A Practical Approach to Design and Construction Detailing for Road, Industrial and Aircraft Pavements

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SUMMARY

The success and performance of a segmental concrete pavement relies on a number of factors. These include suitable pavement design based upon proper site investigation, and assessment of vehicle loadings, along with appropriate design and construction detailing.

Methods for the pavement design are many, and are well documented. A relevant pavement thickness design, combined with good design and construction detailing is paramount to ensure the pavement performs well throughout its design life.

This paper takes a practical approach to the relevant design and construction issues, not currently addressed by any single Australian Standard or industry document.

It is based upon the author's 11 years experience in the segmental paving industry.

INTRODUCTION

This paper gives an overview of current practices used in the State of Queensland (Qld), Australia, for design and construction detailing for Road, Industrial and Aircraft Pavements using concrete segmental pavers.

BACKGROUND

Queensland occupies the north-eastern portion of the Australian continent, and enjoys a sub tropical to tropical climate. Of the six States of Australia, Queensland ranks second in area, and third in population with just over 3 million residents.

Brisbane is the capital of Queensland, and forms the hub for five of the top ten fastest growing Australian municipalities. It has the largest municipal government in Australia, and third only to New York and Los Angeles in the world, covers 1220 square kilometres and is home to 751,225 people.

With a population increasing at twice the national average, the growth of Brisbane's economy growth is assured for years to come. Combined with this, it offers the lowest taxes, charges and capital costs in Australia, an excellent industrial relations climate, the most modern infrastructure in the country and stable pro-enterprise city and state governments.

Queensland's share of Australia's population is expected to increase from about 17% at present to 19% in 20 years, most of which will be centred in the south east of the state. The attractive climate and growing economy despite recessionary times, have contributed to the migration of approximately 1000 people per week from southern states.

As a result, building and housing development have been major growth areas for the use of segmental paving. Many developers and Local Authorities have chosen paving over other road pavement treatments for the aesthetic and practical appeal it offers.

Some of the most significant heavy duty pavements in Qld and are situated at the Port of Brisbane Authority's Fisherman Islands Complex at the mouth of the Brisbane River, and at Cairns International Airport.

The Port of Brisbane has experienced an increase in trade of 72% from 1982/83 to 1990/91. The Port of Brisbane Authority manages 30 wharves with some 6.7 km of berth space providing extensive cargo handling capabilities. The Port of Brisbane has been clearly identified as the leading port in Australia in a number of key areas relating to port pricing and cargo handling productivity.

The Fisherman Islands terminal - the modern "heart" of the Port of Brisbane is located at the mouth of the Brisbane River and can comfortably handle the largest (about 60,000 d.w.t.) container and roll on - roll off ships in the world as well as bulk grain carriers to 80,000 d.w.t. and oil tankers in the 100,000 d.w.t. class.

The tremendous growth of port trade has seen the building of new, and upgrading of many existing facilities.

Cairns International Airport has undergone significant re-development since 1984 to cater for the huge increases in tourism, both domestic and inbound. Cairns is the main international gateway to the Great Barrier Reef and Daintree World Heritage Rainforest Areas.

The 24 hour a day operation is currently served by 10 international carriers (regular operators and charter airlines) with over 100,000 aircraft movements and 2 million passengers per annum. It is Australia's 5th busiest international airport, and 6th busiest overall.

Segmental paving has been chosen by Port of Brisbane Authority and Cairns Port Authority as the preferred pavement system in heavy duty areas because it offers durability and a temperature insensitive surface resistant to oil and fuel spills.

BASE DESIGN

Many methods have been developed for the design of segmental pavements. These designs cover domestic applications, roadways, industrial pavements and aircraft pavements. Some of these designs take into effect the structural capacity of the paver layer (lock up), such as the Cement and Concrete Association of Australia (1986) design curves, Lockpave Version 7 (& previous versions) where as other methods don't take the effect of lock up into considerations, such as Emery & Knapton's (1988) adaptation of the Federal Aviation Administration Authority (FAA) empirical design charts for flexible aircraft pavement design.

For road pavements constructed in Queensland by Local Authorities and private land developers (who hand them over to the relevant local authority after an initial maintenance period), no consideration is given to the concept of lock up. The pavements are designed as conventional flexible pavements but the surfacing is replaced by 80 mm concrete pavers plus bedding sand.

The Port of Brisbane pavements constructed in 1986 were designed using an early version of the Lockpave computer design program but were cross checked with a combination of the Portland Cement Association and the US Corps of Engineers pavement design methods. The pavement constructed in 1992 (35,000 m^2) was designed using Lockpave Version 6.

The design approach adopted for the International apron at Cairns Airport considered the segmental concrete pavers only as a surfacing layer to a conventionally designed flexible pavement. The pavement structural design was carried out in accordance with that normally used in Australia for design of aircraft pavements. The concrete pavers and bedding sand were used in substitution for the usual surfacing of 50 mm of bituminous concrete.

PAVERS

There is currently no Australian Standard that covers the manufacturing and testing of pavers. The concrete paving industry is guided by the Concrete Masonry Association of Australia (CMAA) document MA20, "Specification for Concrete Segmental Paving Units." This document details test methods for specific applications, and suggests minimum criteria for:

a) Characteristic Compressive Strength
b) Abrasion Resistance, measured by the ball race test
c) Dimensional Tolerance
d) Shape, thickness and paving unit application

This document is currently under review by the CMAA Technical Committee and the revised document should be published in 1994. The document will align with the proposed Australian Standard currently being drafted, and will recommend additional minimum criteria to the above, such as minimum breaking loads and skid resistance.

Spacer nibs are a contentious issue. There have been many arguments for and against the use of nibs. In theory, nibs are not necessary, however in reality it is not commercially viable for the laying contractor to achieve correct, consistent joint spacing unless assisted by spacer nibs. The CMAA Qld Promotion Committee recommendations for aircraft pavements are:

"Paving units shall have spacing nibs on the vertical faces. The size and location of the nibs shall be such as to separate all pavers to achieve joint spacing generally within the range of 1.5 mm to 4 mm with no more than 5% in any 3m x 3m area exceeding 4 mm. No joint shall be less than 1.5 mm nor more than 5 mm."

This recommendation would also apply to road and industrial pavements.

The sizing of pavers is critical to achieve consistent joint spacing. The size variation during manufacture is caused by:

a) Mould Dimension Accuracy
The manufacturers of the moulds cannot guarantee identical sized mould compartments due to variations in plasma cutting, machining tolerances, assembly and distortion caused by heat treatment.

b) Mould Wear
As the mould wears, the pavers produced will increase in plan dimension. In a plant that uses vibrating type manufacturing, it is likely that after the production of 25,000 m^2 the mould size may have increased by 1.0 - 2.0 mm from the original dimensions. In a plant using pressing type manufacturing, the mould may be at this same level of wear after a relatively short period of production, due to the high abrasive action of the mix, abrasion and high pressing pressures.

c) Slumping
Slumping and bulging of the pavers after ejection from the mould is sensitive to mix design and water content.

Due to size variation in the production of the pavers, it is difficult to achieve consistent joint spacing if batches of pavers are randomly selected from the production run for laying. It is very important to control the size of the pavers, the sequence of pavers delivered to site, and where they are laid in the pavement. The larger the area, the more important this aspect is, to the point that it is critical for industrial and Aircraft Pavements. The CMAA Qld Promotions Committee recommends that the designer specifies that the manufacturer shall install the paving.

A special requirement for aircraft pavements is that the surface of the pavers must be tightly bonded to prevent the occurrence of potential Foreign Object Damage (FOD) to aircraft engines and components. Care must be taken when manufacturing pavers using vibrating type machines to ensure a dense surface texture. Generally pressing type machines should have no trouble producing a smooth surface texture.

A laboratory test method has been developed for measuring the surface texture. This procedure is a modified sand patch test, allowing a maximum average surface texture depth of 0.11 mm.

DRAINAGE - SURFACE, BEDDING SAND AND SUB SOIL

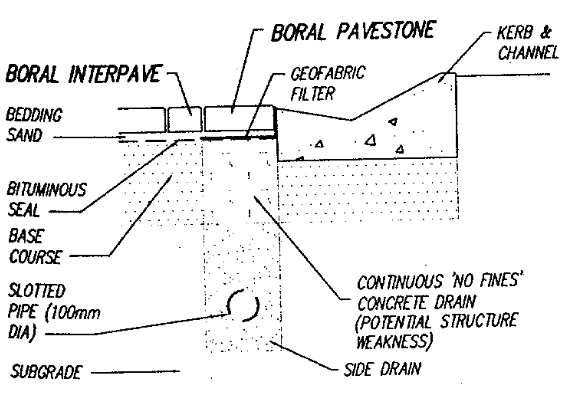
Good surface drainage, bedding sand and sub soil drainage are essential prerequisites for satisfactory pavement performance. Unless these drainage methods are instrumented, the pavement may suffer distress, decrease in performance, reduce in service life, or fail totally.

The requirements for draining surface water, ie profiles, locations and sizes of drainage kerbs, and gully pits and contours are the same as conventional pavements.

Water will penetrate the pavement via the sand-filled joints. Detritus will be deposited by traffic and this will help reduce the permeability of the surface at these points, however traffic usually "tracks" so it is highly unlikely that total surface permeability will be reduced substantially. It is recommended that the pavement surface is considered permeable and appropriate steps taken.

The base course must be protected with water proof seal (bituminous seal). Surface water that penetrates through the joint sand into the bedding sand will be trapped and may percolate into the base, sub base and sub grade unless drained. Bedding sand drainage is achieved by draining directly into the subsoil drainage system and drainage pits.

Care must be taken not to introduce a potential structural weakness in the pavement. The following illustration details preferred and non preferred methods.



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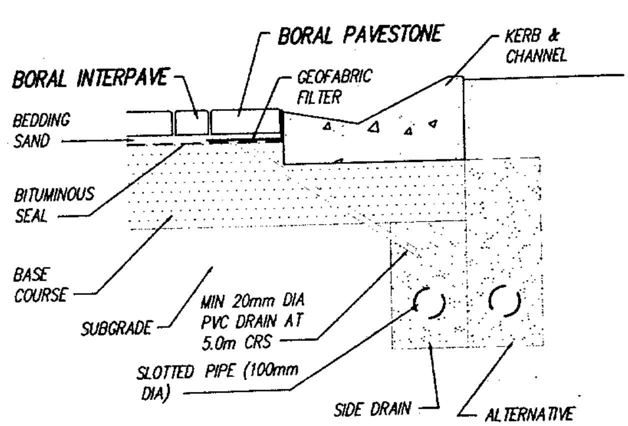

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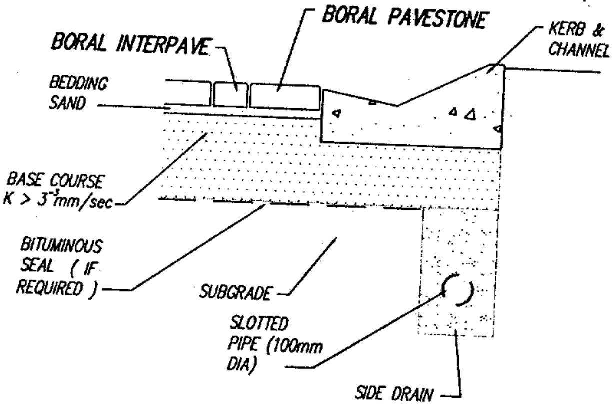

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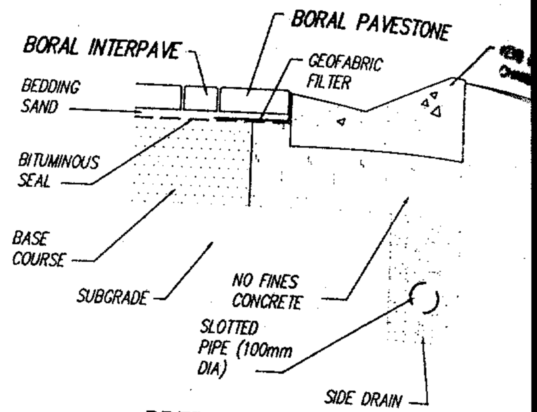

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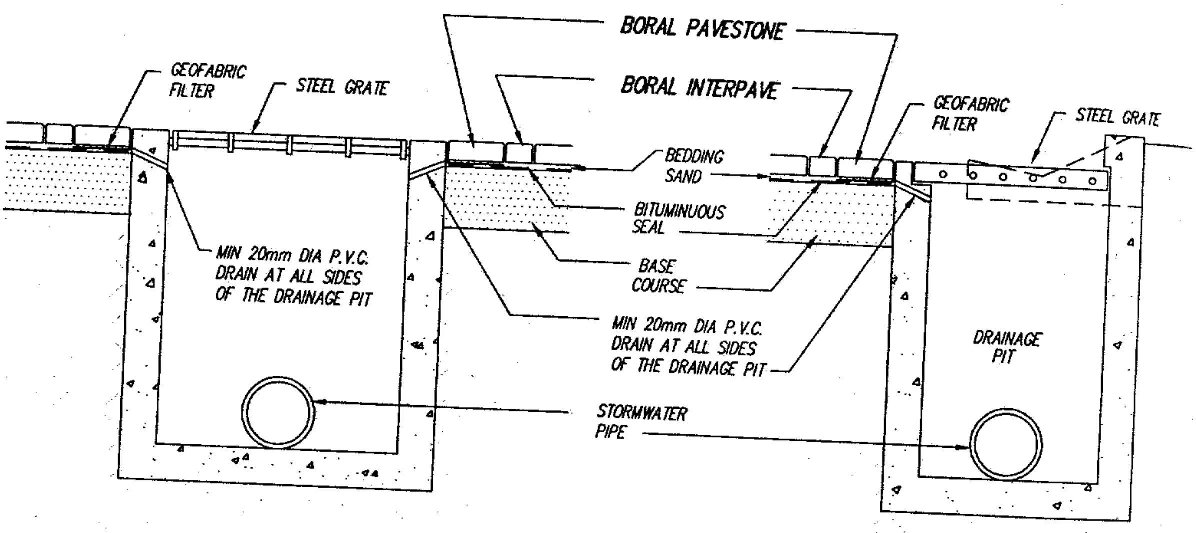
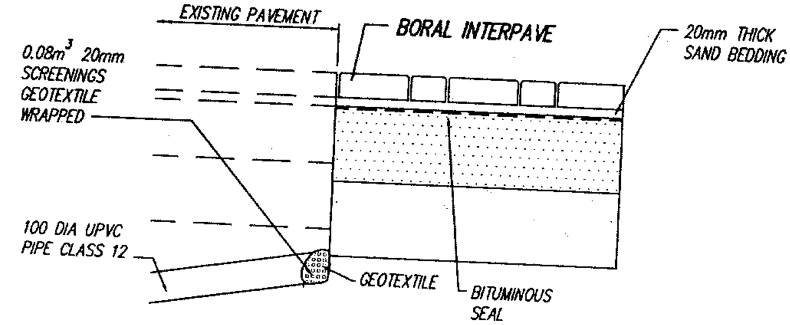


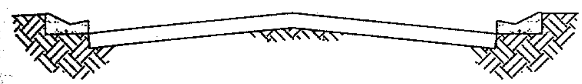


GRADIENT TRANSITION

To minimise excessive joint spacing at pavement crowns, or butt jointing of pavers at inverts, which may lead to surface spalling, it is important that the basecourse is trimmed and rolled to form a transient curve between gradient changes.

For complex draining pavements, such as some industrial or aircraft pavements it is advisable to locate and mark the crowns and inverts to ensure that their position is maintained before the bedding sand is placed.

The minimum and maximum gradients can be the same as asphalt or concrete pavements, however if nominal graded pavements are required, then the likelihood of water ponding is increased.



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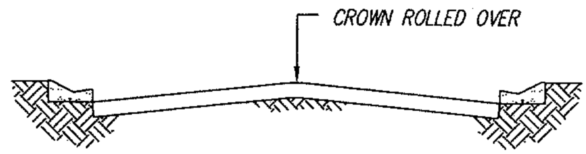

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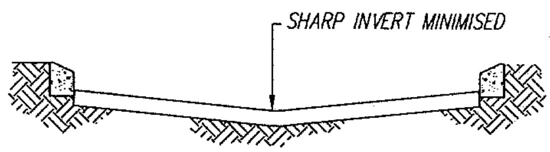

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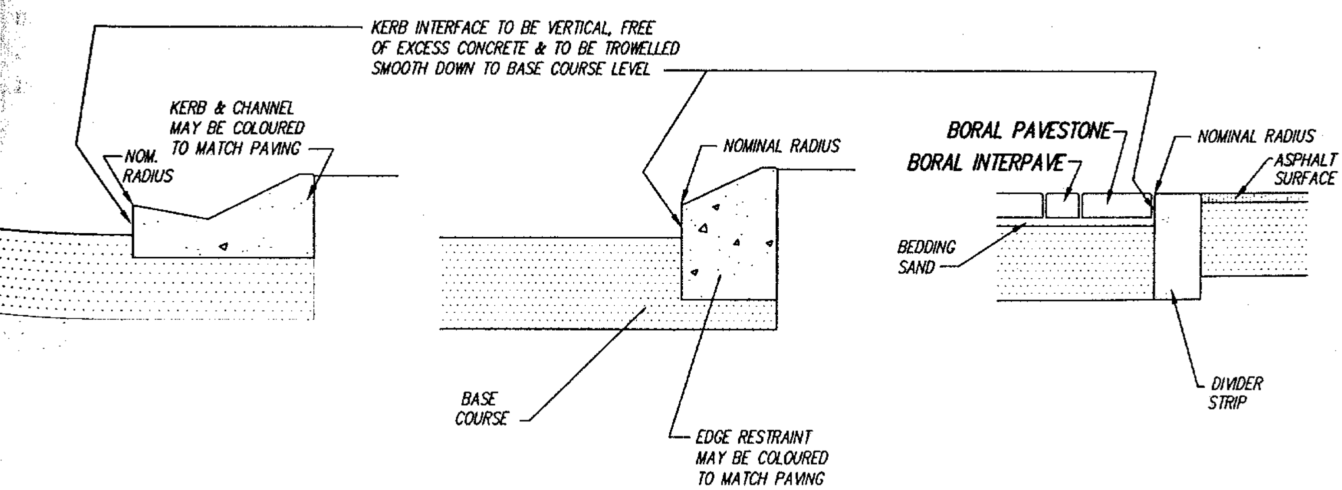
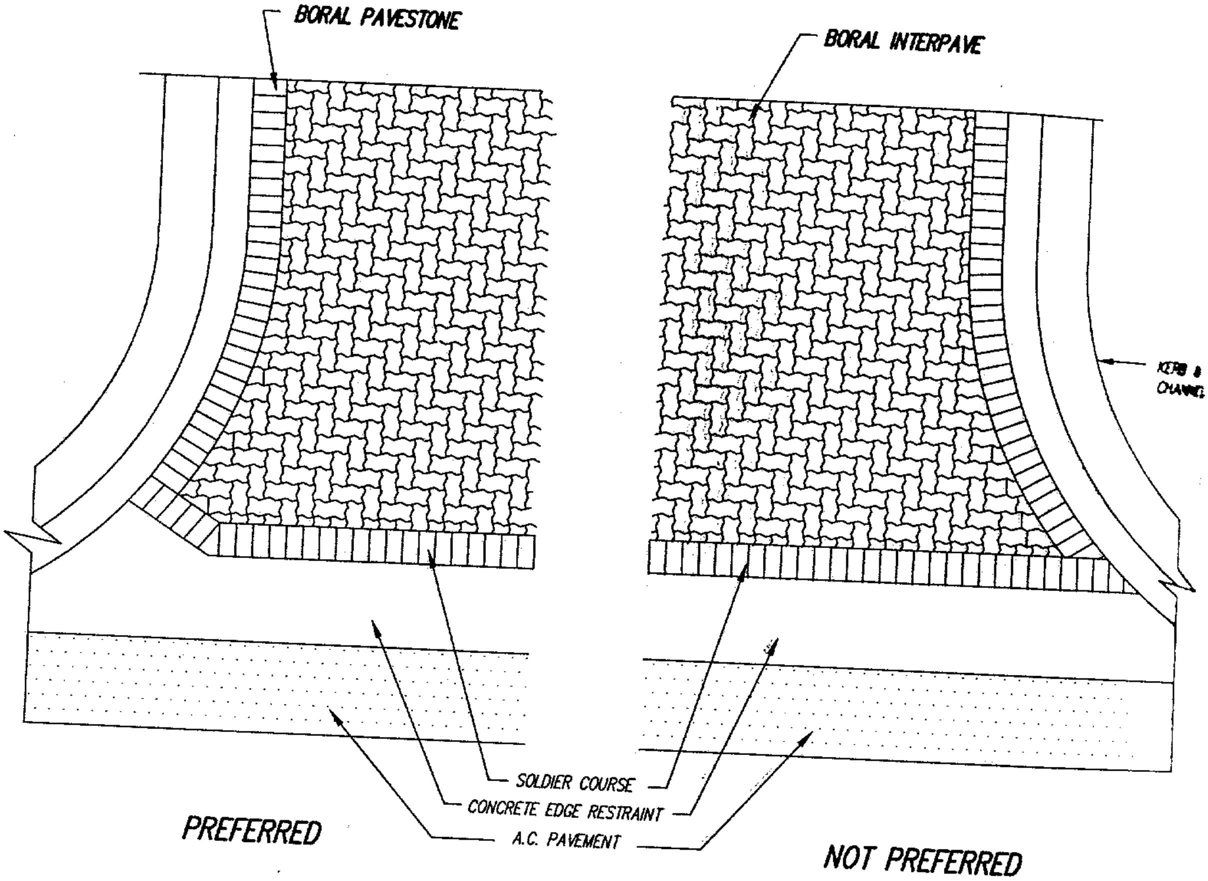
EDGE RESTRAINTS

The pavement must be restrained to maintain its structural integrity. This restraint is achieved by kerbs, drainage channels, specially designed edge restraints, or building slabs. Illustrated below are some typical restraints. Restraints must be designed and constructed to carry anticipated wheel loads.



ENTRY STATEMENTS

Where entry statements or similar shaped areas are to be paved it is advisable to truncate the paving so narrow areas are not paved. This is because it is extremely difficult to achieve the required levels of compaction and surface tolerance of the base course in these areas. Illustrated below are typical details.



BASE COURSE TOLERANCE AND SURFACE SMOOTHNESS

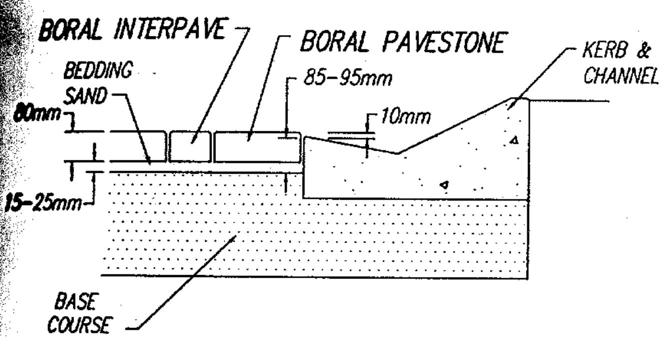
Experience has proven, and it is well documented that the surface of a pavement with a thin sand bedding layer is less likely to deform than a pavement using a thick bedding sand layer. The accuracy of bedding sand thickness and the accuracy of the resultant finished pavement levels are directly related to the accuracy of the base course smoothness.

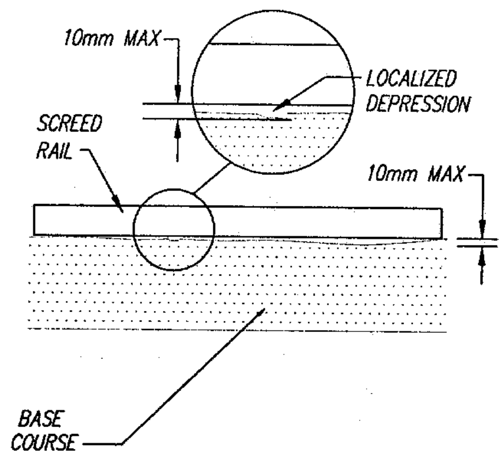
The bedding sand thickness after compaction should be a nominal 20 mm ± 5 mm. Specifications that call up a generous tolerance on the base and a tighter tolerance on the surface smoothness of the pavement are a nonsense! The bedding sand thickness is controlled by screed rails laid directly onto the base and screeding on these rails and/or adjacent edge restraints. Practical experience has shown that the moisture content is impossible to control and has no effect on surface smoothness of the pavement after full compaction of the bedding sand.

most applications a base course tolerance of +10 mm - 0 mm is suitable. It must be noted that it is extremely difficult to achieve base course that is 100% within tolerance, even if it is technically within tolerance, the surface smoothness and finish may result in extreme variation of bedding sand thickness. This variation in bedding sand thickness may be reflected in the surface smoothness of the finished pavement. If a surface smoothness of ± 7mm is required then the base smoothness must be ± 7mm.

recommended that remedial procedures be specified to correct the deficiency in the base course, such as correcting with asphalt, stabilised sand, concrete, epoxy compounds, or pre-compacted sand. Under no circumstances should uncompacted bedding sand be used to correct defective base course levels.

The base course depths adjacent to edge restraints and pavement penetrations must be such that using bedding sand thickness of 15 -25 mm will assure that the pavers finish at the correct height adjacent to these restraints.





For aircraft applications, there is a special requirement to achieve a specific level of surface smoothness of the pavement surface. (This is measured using a mobile straight edge with audible alarm.) Therefore, critical attention must be paid to the surface smoothness of the base course, bedding sand thickness, and the thickness consistency of the pavers.

LIPPING

The current industry documents instruct that the pavement be vibrated until there is no lipping. This result is impossible to achieve unless all paving thicknesses are identical, which is not possible, and is further exacerbated by the local practice of laying on thin bedding sand.

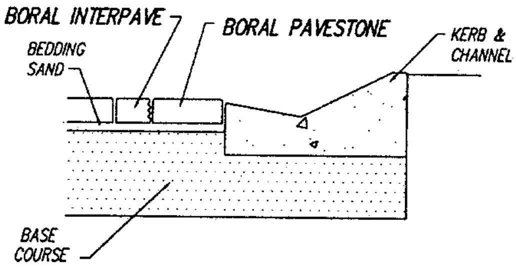
As a result, the CMAA Qld Promotions Committee makes the following recommendation -

"The difference in level (lipping) between adjacent units shall not exceed 4 mm with not mor than 1% in any 3m x 3m area exceeding 2mm."

SOLDIER COURSE & EDGE TREATMENT

The correct detailing at edge restraints not only affects the aesthetics of the pavement but its performance because it is essential that the pavers remain "locked in". Without a soldie course, small pieces of pavers that abut kerbs or edge restraints may dislodge or rotate.

This problem is further exacerbated if the kerb or restraint has a large "bull nose" radiu and its face is not vertical and not trowelled smooth.



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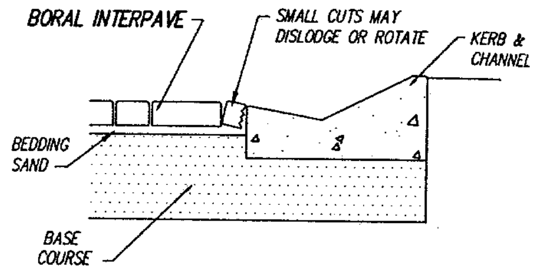

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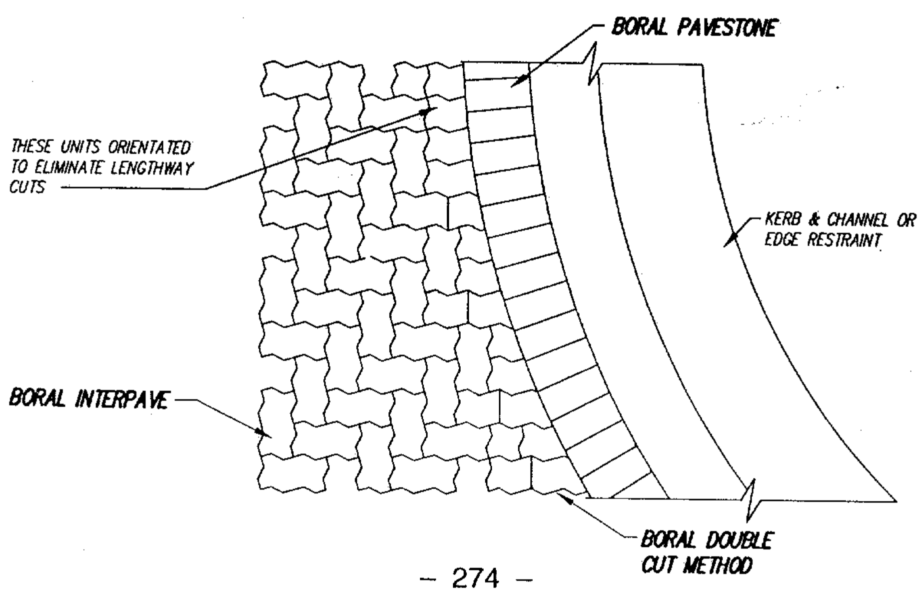
These problems can generally be overcome by a combination of:

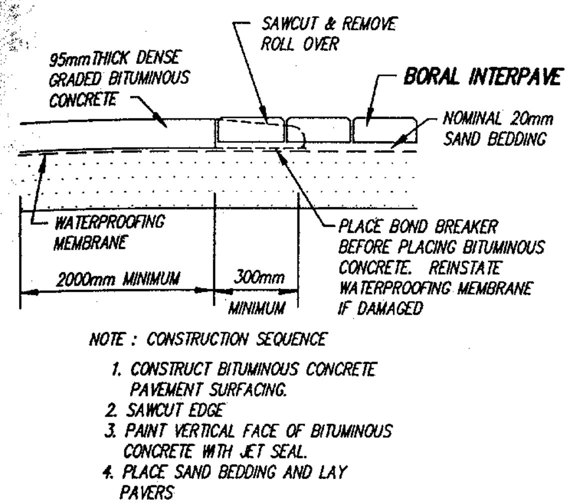
a) The use of BORAL rectangular pavers as a stack bonded soldier course;

b) compromise the herringbone pattern to orientate the cuts of the pavers widthways thus eliminating the likelihood of breaking long slender cut pieces;

c) BORAL double cutting method.



Alternatively, for square and rectangular pavements whose overall dimensions are nominal then the pavement size is adjusted to coincide with an exact number of full pavers. It can be bordered by a soldier course or completed utilising specially manufactured half size and closure units.



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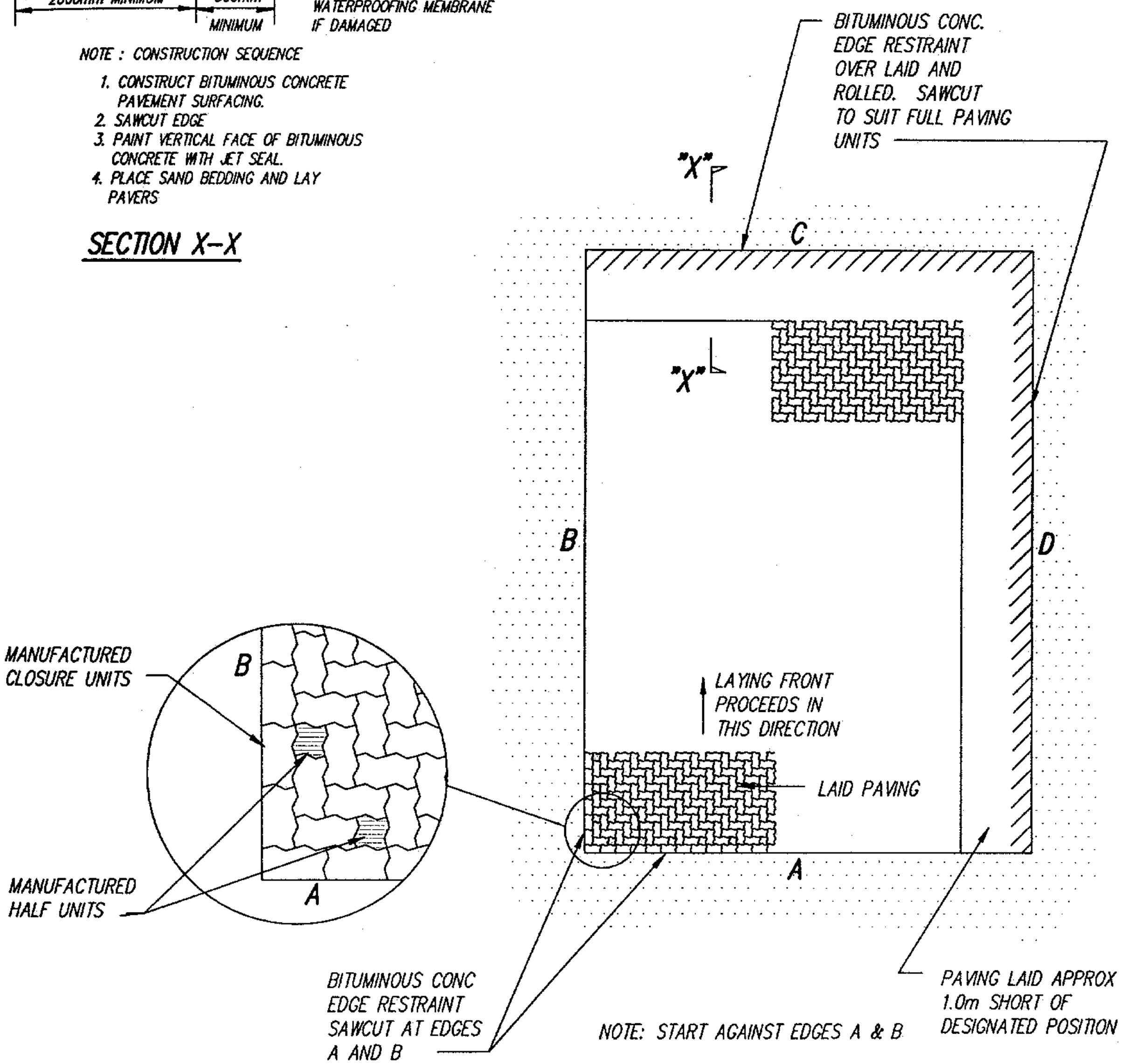


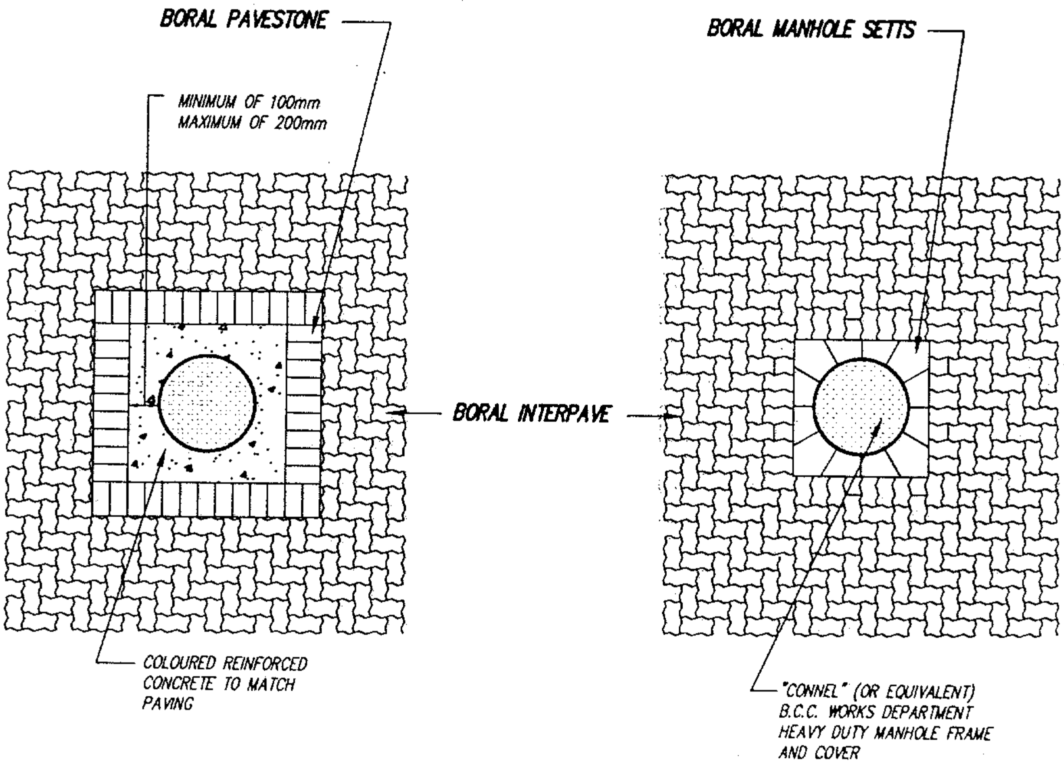
PAVEMENT PENETRATIONS

All pavements usually have some type of penetration, such as manholes, service pits, drainage pits, etc. In a segmental pavement it is highly improbable that those penetrations will correspond in shape, dimensions or squareness to the pattern and shape of the pavers surrounding it.

For structural reasons, it is important that the pavers fit closely around these penetrations to maintain structural integrity of the pavement. Square or rectangular penetrations that have a fixed location in the pavement such as drainage pits can be bordered by solider course, and the adjacent pavers cut in as described previously.

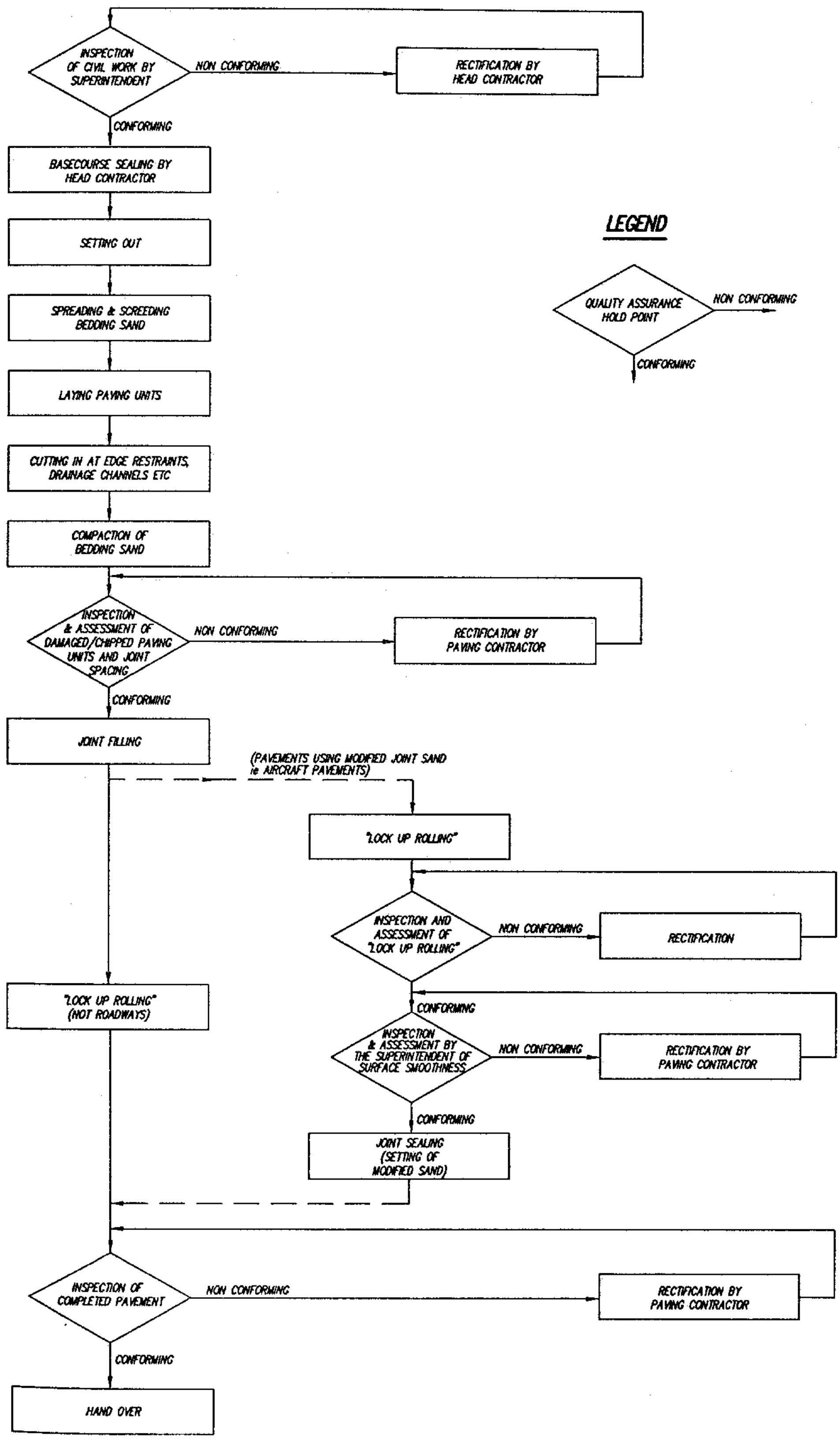
Circular or irregular shape penetrations can be surrounded by reinforced concrete, the dimensions are such that only full and half size units are needed. Alternatively, specially manufactured closure units can be utilised, such as Boral manhole sets.

It is important that any penetration is constructed to the correct level and grade in relation to the finished surface level. In the case of drainage pits, the pavers should finish between 10 - 15 mm above the pit. In the case of manhole and non drainage pits, the paving should finish between 0 - 5 mm above the penetration.



CONSTRUCTION PROCEDURE AND QUALITY ASSURANCE HOLD POINTS

The flow chart below illustrates the site procedure and suggests Quality Assurance hold points. Note that for aircraft pavements the construction procedure is slightly different. This is because of the use of joint sand that is resistant to aircraft jet blasts. This sand contains a hydrated polymer glue, that when wetted will activate the glue and will bind the sand particles together but will remain in a flexible state.



CONCLUSION

There is an increase in demand in the use of segmental concrete paving as more developers and designers recognise the significant advantages of this type of pavement.

Experience has shown that poor pavement performance can be attributed to inadequate or non existent drainage and poor design and construction detailing.

It is recommended that:

a) The manufacturer of the pavers is contracted to manufacture, supply and install the pavers.

b) The manufacturer has a Quality Assurance procedure for both manufacture and installation.

c) The manufacturer has documented procedures for monitoring paver growth and controlling resulting joint widths.

d) The relevant details in this paper are implemented together with a sound pavement design.

e) The manufacturer or industry associations are invited to be involved at the concept and design stage to assist in design detailing, construction procedures, construction programming and to discuss any other special requirements.

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