pavement Type	Pavement Design
Type 1 – Log Yard,	120 mm concrete block pavers 30 mm sand bedding 100mm AP40 basecourse 650mm cement stabilised sub-base 900mm total depth
Type 2 – Log Conditioning Yard	120 mm interlocking concrete block pavers 30 mm sand bedding 150mm basecourse 500mm cement stabilised sub-base 800mm total depth
Type 3A – Green Waste Yard	120 mm concrete block pavers 30 mm sand bedding 100mm AP40 basecourse 200mm sub-base 300 compacted hardfill 750 mm total depth

10.7 Concrete Paving Edge Restraint and Kerb
Concrete paving edge restraints (400mm x 460mm in section) were designed to be laid around the perimeter of the paving block areas to confine the paving blocks.

10.8 Design Pavement
The design pavement thicknesses are as summarised in Table 3.
Concrete paving areas design was based on Austroads Pavement Design, Section 9, and Design of New Rigid Pavements. The design was checked against the National Roads Board RRU Technical Recommendations TR6, Design and Construction of Concrete Road Pavements.

11. PAVER SPECIFICATION

Documents: AS/NZS 4455.1997 Masonry Units and Segmental Pavers
AS/NZS 4456.1997 Masonry Units and Segmental Pavers–Methods of Test
NZS 3116:1991 Interlocking Concrete Block Paving



Figure 5.

11.1 Product: Rectangular 198mmx98mmx120mmthick
Laying Pattern: Herringbone with a header course around fixed abutments, manholes and drains.
Frequency of testing: Sampling as to AS/NZS 4456.1. A "Lot" comprises of 10 000 units or every 200m^2.

Testing criteria:
Abrasion resistance to AS/NZS 4456.9 for assessment of each Lot 20 units per Lot were tested. The maximum mean abrasion for 60-day concrete is 3.2 with no single value above 4.
Compressive Strength was as per NZS 3116:1991 Five specimens per Lot. (The min 28day Characteristic Compressive Strength of 55 MPa.)

12. SANDS

Bedding sand: Hard, durable, angular particles, with no pumice and argillite particles, and to NZS 3116:1991 except for the specified 0% passing the 75 μm sieve size. Grading limits as per Table 1.
Jointing sand: hard, durable, angular particles, with no pumice and argillite particles, and to NZS 3116 and to the grading limits of Table 2

Table 1.

Sieve size	Percent Passing
9.52mm	100
4.75mm	95 – 100
2.36mm	80 – 100
1.18mm	50 – 95
600µm	25 – 60
300µm	10 – 30
150µm	0 – 15
75µm	0

Table 2.

Sieve size	Percent Passing
2.36mm	100
1.18mm	90 – 100
600µm	55 – 100
300µm	15 – 60
150µm	3 – 30
75µm	0 - 5

13. MECHANICAL INSTALLATION

The mechanical installation of the 120-mm concrete pavers at the LVL has assisted the engineers in achieving the required structural properties for the increasing loads and demands of investors and equipment within the timber industry for extremely abrasive industrial applications.

Handling the heavy concrete pavers (198 x 98 x 120mm thick, +- 5.1Kg each) by machine had quite evident advantages for those who were employed to install them.

As both cost and speed of installation were important requirements for this project the minimizing of personnel for each work crew, by efficient mechanical means enabled delivery of high quality installation with reduced labour cost.



Figure 6.



Figure 7.

13.1 Optimus H77 laying 120mm thick pavers

The Optimas system produced continued installation at 850 sq^2 per day with a work crew totalling 10. Each cluster of 340 Kg's representing 64 standard pavers was delivered for quick installation with a cycle time of 30 seconds. This equates to 2.56 m^2 per minute.

14. CONCLUSIONS

The concrete pavers have performed well since the logyard was commissioned 12 months ago.

Fines from bark and dust appear to be providing some sealing of joints between pavers. The absence of ponding on the relatively flat 2% gradient is attributed to the standard of installation quality control.

There is minor wheel track deformation in the most highly channelised areas. However this is only noticeable where pavers abut concrete ramps and floor slabs.

These benefits continue to promote and develop new markets for concrete block paving in heavy industrial applications within New Zealand, enabling paving to compete with poured concrete and asphalt pavements in the large industrial market associated with manual installation methods.

15. REFERENCES

British Ports Association manual, 'The Structural Design of Heavy Duty Pavements for Ports and Other Industries'

'Lockpave' - Concrete Masonry Association of Australia Limited.

National Roads Board RRU Technical Recommendations TR6, Design and Construction of Concrete Road Pavements.

AS/NZS 4455.1997 Masonry Units and Segmental Pavers

AS/NZS 4456.1997 Masonry Units and Segmental Pavers–Methods of Test

NZS 3116:1991Interlocking Concrete Block Paving

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CURRICULUM VITAE
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Allan is a Civil Engineer with a background in the forest and solid waste industries in New Zealand. He has worked for various governmental agencies and more recently a large forestry corporate. Over the last four years Allan has been operating his own consultancy based in Tokoroa, a small provincial forestry and farming centre located in the central North Island.

Specific projects have included the development of landfill gas to electricity on Auckland's two largest landfills, strategic planning of proposed highway routes, new landfill planning, and a significant upgrade of the Kinleith Logyard.

The Kinleith Logyard up grade relied on the use of industrial pavers that had been first used at the site about 8 years previously. Design of the upgrade was largely based on the good previous performance of the industrial pavers.