SPECIFICATIONS AND STANDARDS FOR CONCRETE PAVING BLOCKS

A WORLD-WIDE SURVEY BASED ON AN INQUIRY BY THE PROGRAMME COMMITTEE CBP

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SUMMARY
The paper is a compilation of the answers of 16 countries to a world-wide inquiry by the Programme Committee of the Second International Conference on Concrete Block Paving into specifications and standards for concrete paving blocks. The questions are dealing with mix design, sampling of blocks for production control tests, properties of the blocks and special blocks. After a brief review of the contributions given in the questionnaire, four specifications are discussed in more detail: sampling, dimensions, dimensional tolerances and strength of the concrete paving blocks.

1. INTRODUCTION

The Programme Committee of the Second International Conference on Concrete Block Paving has taken the initiative to set up a world-wide inquiry into specifications and standards for concrete paving blocks. The inquiry concerned the requirements regarding mix design, sampling of blocks for production control tests, properties of the blocks and special blocks. The objective of the inquiry was to get a better insight into the specifications and standards for concrete paving blocks in various countries and to find out how far they correspond or differ with each other. Furthermore, countries where concrete paving blocks are being introduced should get some guidelines and references for developing specifications and standards for this pavement material.
The questionnaire has been sent to Standards Institutions (members of the International Standardization Organisation ISO), Associations of Concrete Paving Block Manufacturers (members of Bureau International de Béton Manufacturé BIBM) and Quality Assurance Institutes in 46 countries. The questionnaire was returned by 16 countries and this paper is a compilation from their answers*.
In chapter 2 a review of the requirements for concrete paving blocks in the 16 countries will be presented. Next, in chapter 3 the sampling of concrete paving blocks for production control tests will be discussed. In chapter 4 the specifications and standards regarding the dimensions, the dimensional tolerances and the strength of the concrete paving blocks will be described in detail.

* The questionnaire from India is not included in this paper because the specifications and standards apply to four types of elements that should be marked as tiles instead of blocks. These elements are described in the paper 'Development of special purpose paving blocks in India', Central Road Research Institute (CRRI), New Delhi, India.

2. REVIEW OF REQUIREMENTS

The main results of the inquiry into specifications and standards for concrete paving blocks are summarized. It is shown for each of the 16 countries whether any specific requirement exists (x) or does not exist (-).

It appears that all countries have requirements regarding sampling of concrete paving blocks for production control tests, dimensions of the blocks, dimensional tolerances and strength of the blocks, therefore these requirements will be discussed in more detail in the next chapters. As only a part of the countries has requirements regarding the other aspects (mix design, other properties of the blocks and special blocks), no further attention will be paid to these aspects in this paper.

MAIN RESULTS OF THE INQUIRY INTO SPECIFICATIONS AND STANDARDS FOR CONCRETE PAVING BLOCKS

Questions \ Countries	Au	A	Be	Ca (d)	De	Fi	Fr	Ge	Is	It	Ja (d)	Ne	NZ	No	UK	USA
1. GENERAL																
Specification or Standard	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Status:																
- national	-	x	x	x	x	x	x	x	x	-	-	x	x	-	-	x
- regional	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- municipal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- association of users	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
- association of manufacturers	x	-	-	-	-	-	-	-	-	x	x	-	-	x	x	x
Other (additional) requirements	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quality assurance scheme (testing for quality assurance)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Manufacturers certification scheme	-	-	-	-	x	-	x	-	-	x	-	x	x	x	x	-
2. MIX DESIGN																
Requirements regarding:																
- coarse and fine aggregates (natural, artificial, waste materials)	-	x	-	x	-	-	x	x	x	x	x	-	x	x	x	x
- cement	x	-	-	x	x	-	x	x	x	x	x	-	x	x	x	x
- water	-	-	-	-	-	-	x	-	x	x	x	-	x	x	x	-
- admixtures (additives)	x	x	-	x	-	-	x	x	-	x	x	-	-	x	x	x
- pigments	x	-	-	x	-	-	-	-	x	x	x	x	x	-	x	x
- quantities (mix proportions, ratios)	-	-	-	-	-	-	-	-	x	x	-	-	-	-	x	-
3. SAMPLING																
Requirements regarding:																
- the method of sampling (one sample per day or per production unit)	x	-	x	x	x	x	x	-	x	x	x	x	x	x	x	x
- the size of the sample (number of sample units)	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
- the age of the blocks at the time of testing	-	x	-	x	x	x	x	x	x	x	x	x	x	x	-	x

MAIN RESULTS OF THE INQUIRY INTO SPECIFICATIONS AND STANDARDS FOR CONCRETE PAVING BLOCKS

(continued)

Questions \ Countries	Au	A	Be	Ca (d)	De	Fi	Fr	Ge	Is	It	Ja (d)	Ne	NZ	No	UK	USA
4. PROPERTIES OF THE BLOCKS																
Requirements regarding the uniformity of:																
- shape	x	x	x	-	-	-	x	x	x	x	-	x	x	x	x	x
- appearance	-	-	-	-	-	-	x	x	x	x	x	x	-	-	-	-
- texture	-	-	-	-	-	-	-	x	x	x	-	x	x	-	-	-
- colour	-	-	-	-	-	-	-	x	-	x	-	x	x	-	-	-
Dimensions of the blocks:																
- specified	x	x	x	x	-	-	x	x	x	x	-	-	x	x	x	x
- recommended	x	-	-	-	x	x	-	-	-	-	-	x	-	-	-	-
Requirements regarding:																
- the dimensional tolerances	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
- chamfer or radius	-	-	-	-	-	x	-	-	x	x	-	x	x	-	x	-
Requirements regarding blocks with special surface topping (e.g. thickness, bond and composition of surface topping)	-	-	-	-	x	-	-	x	x	x	-	x	-	-	x	-
Requirements regarding:																
- compressive strength	x	-	x	x	x	-	-	x	x	x	x	-	x	x	x	x
- flexural strength	-	-	-	-	-	x	-	-	-	-	-	x	-	-	-	-
- splitting strength	-	x	-	-	-	-	x	-	-	-	-	-	-	-	-	-
- skidding resistance	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
- abrasion resistance	-	x	x	-	-	-	x	-	x	x	-	-	-	-	-	x
- density	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
- water absorption	-	-	x	-	-	-	x	-	-	x	x	-	-	x	-	x
- frost resistance	-	x	-	x	-	x	-	x	-	-	-	-	-	x	-	x
- colour retention	-	-	-	x	-	-	-	-	-	x	-	-	-	-	-	-
5. SPECIAL BLOCKS																
The special blocks (with regard to laying pattern, e.g. bishop's hat and other edge blocks) have to comply with the above mentioned requirements	-	x	x	-	x	-	x	-	-	-	-	-	-	x	x	-

(d) = draft

Au = Australia
A = Austria
Be = Belgium
Ca = Canada
De = Denmark
Fi = Finland
Fr = France
Ge = Germany
Is = Israel
It = Italy
Ja = Japan
Ne = The Netherlands
NZ = New Zealand
No = Norway
UK = United Kingdom
USA = United States of America

3. SAMPLING

The requirements regarding sampling of concrete paving blocks for production control tests in the 16 countries are summarized in the following review.

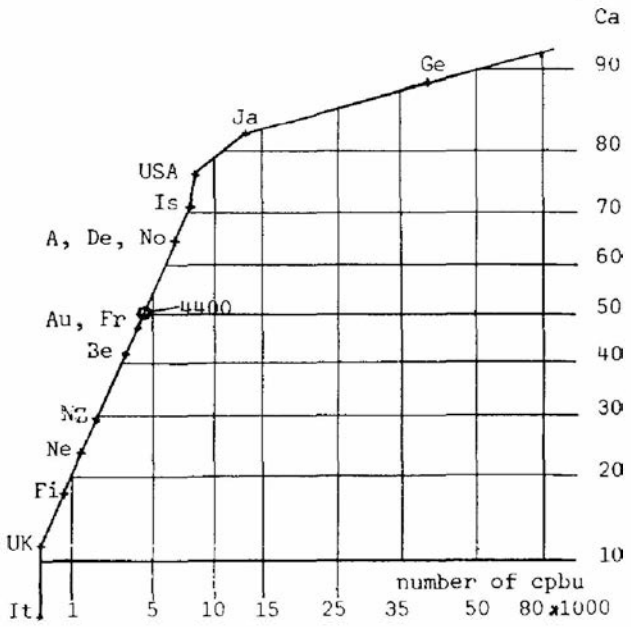
Australia (Au) (CMAA)	For the dimensions and strength determinations, 5 units shall be selected at random from each lot of 20,000 units.
Austria (A) (ÖNORM B 3258)	For the dimensions, strength, abrasion resistance and frost-thaw salt resistance determinations, 6 units shall be selected from a lot (number of units per lot not specified).
Belgium (Be) (NBN B21-311)	For the dimensions, water absorption, abrasion resistance and strength determinations, 8 units (and 16 additional units) shall be selected at random per 2,000 m^2. The 16 additional units are tested only if the 8 original units do not comply with any requirement.
Canada (Ca) (draft)	For the dimensions, strength and frost resistance determinations, 10 units shall be selected at random per 20,000 m^2.
Denmark (De) (DS/R 400.2)	For the dimensions, water absorption and strength determinations, 2 units (and 4 additional units) shall be selected at random from a lot (number of units per lot not specified). The 4 additional units are tested only if 1 of the 2 original units does not comply with any requirement; this additional testing must be done on the specific failing property/ properties.
Finland (Fi) (N:O 14 1981)	For the dimensions, strength and frost resistance determinations, 6 units shall be selected at random from each lot of 5,000 units.
France (Fr) (NF P 98-303)	For the dimensions and strength determinations, 1 unit shall be selected at random per 4,000 units; for the water absorption determinations, 3 units a week shall be selected at random; for the abrasion resistance determinations, 1 unit a year shall be selected at random.
Germany (Ge) (DIN 18 501)	For the dimensions and strength determinations, at least 5 units per 5 days of production shall be selected.
Israel (Is) (IS 8-1979)	For the dimensions, strength and abrasion resistance determinations, 5 units shall be selected at random from a lot (number of units per lot not specified).
Italy (It) (Pavitalia)	For the dimensions, strength, abrasion resistance, density and water absorption determinations, 50 units shall be selected at random per 15,000 units.
Japan (Ja) (draft)	For the dimensions, strength and water absorption determinations, 3 units per day of production shall be selected at random.
The Netherlands (Ne) (NEN 7000)	For the dimensions, strength, skidding resistance and sand blast resistance determinations, 15 units (and 15 additional units) shall be selected at random from a lot (number of units per lot not specified). The 15 additional units are tested only if the 15 original units do not comply with any requirement; this additional testing must be done on the specific failing property/properties.
New Zealand (NZ) (NZS 3116:1981)	For the dimensions and strength determinations, 5 units shall be selected at random from each lot of not more than 10,000 units.
Norway (No) (NBVF 79)	See Denmark.
United Kingdom (UK) (CCA/CSS/Interpave)	For the dimensions and strength determinations, 16 units shall be selected at random from each lot of 5,000 units or fraction thereof.
USA (ASTM C 936-82)	For the strength, absorption and moisture content determinations, 6 units shall be selected at random from each lot of 50,000 units or fraction thereof. For lots of more than 10,000 and less than 50,000 units 6 additional units have to be selected.

Above mentioned requirements are not comparable. Assuming that one lot is equal to one day production of one machine (about 40,000 blocks) and supposing furthermore that in general 40 blocks cover 1 m^2, one can get a better idea of how many concrete paving blocks are represented by 1 unit of the sample.

Country		1 unit per ... units
Italy	(m)	300
United Kingdom	(m)	313
Finland		833
The Netherlands		1,333
New Zealand		2,000
Belgium		3,333
Australia	(m)	4,000
France		4,000
Denmark		6,667
Norway	(m)	6,667
Austria		6,667
Israel		8,000
United States	(m)	8,333
Japan	(m)	13,333
Germany		40,000
Canada		80,000

(m) = association of manufacturers.

As can be seen in the next figure the median number of concrete blocks, for which 1 unit of the sample is representative, is clearly 4,000 - 5,000. The conclusion is that in general 1 sample unit represents 109 m^2, or on the other hand that from one day production of one machine 9 blocks are sampled.



Special attention is drawn to the fact that manufacturers tend to more control tests than the national standards!

Compared with general practice in controlling asphalt in The Netherlands (2 cylinders per 2,000 m^2) a much more intensive control is carried out on concrete blocks. Even the least intensive control (1 per 80,000 blocks) is about equal to the mentioned quality control with asphalt.

It should be noticed that not only the number of blocks, for which 1 unit is representative, is different, but furthermore that there is a big difference in the procedure of acceptance or rejection in the various countries which makes a direct comparison rather complicated.

4. PROPERTIES OF THE BLOCKS

4.1 Dimensions

The specified or recommended dimensions of concrete paving blocks in the 16 countries are given in the following review.

Australia (Au) (CMAA)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: top surface max. 60,000 mm^2.
Austria (A) (ÖNORM B 3258)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: thickness to length ratio min. 0.25.
Belgium (Be) (NBN B21-311)	Specified dimensions for rectangular concrete paving blocks: length 220 mm, width 107 mm, thickness 80, 100 mm length 220 mm, width 130 mm, thickness 130 mm Specified dimensions for non-rectangular concrete paving blocks: top surface 18,000 - 50,000 mm^2 thickness 80, 100, 130 mm.
Canada (Ca) (draft)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: no dimensions greater than 250 mm.
Denmark (De) (DS/R 400.4.2)	Recommended dimensions, both for rectangular and non-rectangular concrete paving blocks: top surface max. 30,000 mm^2 thickness 60, 65, 70, 75, 80, 85, 90, 95, 100 mm.
Finland (Fi) (N:O 14 1981)	Recommended dimensions for rectangular concrete paving blocks: length 208 mm, width 68 mm, thickness 60, 80 mm length 195 mm, width 95 mm, thickness 60 mm 5 types of non-rectangular concrete paving blocks are recommended in N:O 14 1981; thickness 60-100 mm.
France (Fr) (NF P 98-303)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: thickness 60, 80, 100, 120, ... mm top surface (mm^2) to thickness (mm) ratio not greater than 1000.
Germany (Ge) (DIN 18 501)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: length max. 280 mm thickness 60, 80, 100, 120, 140 mm.
Israel (Is) (IS 8-1979)	Specified dimensions for rectangular concrete paving blocks: length 200 mm width 100 mm thickness 80, 100 mm Specified dimensions for hexagonal concrete paving blocks: side 125 mm thickness 80, 100 mm Specified dimensions for I-shaped concrete paving blocks: length 200 mm width 165/115 mm thickness 80, 100 mm
Italy (It) (Pavitalia)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: top surface 5,000 - 40,000 mm^2 excluding chamfer thickness 60-100 mm.
Japan (Ja) (draft)	No dimensions are specified or recommended.

The Netherlands (Ne) (NEN 7000)	Recommended dimensions for rectangular concrete paving blocks: length 213 mm width 105 mm thickness 70, 80, 90 mm.
New Zealand (NZ) (NZS 3116:1981)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: length max. 250 mm width min. 75 mm at any section thickness min. 60 mm mean length to mean width ratio not greater than 2.
Norway (No) (NBVF 79)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: top surface max. 30,000 mm^2 thickness 60, 80, 100 mm.
United Kingdom (UK) (CCA/CSS/Interpave)	Specified dimensions for rectangular concrete paving blocks: length 200 mm width 100 mm thickness 60, 80, 100 mm Specified dimensions for non-rectangular concrete paving blocks: length to width ratio 1.5 - 2.5 width 80 - 115 mm thickness 60, 80, 100 mm.
USA (ASTM C 936-82)	Specified dimensions, both for rectangular and non-rectangular concrete paving blocks: length max. 240 mm width max. 160 mm thickness max. 140 mm.

From this review it appears that some countries do specify or recommend all dimensions of the concrete paving blocks. In other countries, however, the top surface (and the thickness) are specified or recommended to cover both rectangular and non-rectangular concrete paving blocks.
With regard to the dimensions, a concrete paving block could be defined as a precast concrete element with:
- top surface between 5,000 mm^2 and 60,000 mm^2
- horizontal dimensions not greater than 280 mm
- mean length to mean width ratio between 1 and 3
- thickness between 60 mm and 140 mm.

4.2 Dimensional tolerances

The dimensional tolerances in the 16 countries are given in the following review.

Australia (Au) (CMAA)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 3 mm
Austria (A) (ÖNORM B 3258)	Permissible variation:	length : ± 3 mm width : ± 3 mm thickness : ± 4 mm
Belgium (Be) (NBN B21-311)	Permissible variation:	length : ± 3% of block thickness width : ± 3% of block thickness thickness : ± 5% of block thickness
Canada (Ca) (draft)	Permissible variation:	length : ± 1.6 mm width : ± 1.6 mm thickness : ± 3.2 mm

Denmark (De) (DS/R 400.4.2)	Permissible variation:	length : --- width : --- thickness : ± 3 mm
Finland (Fi) (N:O 14 1981)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 2 mm
France (Fr) (NF P 98-303)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 3 mm
Germany (Ge) (DIN 18 501)	Permissible variation:	length : ± 3 mm width : ± 3 mm thickness : ± 5 mm
	Bulging (at a side)	< 2 mm if block thickness ≤ 80 mm < 3 mm if block thickness > 80 mm
Israel (Is) (IS 8-1979)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : + 4 mm - 2 mm
Italy (It) (Pavitalia)	Permissible variation:	length : ± 3 mm width : ± 3 mm thickness : ± 3 mm
Japan (Ja) (draft)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 3 mm
The Netherlands (Ne) (NEN 7000)	Permissible mean variation:	length : ± 2 mm width : ± 2 mm thickness : ± 2 mm
	Permissible standard deviation:	length : ± 1.1 mm width : ± 1.1 mm thickness : ± 1.7 mm
New Zealand (NZ) (NZS 3116:1981)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 2 mm
Norway (No) (NBVF 79)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 3 mm or ± 2 mm (special cases)
United Kingdom (UK) (CCA/CSS/Interpave)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 3 mm
USA (ASTM C 936-82)	Permissible variation:	length : ± 2 mm width : ± 2 mm thickness : ± 3 mm Length and width related to approved samples. Thickness related to specified standard dimension.

In The Netherlands a dimensional tolerance is specified as a mean value together with a standard deviation of the permissible variation in dimensions, in all the other countries a dimensional tolerance is specified as a maximum permissible variation in dimensions.
The dimensional tolerance for the length and the width of concrete paving blocks varies from ± 1.6 mm to ± 3 mm, in the majority of countries the dimensional tolerance is ± 2 mm.

The dimensional tolerance for the thickness of concrete paving blocks varies from ± 2 mm to ± 5 mm, in the majority of countries the dimensional tolerance is ± 3 mm.
It should be noted that the dimensional tolerances in Austria, Belgium, Germany, Italy and The Netherlands are greater than the above - mentioned mean values.

4.3 Strength

In chapter 2 it appeared that 12 out of 16 countries are using the compressive strength as a production control test. France and Austria have accepted the splitting strength and 2 other countries, viz. Finland and The Netherlands, have adopted the flexural strength.
Below a summary is given of the way of testing in the 16 countries mentioned.

Australia (Au) (CMAA)

Storage of blocks prior to testing: not specified.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: not specified.
Test procedure: - packing sheets: 4 mm plywood or equivalent.
- rate of travel: 0.04 mm/s or constant rate of stress 0.15 - 0.70 N/mm^2 per second.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{maximum applied load (N)}}{\text{nett area of top surface, excluding chamfers } (mm^2)}$$

The characteristic compressive strength (5 specimens tested), defined as the mean value minus 0.43 times the sample range, shall be not less than 35 and 45 N/mm^2 for the grade designation 35 and 45 respectively.

Austria (A) (ÖNORM B 3258)

Storage of blocks prior to testing: not specified.
Strength requirement: splitting strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: at least 28 days.
Test procedure: described in ÖNORM B 3303.

$$\text{Splitting strength } (N/mm^2) = \frac{2}{\pi} \cdot \frac{\text{maximum applied load (N)}}{\text{block length (mm) times block thickness (mm)}}$$

The mean splitting strength (6 specimens tested) shall be not less than 5 N/mm^2.
No single value shall be less than 4 N/mm^2.

Belgium (Be) (NBN B21-311)

Storage of blocks prior to testing: 24 hrs at 105 ± 5°C.
Strength requirement: compressive strength.
Size and shape of the specimens: cube or cylinder.

block thickness (mm)	80	100	130
side of cube (mm)	70	90	100
diameter of cylinder (mm)	80	100	113
height of cylinder (mm)	70	90	100

Age of specimens at test: not specified.
Test procedure: - contact faces of specimens shall be polished.
- according to NBN B 15-220.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{maximum applied load (N)}}{\text{contact area of cube or cylinder } (mm^2)}$$

The mean compressive strength (3 specimens tested) shall be not less than 60 N/mm^2.
No single value shall be less than 50 N/mm^2.

Canada (Ca) (draft)

Storage of blocks prior to testing: not mentioned.
Strength requirement: compressive strength.
Size and shape of the specimens: cube.
Age of specimens at test: not specified (testing at time of delivery to the site).
Test procedure: not known.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{maximum applied load (N)}}{\text{contact area of cube } (mm^2)}$$

The mean compressive strength (5 specimens tested) shall be not less than 50 N/mm^2.
No single value shall be less than 45 N/mm^2.

Denmark (De)
(DS/R 400.2)

Storage of blocks prior to testing: stockpile equivalent.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: 28 days (ordinary Portland cement)
14 days (rapid-hardening Portland cement).
Test procedure:
- between two cylindrical steel plates, thickness 25 mm each, area 2500 mm^2 each.
- packing sheets: 12 mm wood fiber, density 250-300 kg/m^3.
- rate of stress: not greater than 2.5% of the required compressive strength per sec.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{maximum applied load (N)}}{2500\ (mm^2)}$$

No single value shall be less than 52, 49 or 46 N/mm^2 if the block thickness is 60, 80 or 100 mm respectively.

Finland (Fi)
(N:O 14 1981)

Storage of blocks prior to testing: not known.
Strength requirement: flexural strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: 7 days.
Test procedure:
- centre-point bending test.
- packing sheets: unknown.
- rate of stress: 0.5 ± 0.2 N/mm^2 per second.

$$\text{Flexural strength } (N/mm^2) = \tfrac{1}{4} \cdot \frac{\text{maximum applied load (N) times (block length-50 mm)}}{\text{modulus of section } (mm^3)}$$

The mean flexural strength (6 specimens tested) shall be not less than 5.0 N/mm^2.

France (Fr)
(Fiche Pratique
Lv 252)

Storage of blocks prior to testing: 6 hours in water at 20 ± 2°C.
Strength requirement: splitting strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: not specified.
Test procedure: rate of stress 0.05 ± 0.01 N/mm^2 per second.

$$\text{Splitting strength } (N/mm^2) = \frac{2}{\pi} \cdot \frac{\text{maximum applied load (N)}}{\text{block length (mm) times block thickness (mm)}}$$

The characteristic splitting strength (5% defective) shall be not less than 4 N/mm^2.
No single value shall be less than 3.2 N/mm^2.

Germany (Ge)
(DIN 18 501)

Storage of blocks prior to testing: not specified.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: not greater than 28 days.
Test procedure:
- contact faces of specimens shall be polished.
- between two rectangular steel plates, thickness 30 mm each with width equal to thickness of specimen, length equal to two times thickness of specimen; plates shall not be used when thickness of specimen is not less than 0.9 times nett width, excluding chamfer.
- rate of stress 0.5 N/mm^2 per second.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{maximum applied load (N)}}{\text{smallest contact area } (mm^2)}$$

The mean compressive strength (at least 5 specimens tested) shall be not less than 60 N/mm^2. No single value shall be less than 50 N/mm^2.

Israel (Is)
(IS 8-1979)

Storage of blocks prior to testing: not known.
Strength requirement: compressive strength.
Size and shape of the specimens: not known.
Age of specimens at test: 28 days.
Test procedure: not known.
The mean compressive strength (5 specimens tested) shall be not less than 50 N/mm^2.
No single value shall be less than 45 N/mm^2.

Italy (It)
(Pavitalia)

Storage of blocks prior to testing: stockpile equivalent.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: 28 days.
Test procedure:
- rate of stress 0.5 N/mm^2 per second.
- according to UNI 6132.

$$\text{Compressive strength } (N/mm^2) = K \cdot \frac{\text{maximum applied load (N)}}{\text{nett area of top surface, excluding chamfers } (mm^2)}$$

$$\text{where: } K = \frac{50}{\frac{13\sqrt{S}}{H} + 19.35}$$

where S = plan area, including chamfers (mm^2)
H = thickness (mm)

The mean compressive strength (8 specimens tested) shall be not less than 50 N/mm^2. No single value shall be less than 42 N/mm^2.

Japan (Ja)
(draft)

Storage of blocks prior to testing: indoor natural curing.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: 28 days.
Test procedure: contact faces of specimens shall be capped.
The mean compressive strength (3 specimens tested) shall be not less than 58.8 N/mm^2.

The Netherlands (Ne)
(NEN 7000)

Storage of blocks prior to testing: 48 hours in water at room temperature.
Strength requirement: flexural strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: at least 28 days.
Test procedure:
- centre-point bending test.
- packing sheets: cardboard, thickness 3 mm.
- rate of stress: 0.5 ± 0.02 N/mm^2 per second.

$$\text{Flexural strength } (N/mm^2) = \tfrac{1}{4} \cdot \frac{\text{maximum applied load (N) times 150 (mm)}}{\text{modulus of section } (mm^3)}$$

The characteristic flexural strength (15 specimens tested), defined as the mean value minus 1.65 times the standard deviation, shall be not less than 5.9 N/mm^2.

New Zealand (NZ)
(NZS 3116:1981)

Storage of blocks prior to testing: 24-48 hours in water at 21 ± 5°C.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: not specified.
Test procedure:
- packing sheets: 10 mm soft board.
- rate of stress: 0.17 - 0.33 N/mm^2 per second.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{maximum applied load (N)}}{\text{nett area of top surface, excluding chamfers } (mm^2)}$$

The characteristic compressive strength (5 specimens tested), defined as the mean value minus 0.35 times the sample range, shall be not less than 40 N/mm^2.

Norway (No)
(NBVF 79)

Storage of blocks prior to testing: 24 hours in water at 20 ± 2°C.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: 28 days.
Test procedure:
- between two cylindrical or square steel plates, area 2,500 mm^2 each.
- packing sheets: 9 mm wood fiber.
- rate of stress: not known.

$$\text{Compressive strength } (N/mm^2) = \frac{\text{maximum applied load (N)}}{2{,}500 \ (mm^2)}$$

No single value shall be less than 54, 51 or 48 N/mm^2 if the block thickness is 60, 80 or 100 mm respectively.

United Kingdom (UK)
(CCA/CSS/Interpave)

Storage of blocks prior to testing: at least 24 hours in water at 20 ± 5°C.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: not specified (testing at time of delivery to the site).
Testing procedure:
- packing sheets: 4 mm plywood.
- rate of stress: 0.25 N/mm^2 per second.

$$\text{Compressive strength} = C \cdot \frac{\text{maximum applied load (N)}}{\text{plan area, including chamfers (mm}^2\text{)}}$$

where C =

block thickness (mm)	plain block	chamfered block
60 or 65	1.00	1.06
80	1.12	1.18
100	1.18	1.24

The mean compressive strength (16 specimens tested) shall be not less than 49 N/mm^2. No single value shall be less than 40 N/mm^2.

USA
(ASTM C 936-1982)

Storage of blocks prior to testing: indoor natural curing.
Strength requirement: compressive strength.
Size and shape of the specimens: full-size block.
Age of specimens at test: not specified (testing at time of delivery to the site).
Test procedure:
- contact faces of specimens shall be capped.
- at a uniform rate of travel of the moving head, the latter 50% of the maximum load shall be reached in not less than 60 seconds nor more than 120 seconds.

$$\text{Compressive strength (N/mm}^2\text{)} = \frac{\text{maximum applied load (N)}}{\text{nett area of top surface, excluding chamfers (mm}^2\text{)}}$$

The mean compressive strength (number of specimens tested: one half of the sample) shall be not less than 55 N/mm^2. No single value shall be less than 50 N/mm^2.

Addition:
Strength requirements according to the National Concrete Masonry Association (NCMA):
. Freeze-thaw regions:
the mean compressive strength (number of specimens tested: 5/6 of the sample) shall be not less than 55 N/mm^2. No single value shall be less than 50 N/mm^2.
. Non-freeze-thaw regions:
the mean compressive strength (number of specimens tested: 5/6 of the sample) shall be not less than 42 N/mm^2. No single value shall be less than 38 N/mm^2.

This survey shows that in 7 out of 12 countries using the compressive strength, the load is applied at the full-size block. Denmark and Norway are using the full-size block for testing, but the load is applied at only 2500 mm^2 of the specimen. Finally Belgium and Canada are preparing a specimen (cube or cylinder) out of the concrete block to estimate the compressive strength. Regarding Israel the size and the shape of the specimen is not known, because the specification is written in Hebrew. It is not easy to make a comparison between the admissible strength in the several countries as there are many differences in the way of testing. Even between the 7 countries where the load is applied on the full-size block only a rough analysis is possible, because there are differences in:

- storage of the blocks prior to test (dry, stockpile equivalent, in water, indoor natural curing).
- age of specimen at test (28 days, at delivery, etc.)
- test procedure (packing sheets, rate of stress, etc.)
- number of specimen tested (2, 3, 5, 8, 16, etc.)
- definition of the strength (mean, single, mean and single, characteristic).

If the above mentioned aspects are left out of consideration the admissible compressive strength of the single block in the most cases is 45 to 50 N/mm^2. As far as the test procedure of the splitting test and the flexural test is concerned, see the above survey.

5. CONCLUSIONS

Uniformity in the judgement of concrete paving blocks?
There is not a bit of it! Nothing of the sort! That is altogether out of the question!

It is true that strength and dimensions are recognized as essential facts to judge, but it is done in an incomparable way.
Neither sampling, nor the method of testing nor the requirements are comparable.

Where do we go from here?

It is to be wished that the ISO-Organisation pays attention to this matter, although concrete paving blocks are not yet an international commodity.

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