NZS 3116:2002
Incorporating Amendment No. 1

New Zealand Standard

Concrete segmental and flagstone paving

Superseding NZS 3116:1991

NZS 3116:2002

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This Standard was prepared under the supervision of the Interlocking Concrete Block Paving Committee (P 3116) for the Standards Council established under the Standards Act 1988.

The committee consisted of representatives of the following:
Co-opted Member (Chairperson)
Aggregate and Quarry Association of New Zealand (Inc)/New Zealand Contractors' Federation
Building Officials Institute of New Zealand
Cement and Concrete Association of New Zealand
INGENIUM (Association of Local Government Engineers NZ)
New Zealand Concrete Masonry Association

The 3116 Amendment No. 1 committee consisted of representatives of the following:
Cement and Concrete Association of New Zealand
Local Government New Zealand
New Zealand Concrete Masonry Association
New Zealand Concrete Society
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AMENDMENTS

No	*Date of issue*	*Description*	*Entered by, and date*
1	February 2009	Extends the scope of the Standard to include flagstones	Incorporated in this edition

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REFERENCED DOCUMENTS

Reference is made in this document to the following:

NEW ZEALAND STANDARDS

NZS 3103:1991	Sands for mortars and plasters
NZS 3111:1986	Methods of test for water and aggregate for concrete
NZS 4210:2001	Masonry construction: Materials and workmanship
NZS 4402:1986	Methods of testing soils for civil engineering purposes –
Part 6 Section 1:1986	Determination of the California Bearing Ratio (CBR)
NZS 4407:1991	Methods of sampling and testing road aggregates
Part 3.5:1991	Laboratory tests – Test 3.5 The clay index
Part 3.8.2:1991	Laboratory tests – Test 3.8.2 Subsidiary method by dry sieving

JOINT AUSTRALIAN/NEW ZEALAND STANDARDS

AS/NZS 3661.2:1994	Slip resistance of pedestrian surfaces – Guide to the reduction of slip hazards
AS/NZS 4455:1997	Masonry units and segmental pavers
AS/NZS 4456:2003	Masonry units, segmental pavers and flags – Methods of test
AS/NZS 4586:2004	Slip resistance classification of new pedestrian surface materials

AUSTRALIAN HANDBOOK

SAA HB 197:1999	An introductory guide to the slip resistance of pedestrian surface materials

BRITISH STANDARDS

BS EN 1339:2003	Concrete paving flags. Requirements and test methods
BS 7533.4:2006	Pavements constructed with clay, natural stone or concrete pavers. Code of practice for the construction of pavements of precast concrete flags or natural stone slabs

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OTHER DOCUMENTS

Austroads	Guide to Pavement Technology Part 4D 2006 Stabilised Materials. AGPT 04D/06
Department of Building and Housing	New Zealand Building Code (NZBC)
Transit New Zealand	
TNZ B/2:1987	Construction of unbound granular pavement layers
TNZ F/1:1986	Earthworks construction
TNZ F/2:1984	Pipe subsoil drainage construction
TNZ F/6:1985	Fabric wrapped aggregate subsoil drain construction
TNZ M/3 Notes:1986	Sub-base aggregate

LATEST REVISIONS

The users of this Standard should ensure that their copies of the above mentioned Standards are the latest revisions. Amendments to referenced New Zealand and joint Australian/New Zealand Standards can be found at http://www.standards.co.nz.

REVIEW OF STANDARDS

Suggestions for improvement of this Standard will be welcomed. They should be sent to the Chief Executive, Standards New Zealand, Private Bag 2439, Wellington 6140.

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FOREWORD

This Standard is a revision of NZS 3116:1991 Interlocking Concrete Block Paving and contains provisions for the non-specific engineering design and construction of pavements using segmental pavers and flagstones. The revision provides for New Zealand variations to paver and flagstone manufacture and tests in relation to the Joint Standards AS/NZS 4455 and AS/NZS 4456.

The many applications for interlocking concrete segmental pavements and flagstone pavements flow directly from the advantages inherent in this form of construction, as opposed to more conventional pavements. These advantages include:

(a) Access to underground services without significant damage of the concrete pavers and flagstones, and opportunity of reinstatement without leaving unsightly and poorly finished patches;

(b) Ease of reinstatement of areas of localized settlement without destruction of the pavement or use of road-breaking equipment;

(c) Simple construction methods suited to unskilled labour but with skilled supervision;

(d) Low construction plant cost;

(e) Low maintenance costs and long service life;

(f) Ability to withstand repeated pavement flexing under traffic loads;

(g) Suitable for many types of pavements from light duty through to heavy duty with high wheel loads or (with appropriate paver specification) with tracked vehicles;

(h) Suitability for re-use after lifting for service access, maintenance, or to change layouts;

(i) Durability and abrasion resistance;

(j) Design flexibility;

(k) Suitability for paving both large and small complex areas;

(l) Aesthetic appeal;

(m) Wide range of colours;

(n) Specific areas can be delineated by the use of pavers of contrasting colour.

The range of paver thickness provided by this Standard is 40 mm to 80 mm. While all edge restrained paving to this Standard exhibits some interlocking characteristics, thicknesses of pavers below 50 mm are not regarded as providing any significant interlock. Only 50 mm thickness and over should be used for vehicular traffic. A table of suitable paver applications is included as table 1.

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The range of flagstone thickness provided by this Standard is 40 mm to 60 mm. A table of suitable flagstone applications is included as table 1A.

Previous versions of this Standard did not contain performance criteria or provide a suitable test method for evaluating abrasion resistance. This edition contains both performance criteria and a referenced test method.

Modifications to the acceptable grading limits for bedding sands have been introduced.

Appendix A – Method for the determination of abrading stability is normative i.e. an integral part of this Standard.

Amendment No. 1 in 2009 extended the scope of the Standard to include flagstone paving. It is incorporated in this edition.

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NOTES

NEW ZEALAND STANDARD

CONCRETE SEGMENTAL AND FLAGSTONE PAVING

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PART 1 GENERAL

101 SCOPE

101.1
This Standard is in three parts. General clauses are contained in Part 1. The manufacture, testing, acceptance, and supply of concrete segmental pavers and flagstones are contained in AS/NZS 4455 and AS/NZS 4456, and further requirements are contained in Part 2. The design and construction of the concrete segmental and flagstone paving is covered in Part 3.

101.2
Pavement loadings described in this Standard range from highway traffic to pedestrian use. Pavements carrying special purpose traffic loading shall be the subject of specific engineering design. Flagstone pavements carrying road traffic are outside the scope of this Standard, and therefore require specific engineering design.

C101.2
Recommended specifications for the design and construction of segmental concrete and flagstone pavements are given in Part 3, but the overall design of the pavement thickness should be carried out for the specific loading condition.

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101.3
The interlocking pavers and bedding are alternatives to part or all of the surfacing and basecourse in conventional flexible pavement construction.

101.4
Pavements constructed in accordance with this Standard are suited to traffic speeds of up to 60 km/h with respect to ride characteristics, noise level and skid resistance.

101.5
Pavers used in this Standard are of a plan size not exceeding 0.08 m^2, a width to length ratio not exceeding 2 and thicknesses ranging from 40 mm to 80 mm.

Flagstones used in this Standard are of a plan size exceeding 0.08 m^2, a width to length ratio not exceeding 2 and thicknesses ranging from 40 mm to 60 mm.

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101.6
This Standard does not cover the design and construction of permeable pavements.

102 INTERPRETATION

102.1
In this Standard, the word "shall" or the imperative mood indicates a requirement that is to be adopted in order to comply with the Standard. The word "should" indicates a recommended practice. Clauses prefixed by "*C*" and printed in italic type on a grey background are intended as comments and the Standard can be complied with if the comment is ignored.

102.2
The full titles of reference documents cited in this Standard are given in the list of Referenced Documents immediately preceding the Foreword.

103 DEFINITIONS

103.1
For the purpose of this Standard, unless inconsistent with the context the following definitions shall apply:

BASECOURSE means the upper part of the structural pavement, bounded by the overlying surfacing and underlying sub-base.

BEDDING COURSE means the sand layer into which the surface course is bedded.

CONCRETE SEGMENTAL PAVING

(a) INTERLOCKING PAVING means a pavement structure comprising a surface course of interlocked concrete pavers of at least 50 mm in thickness and less than 0.08 m^2 in plan, with sand filling in the joints between pavers, a sand bedding course, a basecourse, a sub-base (depending on subgrade and traffic loading conditions), the subgrade, and edge restraint (see figure 1).

(b) OTHER SEGMENTAL PAVING means a pavement structure comprising pavers under 50 mm in thickness and less than 0.08 m^2 in plan, with sand filling in the joints between pavers, a sand bedding course, a basecourse (depending on subgrade conditions), the subgrade and edge restraints.

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EDGE RESTRAINT means kerbing, edge restraints or other rigid structure along the perimeter of the paved area, or internally dividing large areas providing lateral support to the segmental paving.

FLAGSTONE means a large format solid paver with a gross plan area greater than 0.08 m^2.

FLAGSTONE PAVING means a pavement structure comprising a surface course of flagstones at least 40 mm in thickness with sand filling between the joints, a precompacted sand bed to 309.3.2 or specifically designed alternative, a basecourse, a sub-base (depending on sub-grade), and edge restraint.

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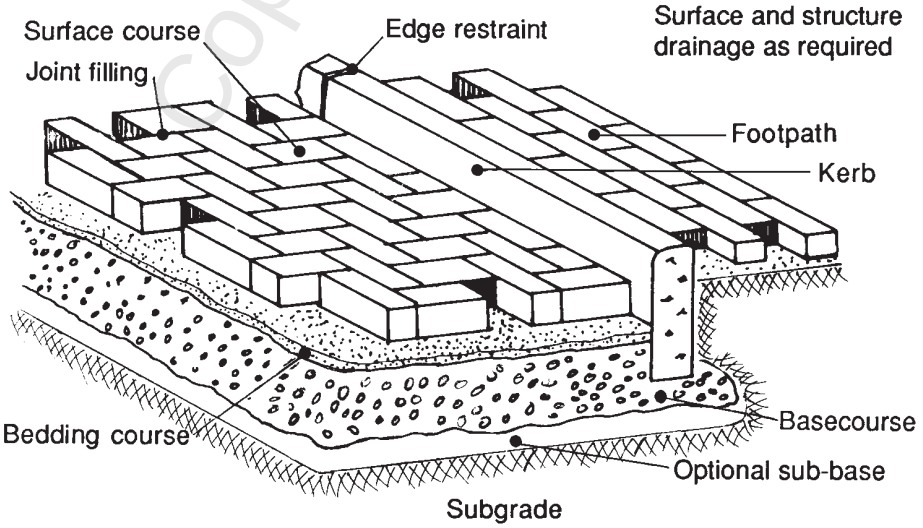

Figure 1 – Basic components of segmental and flagstone paving

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INTERLOCK means the horizontal and vertical shear resistance developed by the keying action of the sides of pavers or flagstones and the frictional forces developed between pavers or flagstones having a minimum thickness of 50 mm and a bonded laying pattern.

JOINTING SAND means a special graded sand placed and compacted in the joints between the pavers and flagstones.

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PAVER means a rectangular or shaped solid unit of up to 0.08 m^2 in face area manufactured to close tolerances, with plane or dentated sides, top and bottom faces parallel, preferably with arrises of the top surface chamfered, and of a size that can be hand placed.

SUB-BASE means the portion of the pavement between the basecourse and the subgrade.

SUBGRADE means the earthworks on which the pavement is constructed. This may comprise the natural ground, or may be selected imported material.

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SURFACE COURSE means pavers or flagstones laid together in a specific pattern with joints between them filled by sand which is densified by vibration.

TRAFFIC LOADING CLASSIFICATION means a broad grouping of severity of traffic loading as follows:

(a) **Residential pedestrian**

(b) **Residential driveway**

Light Traffic	Operation of vehicles with a gross mass not exceeding 3 tonnes.
Medium Traffic	Operation of vehicles with a gross mass exceeding 3 tonnes but not exceeding 10 tonnes with occasional use by heavier vehicles not exceeding the statutory limits for tyre, wheel and axle loads.

(c) **Public footpaths**

Low Impact	Paths to public gardens, pavements to schools or institutional buildings, hard landscape areas and common outdoor areas of residential buildings.
High Impact	Pavements with high volume pedestrian traffic containing significant use of high heeled footwear and at localized positions such as automatic teller machines, mall entrances and inner city areas.

(d) **Roads**

Minor	Up to 150 vehicles per day
Local	150 to 4000 vehicles per day
Main	Over 4000 vehicles per day

(e) **Industrial**: Areas such as:

(i) Container terminals, freight forwarders' yards, wharf areas, log yards and similar areas, where the handling equipment, such as fork lift trucks or straddle carriers, has high wheel loads (in excess of 300 kN in some circumstances) and where the materials stored or stacked can also apply high point loads on the pavement (for example, from the corner castings of ISO containers);

(ii) Where solid rubber-tyred vehicles or steel-wheel or tracked vehicles operate frequently, for example, loading docks, loading ramps, industrial floors, factory floors;

(iii) Where other high loadings can occur, such as at airports, plant repair bays.

NOTE –

The two elements of traffic load are:

(i) The magnitude of the heaviest axle which regularly traverses the pavement;

(ii) The number of passages across the pavement of the heavier loads.

Because highway axle weights are limited by regulation, highway loads depend on the volume of truck traffic. The design of footpaths depends on whether or not they can be used by vehicles. The design of carparks and driveways depends on whether or not they can be used by heavy trucks.

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Although pavers and flagstones for different classifications can be selected from tables 1 and 1A, the flexible pavement may need specific engineering design.

PART 2 SPECIFICATION FOR CONCRETE SEGMENTAL PAVERS AND FLAGSTONES

201 INTENDED USE

This specification applies to:

(a) Flagstones designed for pedestrian, and light vehicular traffic as defined in table 1A and constructed in accordance with Part 3 of this Standard; and

(b) Concrete pavers designed for pedestrian traffic or to carry rubber-tyred vehicles and constructed in accordance with Part 3 of this Standard.

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For a manufacturer of pavers or flagstones to demonstrate compliance with AS/NZS 4455 and this Standard, the manufacturer shall make available paver or flagstone work sizes and characteristic breaking loads that satisfy the proposed use of the paver or flagstone as described in tables 1 and 1A of this Standard.

202 PAVER SPECIFICATION AND PRODUCTION

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Manufacture, testing, acceptance, and supply of concrete segmental pavers shall be in accordance with AS/NZS 4455 and AS/NZS 4456 except where modified by the following clauses (a) to (c):

(a) AS/NZS 4456.1 Method 1 Sampling. Table 1 Quantities for Individual Tests.

Where a producer is operating a quality assurance monitoring programme, the number of samples required for dimensions and breaking load tests shall be 5.

When sampling on an individual basis specifically for a purchaser the sampling shall follow the provisions of table 1 of AS/NZS 4456.1.

(b) AS/NZS 4456.5 Method 5 Determining breaking load of segmental and flagstone paving units.

For all products within the maximum dimensional range of 190 mm to 240 mm the test span 'l' for Clause 6 Procedure (a) shall be fixed at 150 mm.

For all products listed in table 1A , the test span 'l' for clause 6 Procedure (a) shall be fixed at 250 mm.

Other products outside the dimensional range specified above, shall follow the requirements of Clause 6 Procedure (a) of AS/NZS 4456.5.

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NOTE – For products over 80 mm in thickness it is recommended that a product control test programme be based on AS/NZS 4456.18 Method 18 Determining tensile strength of masonry units and segmental pavers.

(c) Raised spacer nibs when used shall not cover more than 10 % of any side of the paver and shall not protrude more than 2 mm from the adjacent surface of the paver. They shall be located such that the nib positions on adjacent pavers cannot touch.

The manufacturer's work sizes shall not include the raised spacer nibs.

NOTE – All existing clauses 202 to 212 from NZS 3116:1991 were superseded by AS/NZS 4455 and AS/NZS 4456 and will not be part of this revised NZS 3116:2002.

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C202

Experience has shown that high volumes of pedestrian traffic cause surface abrasion. An abrasion resistance test is contained in AS/NZS 4456.9 Method 9 and should form part of any specification requirements for public footpaths. Not all pavers and flagstones are produced with the abrasion

characteristics as a primary feature and specifiers should check with manufacturers on the availability of such pavers and flagstones before use. Some further guidelines on this issue are shown in tables 1 and 1A of this Standard.

As the breaking load value is not directly used in pavement design, the test spans have been fixed to simplify product testing procedures. The breaking load value is set for overall performance and quality control.

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PART 3 DESIGN AND CONSTRUCTION OF CONCRETE SEGMENTAL AND FLAGSTONE PAVING

301 SCOPE

Part 3 of this Standard sets out the requirements for the paver and flagstone selection, design and construction of pavements for a range of pavers and flagstones used under New Zealand conditions, using products complying with AS/NZS 4455 and Part 2 of this Standard.

Although pavers and flagstones for different classifications can be selected from tables 1 and 1A, the flexible pavement may need specific engineering design.

302 PAVER AND FLAGSTONE SELECTION

The paver type shall be selected in accordance with the proposed application in table 1.

The flagstone type shall be selected from table 1A. Flagstones of nominal size or loading greater than specified in table 1A will require specific engineering design. Specific engineering design requirements need to be agreed between the specifier/designer and the producer. Testing regimes may be arranged between the producer and the product user.

Table 1 – Paver selection

Applications	Characteristic breaking load (1) (kN) per 100 mm width	Minimum thickness (2) (mm)	Shape (3)	Dimensional tolerances (4)	Edge detail (5)	Abrasion resistance (6) at 56 days mean	Minimum slip resistance classification (8)
Relevant AS/NZS	**4456.5**	**–**	**–**	**4455/4456.3**	**–**	**4456.9**	**4586**
1 **Residential**							
Pedestrian	3.0	40	Any	DPB1	SQ/SC/R/CH	Not required	W
2 **Residential driveways**							
Light Traffic	5.0	50	Any	DPB2	CH/R	Not required	W
Medium Traffic	Follow provisions of application 4 Roads: Minor						
3 **Public footpaths**							
Low Impact	5.0	50	Any	DPB2	SQ/SC/CH	6.0	W
High Impact	5.0	50	Any	DPB2	SQ/SC	3.5	W
4 **Roads**							
Minor	6.0	60	Rr/Dd	DPB2	CH	Not required	W
Local	12.0	80	Rr/Dd	DPB2	CH	Not required	W
Main	12.0	80	Rr/Dd	DPB2	CH	Not required	W
5 **Industrial pavements**	Specific engineering design (7)	80	Rr/Dd	DPB3	CH	See Note (7)	W

NOTES to table 1

(1) The characteristic breaking load to AS/NZS 4456.5, as amended by clause 202(b), is carried out on a 150 mm actual paver width in mm. The figures quoted are based on a 100 mm width, i.e. actual breaking load x the ratio of 100 mm divided by the actual paver width mm. The modulus of rupture value of any

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NOTES to table 1 (continued)

paver shall not be less than 4 MPa. Where pavers may be subject to chemical/environmental exposure e.g., marine, swimming pools, thermal pools etc. it is recommended that they be subjected to the resistance test contained in AS/NZS 4456.10 to demonstrate an acceptable performance at 50 cycles of test.

(2) In application 3 where pedestrian areas may be subject to service vehicles, a 60 mm SC paver is recommended.

(3) The principal shapes are:
(a) Rectangular 2:1 ratio (Rr);
(b) Rectangular 2:1 ratio (Dd) but dentated for additional interlock;
(c) Approximately square, see 304.1 for laying patterns.

(4) DPB is fully defined in AS/NZS 4455 and relates to dimensions (D) of paver (P) and specifies a method of measurement (B) with a tolerance (1 or 2). The method of measurement is contained in AS/NZS 4456.3.

(5) Definitions:

SQ – square edge
SC – shallow chamfer no deeper than 2 mm and no wider than 7 mm.
R – rumbled
CH – chamfer no deeper than 4 mm in depth and no wider than 7 mm.

(6) The abrasion index figures quoted are values established as criteria for satisfactory performance of pavers going into service at an age of 56 days in areas subjected to pedestrian impact traffic. Typical abrasion test index values at 28 days rather than 56 days are 7 and 4 respectively. Where abrasion resistance is required, the drawings, specification, and/or purchase order for the pavers should specify the abrasion resistance value to be achieved.

(7) Industrial pavers may be required to have special strength requirements. Specific engineering design requirements need to be agreed between the specifier/designer and the producer. These may require a specified abrasion index. Alternative testing regimes may be arranged between the producer and the product user.

(8) Products with minimum slip resistance classification W when tested in accordance with AS/NZS 4586 and used in accordance with SAA HB 197 and AS/NZS 3661.2 provide an Alternative Solution for the Compliance Document for NZBC Clause D1.

Table 1A – Flagstone selection

Pavement applications	Characteristic breaking load kN per 100 mm width (1)	Nominal size (mm)	Minimum thickness (mm)	Dimensional tolerance (2)	Flatness tolerance (mm)	Edge detail (3)	Abrasion resistance at 56 days (mean) (4)	Minimum slip resistance (5)
Relevant AS/NZS	**4456.5**	**–**	**–**	**4455/4456.3**	**4456.19**	**–**	**4456.9**	**4586**
1 **Residential pedestrian**	2.6	600x600	40	DPB1	2.5	SQ/SC/CH	Not required	W
		500x500	40		2.2			W
		450x450	40		2.0			W
		400x400	40		1.5			W
		300x300	40		1.0			W
2 **Residential driveways** Light Traffic	3.8	300x300	60	DPB2	1.0	CH	Not required	W
3 **Public footpaths**	3.8	450x450	60	DPB2	2.0	SQ/SC/CH	Low impact 6.0	W
Low Impact		400x400	60		1.5		or	W
High Impact		300x300	60		1.0		High impact 3.5	W

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NOTES to table 1A

(1) Breaking loads are characteristic on a 250 mm span by 100 mm nominal width. For large sizes, specimens may be cut, tested, and compared with the results above.

(2) DPB is fully defined in AS/NZS 4455 and relates to dimensions (D) of paver (P) and specifies a method of measurement (B) with a tolerance (1 or 2). The method of measurement is contained in AS/NZS 4456.3.

(3) Definitions:

SQ – square edge
SC – shallow chamfer no deeper than 2 mm and no wider than 7 mm.
CH – chamfer no deeper than 4 mm in depth and no wider than 7 mm.

(4) The abrasion index figures quoted are values established as criteria for satisfactory performance of flagstones going into service at an age of 56 days in areas subjected to pedestrian impact traffic. Typical abrasion test index values at 28 days rather than 56 days are 7 and 4 respectively. Where abrasion resistance is required, the drawings, specification, and/or purchase order for the pavers should specify the abrasion resistance value to be achieved.

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(5) Products with minimum slip resistance classification W when tested in accordance with AS/NZS 4586:2004 and used in accordance with SAA HB 197 and AS/NZS 3661.2 provide an Alternative Solution for the Compliance Document for NZBC Clause D1.

302.1 Colour

Colour shall be by mutual agreement between the manufacturer and purchaser.

C302.1

Changes in colour may be evident over a period of time due to natural occurrences such as drying and efflorescence. Other matters affecting colour relate to batch production and curing.

303 PAVEMENT THICKNESS DESIGN

303.1

The structure of the pavement shall be designed in accordance with recognised pavement design practice, using a pavement thickness appropriate to the subgrade strength and traffic loading.

303.2

For small projects basecourse may be determined from table 2; other applications may warrant specific design. Subgrade strength classifications in table 2 are as follows:

Classification	Typical materials	Minimum CBR*
Weak	Clay and silt	4
Medium	Silty or 'clayey' gravel or sand	7
Strong	Dense sand or gravel or old pavement	15

* California Bearing Ratio (Soaked) in accordance with section 6.1 of NZS 4402.

Table 2 – Basecourse thickness in mm (1)

Loading condition	Subgrade classification		
	Weak Minimum CBR 4	Medium Minimum CBR 7	Strong Minimum CBR 15
Residential pedestrian	50	25	Nil (2)
Residential driveway			
Light Traffic	100	75	50
Medium Traffic	180	125	75
Public footpath (2)			
Low Impact	75	50	Nil (3)
High Impact	75	50	Nil (3)
Roads			
Minor	180	100	75
Local	200	150	100
Main	Specific Engineering Design		
Industrial paving	Specific Engineering Design		

NOTES to table 2:

(1) The nominated basecourse thicknesses are based on strict application of sound construction practices which comply with 308.

(2) Where public footpaths/malls may be subject to access from public and private service vehicles the basecourse thickness shall be determined by specific engineering design.

(3) The sub-grade tolerances shall comply with 307.2.

C303.2

For small jobs, the following subgrade assessment tests may be sufficient. Weather conditions can however significantly influence the test. Generally the test should be carried out under damp or wet conditions:

(a) Weak – walking leaves a strong foot imprint;

(b) Medium – heel pressure leaves an imprint;

(c) Strong – no imprints.

304 LAYING PATTERNS

304.1

The shape of pavers and flagstones and their laying patterns shall be suitable for the loading classification. For applications 4, 5, and medium traffic application 2 as given in table 1 the laying pattern shall be herringbone preferably laid at 45° to the traffic flow. Any of the three basic patterns illustrated in figure 2 may be used for applications 1, 3 and light traffic application 2 unless specified otherwise.

NOTE – Stretcher pattern is the application for square flagstones.

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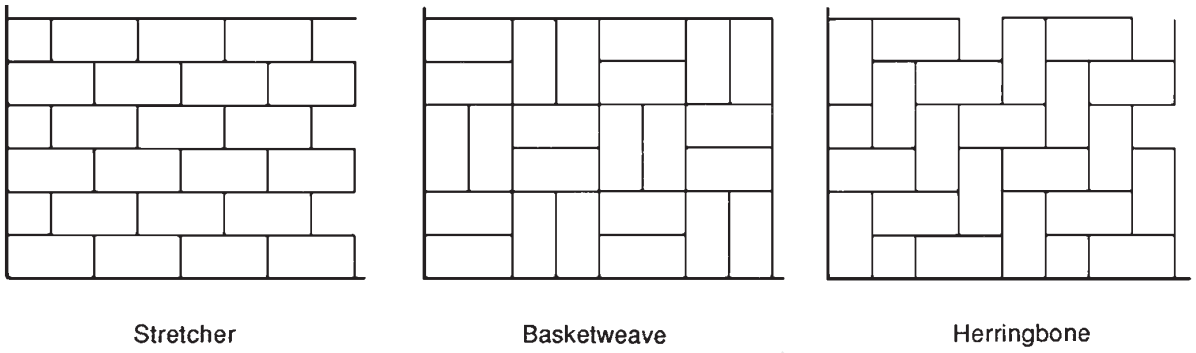
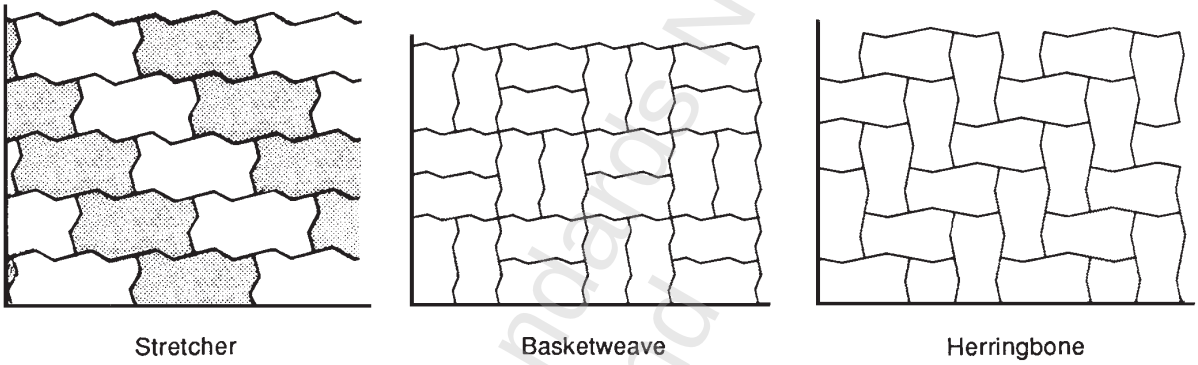
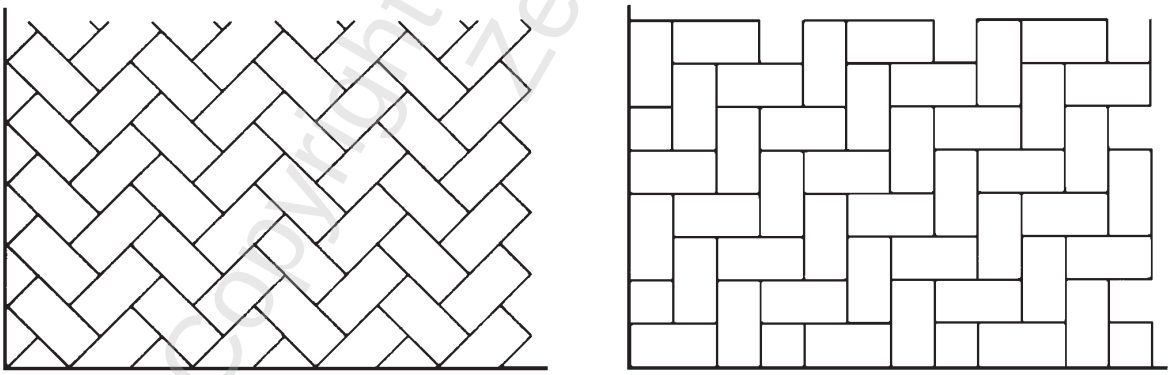


(a) Block laying patterns (plain blocks)



(b) Block laying patterns (dentated blocks)



(c) Use of herringbone pattern of laying (45° and 90°)

Figure 2 – Paver and flagstone laying patterns

NOTE – The possible laying patterns are a function of the shape of the paver/flagstone. Most rectangular pavers and flagstones can be laid in any of the three basic patterns – herringbone, stretcher, and basketweave (or parquet). The herringbone pattern is the most satisfactory as it resists movements of the pavers and flagstones in both plan directions. A herringbone pattern laid at 45° to the traffic direction has been found to be most successful in resisting loads, including braking forces in heavy industrial applications. Square flagstones are laid as stretcher pattern.

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305 DRAINAGE

305.1 Surface grades

The following minimum surface grades shall be provided unless specified otherwise:

(a) Roads – 3 % cross fall;

(b) Other paved areas – $2^1/_2$ % cross fall except that in non-vehicular areas a lesser grade may be appropriate provided the aspects of drainage have been addressed;

The maximum surface grade shall be 2 % for all access routes as defined in the Acceptable Solution D1/AS1 of the Compliance Document for NZBC clause D1.

C305.1

Careful construction using the precompacted sand method (309.3.2) is advised on all slopes required at 2 % grade in order to avoid the ponding of water.

305.2 Drainage channels

Side channels, gully drains and central drain channels shall be provided as required for the removal of surface water. The form of these drainage channels shall meet the requirements of the territorial authority or other road controlling authority.

C305.2

Where central drains are required in large areas, these can often form the edge restraints required by 306.2.

305.3 Pavement structure drainage

The pavement structure shall be designed so that drainage of the pavement layers is provided by adequate material permeability and internal flow gradients. Pavement layers shall either discharge to a feather edge, or to pavement drains. Pavement drains shall be located so that internal flow paths are not longer than 5 m. They shall also be located at all low points in large paved areas.

C305.3

(1) Pavement structure drainage needs careful consideration because segmental paving is subject to high infiltration for the first few months after laying. If adequate drainage is not provided, the resulting saturation of the basecourse and subgrade will lead to a reduction of support strength and possibly pavement distress. The rate of infiltration gradually falls off with time, as the joints between the pavers tend to become sealed. Pavements with larger crossfalls will have better internal drainage than those with lower crossfalls, and therefore pavement structure drainage should be a consideration when deciding on surface grades.

(2) Methods for construction of subsoil drains are given in TNZ F/2 and TNZ F/6.

306 KERBS AND EDGE RESTRAINTS

306.1

Edge restraint shall be provided at the perimeter of the paved area to confine the pavers and flagstones. Kerbs and edge restraints shall extend at least 50 mm below the bedding sand, and other details shall meet the requirements of the territorial authority.

C306.1

Edge restraint may be in the form of a kerb, kerb and channel, edge having mortar bedded solid course or existing foundation structure.

306.2
When the slope of the pavement exceeds 1 in 8, intermediate edge restraints shall be provided at a maximum spacing of 30 m and finished at pavement surface level.

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C306.2
Edge restraint is necessary to prevent the outward migration of pavers and flagstones, resulting in the opening of joints and loss of interlock.

307 SUBGRADE PREPARATION

307.1 General
The subgrade shall be shaped and trimmed to the specified profile and levels and compacted to provide uniform support for the pavement. The compacted subgrade shall be checked for strength and uniformity and any weak areas excavated and replaced with suitable material.

C307.1
Compaction of the subgrade is desirable to minimise future settlement under traffic loading and to improve the shear strength of the soil. All subgrades should be given at least a light rolling, with more compaction for the heavier loadings. It is important that the subgrade be uniform in strength otherwise uneven settlement may occur leading to possible ponding or uneven riding. Methods of subgrade preparation, compaction, stabilisation, and testing are outlined in the Austroads Guide to Pavement Technology Part 4D Stabilised Materials.

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Geotextiles can also offer worthwhile benefits when placed over weak subgrades.

307.2 Tolerances

307.2.1
Subject to 307.2.2 the tolerances for surface finish for the subgrade shall be +0, –20 mm for level at a point and 15 mm departure from a 3 m straightedge or template in any direction. In addition the subgrade shall not pond water.

307.2.2
Where the bedding layer is to be laid directly on the subgrade, the requirements of 308.3 shall apply to the subgrade instead of those of 307.2.1.

308 BASECOURSE

308.1 Material
The basecourse, and sub-base where used, shall consist of graded granular material with hard durable particles free from organic material, or equivalent stabilised material.

C308.1
The principles of selection of material suitable for a basecourse are given in TNZ M/3 Notes. The lower part of the basecourse may need to act as a transition layer between a clay subgrade and the granular basecourse to prevent intrusion of clay. Alternatives to a transition layer include stabilisation of the subgrade and use of a geotextile.

308.2 Compaction

The basecourse, and sub-base where used, shall be constructed in layers not exceeding 150 mm compacted thickness. Each layer shall be compacted to a uniform dense condition especially at manholes, kerbs and edge restraints.

C308.2

For heavier traffic loadings, basecourse construction should be in accordance with TNZ B/2. Particular attention is necessary to the compaction and surface texture of the material to prevent migration of the bedding sand.

308.3 Tolerances

The tolerances for surface finish for the basecourse, and sub-base where used, shall be ±10 mm for level at a point, and 8 mm departure from a 3 m straightedge or template in any direction. In addition the surface shall not pond water.

309 BEDDING COURSE

309.1 Bedding sand

309.1.1 *Material*

Sand selected and graded according to use as given in tables 3 and 4 shall be used subject to the material properties of 309.1.2 being met.

Table 3 – Paving application

Sand category	Application
I	Industrial pavements and road pavements where severe channelling of heavy wheel loads will occur, e.g. straddle cranes, bus lanes etc.
II	Industrial pavements and roads.
III	Residential, residential driveways, public footpaths.

Table 4 – Grading limits for bedding sand

BS sieve size	Percentage by mass passing		
	Sand category I	Sand category II	Sand category III
5.00 mm	90 to 100	89 to 100	89 to 100
2.36 mm	75 to 100	65 to 100	65 to 100
1.18 mm	55 to 90	45 to 100	45 to 100
600 μm	35 to 65	25 to 80	25 to 80
300 μm	10 to 45	5 to 48	5 to 48
150 μm	0 to 10	0 to 15	0 to 15
75 μm	0 to 1.5	0 to 3	0 to 5 (1)

NOTE –

(1) For residential pedestrian applications a 0 – 10 % range can be used.

309.1.2 *Sand properties*

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(a) Sand shall be permeable after compaction with the clay index of the fraction of sand passing the 75μm sieve not greater than 3 when the sand is tested according to NZS 4407.3.5.

(b) Where the aesthetic appearance of the pavement is important, the sand shall be free of deleterious salts or other contaminants.

(c) Manufactured sands or sands containing more than 2.5 % of lightweight particles as determined by NZS 3111, which require a designation of sand category I or II as specified in 309.1.1 shall be subjected to an abrading stability test as specified in Appendix A (normative). The sand shall meet the criteria set out in A4.1

(d) Bedding sand shall not have a chloride content in excess of 0.05 % by its mass where aesthetics of finished paving are of importance.

309.2 Storage

Bedding sand shall be stored in such a manner that it can be reclaimed without contamination. The storage area shall be free draining and the sand shall be protected against the rain when stockpiled, so that the water content is uniform.

309.3 Laying the bedding sand

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309.3.1 *Method 1 Sand surcharge (applicable to segmental pavers only)*

309.3.1.1

Bedding sand shall be laid loose with the aid of screeds over the prepared sub-base or subgrade to a depth, dependent on the grading characteristics of the sand and its water content, that will give a nominal compacted thickness of 30 mm. The surcharge required shall be checked by initial compaction of the first few metres of paving and checking the surface levels so obtained. If the levels are not correct, the pavers shall be lifted and the sand raked and rescreeded at an adjusted surcharge. The required surcharge shall continue to be checked throughout the paving. Temporary screed boards shall be used where screed widths exceed 5 m.

C309.3.1.1

The bedding sand on which the pavers are laid must have a uniform density and thickness so that settlement under compaction is even. The loose layer will generally be 5 to 15 mm thicker than the required compacted thickness. The loose density of sand in a damp condition is reasonably stable over a range of water contents but for sand approaching the dry condition or the saturated condition, loose density is very sensitive to water content change.

309.3.1.2

During laying, the bedding sand in each area of paving shall be at a uniform water content. The sand shall be protected against any form of compaction or passage of traffic until the pavers are laid and have been given initial compaction. Any sand accidentally compacted shall be raked and rescreeded in a loose condition.

309.3.1.3

A minimum extent only of bedding sand shall be placed ahead of the paver laying to avoid compaction problems and under no circumstances shall bedding sand be placed so that it cannot be covered with paving on the same day.

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309.3.2 *Method 2 Sand precompaction (applicable to segmental pavers and flagstones)*
The sand bedding shall be spread and fully compacted by several passes of a motorised vibratory compactor. The top surface of the fully compacted sand shall then be screeded back to a compacted thickness of 15 mm – 25 mm. Any depressions exceeding 5 mm shall be overfilled with sand and recompacted and the area then rescreeded. Upon completing these screeding operations a 5 mm layer of uniformly loose sand shall be screeded or loosely scattered on top of the precompacted sand bed.

C309.3.2
For flagstones over 500 mm with sloping sides refer to manufacturers' recommendations, which may include cement stabilising the bedding sand.

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309.4 Weed control
In pedestrian and light traffic areas, weed control treatments to prevent weed growth shall be considered.

310 SURFACE COURSE

310.1 Layout

310.1.1
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Pavers and flagstones shall be laid together to the specified pattern on the screeded bedding layer.

C310.1.1
It is recommended that squareness, straightness and level should be checked at not more than 5 m centres as laying proceeds.

310.1.2
Joint widths between pavers and flagstones shall be within the range 2 – 4 mm when using jointing sand. Flagstones in pedestrian applications where the joints are to be grouted shall be spaced within the range of 5 – 10 mm.

Where pavers with raised spacer nibs are used, the above joint widths shall apply to the portions of pavers that are not raised.

C310.1.2
Grouted joints should be restricted to pedestrian applications. Grouted joints are not suitable for areas that have any vehicular traffic because relative movement between the flagstones may cause the grout to fail.

Raised spacer nibs ensure an adequate minimum joint width for jointing sand penetration, which in turn inhibits paver spalling and encourages lock-up. It is acceptable for the raised spacer nibs to touch the adjacent pavers after laying.

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310.2 Placing sequence and infills

310.2.1
All full units shall be laid first then closures to perimeter areas and around drainage and other structures filled subsequently with part pavers or flagstones having plan dimensions in two perpendicular directions not less than 50 mm, or when using saw cutting methods, the minimum dimension can be reduced to 30 mm.

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C310.2.1
To ensure that the minimum dimension of any paver or flagstone is not less than 30 mm, the person laying the units should adjust the laying pattern within the tolerance set out in 310.1.2.

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310.2.2
Where there are slopes, laying shall proceed uphill.

310.3 Surface variation
The maximum surface variation between any two adjacent pavers or flagstones when laid shall not exceed 2 mm.

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310.4 Laying and initial compaction of pavers where bedding sand is laid to method 1, 309.3.1.

310.4.1
The compactor used for initial compaction of the paving shall be a mechanical flat plate vibrator having characteristics as follows:

Segmental pavement usage	Minimum plate compaction characteristics
Pedestrian only areas Private driveways	Standard plate compactor(s): 60 – 120 kg static weight 10 – 24 kN centrifugal force
All other uses, especially: Pedestrian areas subject to heavy vehicles; Industrial collector streets; Industrial areas; Residential collector streets.	Heavy duty plate compactor(s) 300 – 600 kg static weight 30 – 65 kN centrifugal force

NOTE –
(1) The purpose of vibratory compaction on the newly laid pavers is to compact the damp bedding sand for shear strength so that it will not further compact under heavy traffic when fully saturated, to eliminate "lipping" of adjacent pavers, and to force bedding sand particles into the bottom of the joints between pavers to encourage "lock-up". Compaction reduces the likelihood of loss of pavement shape, hence it is particularly important on flatter pavements.
(2) The use of heavy duty plate compaction is recommended for all pavements that will be exposed to trucks or other heavy vehicles. It is also recommended for all pavements where the bedding sand has been laid by the sand precompaction method of 309.3.2.
(3) Static weight and centrifugal force is used as a quick reference means of defining vibratory compactors. It is recognised that centrifugal force is not a technically correct means of defining compactability.

310.4.2
The pavers shall be settled into the bedding layer and the bedding compacted by not less than two passes of the plate compactor, at right angles to each other. Compaction shall follow as closely as possible after laying but shall not come within 1 m of the laying face.

C310.4.2
An alternative to heavy duty plate compactors is to give at least 2 passes of a standard plate compactor over the pavers, followed by 2 to 6 passes of a vibrating roller or pneumatic-tyred roller. The roller passes should be after construction of the jointing sand. To limit the risk of damage to the pavers yet still provide compaction, suitable rollers would include 7 to 14 tonne pneumatic-tyred rollers, or vibratory rollers with rubber coated drums, or ride-on vibratory rollers of both static weight less than 4 tonnes and nominal amplitude less than 0.6 mm.

It is important that the bedding sand is compacted as soon as practicable after paver laying to avoid migration of sand in the loose condition due to the displacement of the poorly supported pavers, or the ingress of water.

310.4.3
Where possible all paving using the sand surcharge method of laying shall be left compacted at the completion of each day's laying to within 1 m of the laying face.

310.4.4
All pavers damaged during compaction shall be removed, replaced with sound pavers and recompacted.

310.4.5
Pedestrian traffic may use the paving after initial compaction but heavier loads shall not be applied until the joints have been filled.

310.5 Laying of pavers and flagstones where bedding sand is laid to method 2, 309.3.2
The pavers and flagstones shall be bedded into the loose top surface of the bedding sand.

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C310.5
Flagstones may be positioned and levelled using a rubber mallet.

311 JOINT FILLING

311.1 Joint sand

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311.1.1
The sand used for filling joints between pavers and flagstones shall be graded within the limits given in table 5 and shall comply with 6.1 and 7.1 of NZS 3103.

Table 5 – Grading limits for joint sand

Sieve size	Roads and Industrial Pavements Per cent passing	Other Per cent passing
2.36 mm	100	100
1.18 mm	75 – 90	75 – 100
600 μm	55 – 80	55 – 100
300 μm	20 – 40	15 – 60
150 μm	5 – 15	3 – 30
75 μm	0 – 5	0 – 5

311.1.2
Joint sand shall be free of all soluble deleterious salts and other contaminants. The clay index of the fraction of sand passing the 75μm sieve shall not be greater than 3 when the sand is tested according to NZS 4407.3.5. The sand shall have not more than 2.5 % by weight of lightweight particles as determined by NZS 3111, section 9. Joint sand shall not have a water soluble chloride content in excess of 0.05 % by its mass where aesthetics of the finished paving are of importance.

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C311.1.2
It should be noted that:

(1) For lightly trafficked pavements a more uniformly graded (near single sized) sand can be used.

(2) Soluble salts can contribute to efflorescence.

(3) For pavements on steep slopes a well-graded jointing sand will resist water-induced scour better than a near single-sized sand.

311.1.3
At the time of joint filling, the sand shall be dry enough to be free running.

C311.1.3
Kiln dried sand is preferred to ensure good initial joint filling.

311.2 Placing joint sand

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311.2.1 *For pavers only*
As soon as practicable after the initial compaction of the pavers and infilling of closures, all jointing sand shall be swept across the pavers and introduced into the joints by further passes of a compactor. Joints shall be completely filled with dense sand. For pavements to be trafficked by heavy vehicles, the pavement shall be further compacted by rolling with a smooth wheeled 7 – 14 tonne roller.

C311.2.1
(1) Once joints are filled it is very difficult to adjust the pavement profile. Final joint filling cannot be completed until all closures (including cast in situ concrete and mortar closures) to kerbs and other boundaries have been completed. If construction traffic must use the pavement before closures have been completed, then joint filling short of the closures but significantly beyond the wheel tracks may be used.

(2) Traffic is beneficial to the development of the interlocking strength of the segmental paving as the flexing action densifies the joint filling to an extent which is not possible by vibration. The best performing pavements will be obtained from areas which have been alternatively used by traffic and resanded and revibrated to ensure a regular even surface and densely filled joints.

311.2.2 *For flagstones only*
As soon as practicable after the initial compaction of the flagstones and infilling of closures, all jointing sand shall be swept across the flagstones and introduced into the joints. Joints shall be completely filled with dense sand.

311.2.3
Surface stabilisers shall not be applied until the sand joint has achieved full mechanical lock-up.

C311.2.3
Traffic use increases mechanical lock-up.

311.2.4
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Joints shall be inspected between 1 and 3 days after sanding and after trafficking, and resanded and/or revibrated as necessary. Reinspection and topping up shall continue at intervals between 1 and 2 weeks until two such inspections show no loss or settlement of joint sand.

311.2.5
Excess sand shall be removed from the pavement following the final inspection.

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311.3 Mortar
Mortar for grouted joints shall comply with mortar requirements of NZS 4210.

312 FINAL SURFACE TOLERANCES

312.1
The final surface of the paving shall be within ±10 mm of the design level provided that the surface level is at least 5 mm above drainage channels or gully entries and continuously graded towards them. The surface shall not pond water. The deviation from a 3 m straightedge or template shall not exceed 8 mm and the difference in level between adjacent pavers or flagstones shall not exceed 2 mm.

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C312.1
For pedestrian areas, surface levels of the paving adjacent to any fittings or edges may require tighter tolerances.

313 SURFACE COATINGS AND MAINTENANCE

313.1 Surface coatings
Surface coatings if applied shall not reduce the slip resistance in wet conditions to a classification lower than W in AS/NZS 4586.

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C313.1
Coatings are useful to reduce surface staining, enhance colour and reduce the loss of joint sand through cleaning processes.

313.2 Maintenance
The surface of the paving shall be periodically inspected by the owner for loss of joint sand. Any sand lost shall be replaced and vibrated into the joints.

C313.2
Failure to replace sand can lead to premature pavement failure.

The surface of the paving may need regular cleaning and surface treatment to retain a slip resistance classification of W or better. AS/NZS 3661.2 outlines care and maintenance methods. Manufacturers of pavers and flags should be consulted so that they can advise pavement designers and owners of appropriate maintenance regimes.

Some paving materials polish under foot traffic, reducing their slip resistance. Others abrade, which initially improves slip resistance but may with time attract dirt and biological growth that makes the surface slippery.

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APPENDIX A
METHOD FOR THE DETERMINATION OF ABRADING STABILITY

(Normative)

A1 Scope

This appendix sets out the test procedure for the evaluation of tendency for sand particles to abrade.

A2 Apparatus

A2.1

Apparatus for determining particle size distribution shall follow the requirements of NZS 4407, test 3.8.2.

A2.2

Apparatus for applying the abrading forces to a sand sample shall consist of the following:

(a) Glass or ceramic jar with screw lid, internal diameter 120 ± 2 mm and length 150 mm ± 2 mm or nominal 1 litre jar with an internal diameter to length ratio not exceeding 1.66;

(b) Apparatus for rotating the jar horizontally at 50 ± 2 revolutions per minute, see figure 3; and

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(c) Two 25 mm steel balls each weighing 75 ± 5 grams each.

A3 Procedure

A3.1

Two specimen samples shall be taken from a single dried sand sample.

A3.2

One specimen sample shall be tested to determine the particle size distribution as specified by NZS 4407, Test 3.8.2.

A3.3

The second sample shall be tested for abrading resistance by:

(a) Reducing the second sample in size to 600 ± 20 grams and subdivided into 3 equal samples;

(b) Placing each sample in the glass or ceramic jar together with the two steel balls;

(c) Rotating each sample for a period of 6 hours ±10 minutes at a speed of 50 ±2 revolutions per minute.

A3.4

After the completion of the abrading resistance test, each sample shall be tested to determine the particle size distribution as specified by NZS 4407, test 3.8.2. The average of the three tests shall be determined.

A4 Results

A4.1

The particle distribution analysis of specimen 1 shall be compared with specimen 2. Increases in the finer fractions give an indication of the sand's abrading resistance.

Where fineness restrictions set by table 4 are exceeded by the second specimen the sand can only be used for a lower classification of loading.

Where the percentage passing the 300 μm sieve changes by more than 10 %, the sand quality shall be regarded as poor and shall not be used in vehicular loading situations.

CA.4.1

It is advisable to consider the degree of degradation of a number of different sands in terms of making a decision on using a bedding sand. This is particularly important when considering sand category 1 where channelling traffic conditions will be prevalent.

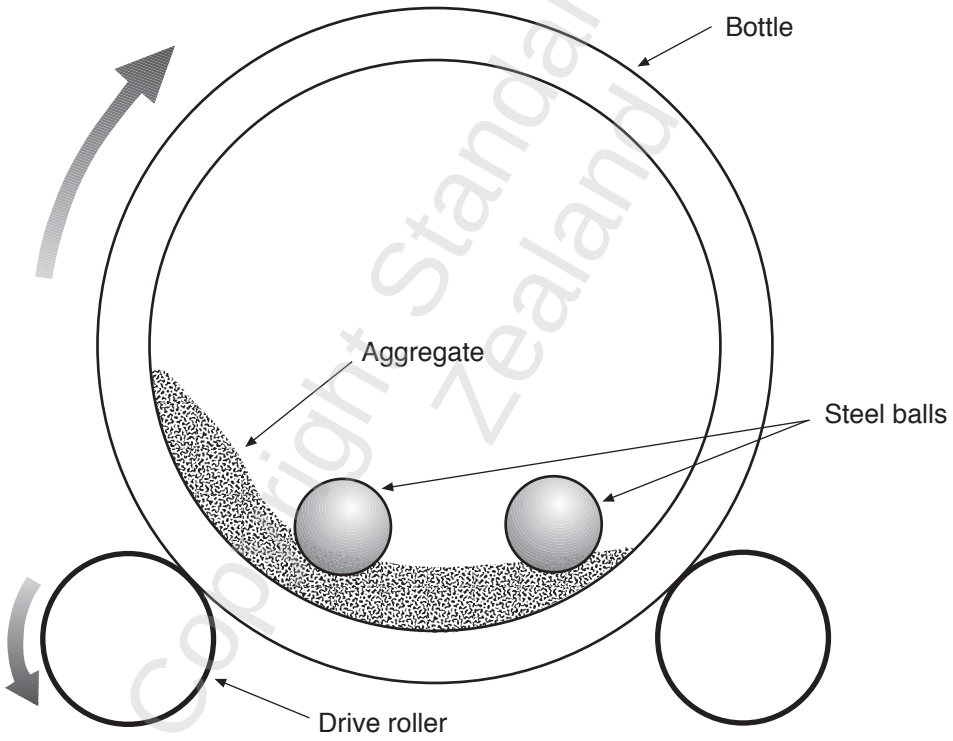

Figure 3 – Schematic view of bottle rolling apparatus

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