Testing of Concrete Paving Blocks The BS EN 1338:2003 British and European Standard Code

by Yulita Arni Priastiwi

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TESTING OF CONCRETE PAVING BLOCKS
THE BS EN 1338:2003 BRITISH AND EUROPEAN STANDARD CODE

Purwanto, Yulita Arni Priastiwi *)

Introduction

Concrete paving Block are produced in various shapes with a wide variety in dimension. The most commonly used are the *square, hexagon and multiple hexagon shapes* (fig 1).

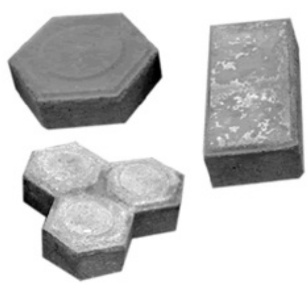

Figure 1. Type of Commonly Paving Blocks

Paving blocks have multiple advantages which are: *fast in assembling, replacement and transportation; excellent drainage capacity, easy handling and fast production*. Further, the blocks are having a very good thaw and freeze performance, which is a major advantage for countries with four seasons.

In Indonesia, paving blocks are widely used for all sorts of purposes starting from parking spaces, parks, to heavy duty roads. The paving blocks in Indonesia are also used to beautify the appearance of a road (fig.2). Paving block with coloring pattern where used in the *Semarang Kota Lama* area and surrounding. Here the blocks perform excellent, even under the influence of sea water intrusion.

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Figure 2. Colored Paving Blocks

The quality of a paving block is, up till now determined based on its *axial load carrying capacity* (BS 6717, SNI 03 – 0691 -1989). The paving blocks are axially loaded using the compression apparatus, and the load at failure is measured. By dividing this load with the area of paving blocks, the ultimate axial load is obtained and compared to the standard.

The BE EN 1338 standard sheds another aspect on the testing procedure; hence, the loading is no longer applied axially. Further, the standard placed several other criteria on the paving blocks' performance.
The following paragraphs will evaluate the old standard versus the most recent standard.

Axial Load Carrying Capacity

Based on the BS 6717:1986 and SNI 03 – 0691 -1989 the quality of paving blocks is measured based on its axial load carrying capacity. The paving blocks are placed in the compression apparatus (fig 3) and the stress at failure is calculated based on the formula:

$$\sigma = \frac{P}{A}$$

Where:

σ = *the ultimate stress at failure in Mpa or kg/cm*^{2}

P = *the ultimate load at failure in Newton or kilograms*

A = *the area perpendicular to the applied load, in mm*^{2} *or cm*^{2}

Figure 3. Paving Block Test based on BS 6717 and SNI 03 – 0691 -1989 code

The stresses are compared to the requirement (table 1). Each and every pavement's strength corresponds to its specific use. The unit price of production will also be a function of its strength.

Table 1. Paving Specification according SNI 03-0691-1989

Quality	*Compression Strength kg/cm*^{2}		*Abrasion Resistance mm/minute*		*Absorption %*
	Average	*Lowest*	*Average*	*Lowest*	
I	400	340	0.090	0.103	3
II	300	255	0.130	0.149	5
III	200	170	0.160	0.184	7

The cracking pattern of the blocks will follow the characteristic failure pattern (fig 4). Influenced by the paving's *Poisson Ratio*, the site areas will undergo tensile stresses, while the centre of the specimen will have compression stresses. The friction between the apparatus' head to the paving will influence the deformation, leading to a conical pattern.

Figure 4. Cracking Pattern of Tested Paving Blocks

Tensile Splitting Strength

From observation on existing *field-pavement-blocks* it can be seen that the cracking pattern *does not* reassemble the behavior of laboratory specimen (fig. 5). The pavements on the site ruptured along the short edge, while the material did not reach it ultimate load carrying capacity.

From here it can be concluded that idealized compression tests as suggested by the BS 6717 and the SNI 03 – 0691 -1989 code did not represent the actual behavior on the field. A cracking pattern as shown by figure 5 was caused by splitting stresses rather than normal stresses.

The BS EN 1338 approaches the testing method by the *Tensile Splitting Test*. The basic of the Splitting Test is the *Brazilian Split Cylinder Test*, performed on concrete cylinders to obtain the concrete tensile strength. Cylinders are placed horizontally, and a point load is applied on its site. The cylinders will fail along the line of applied load.

Figure 5. Actual Behavior of Pavements on the Field

Figure 6 demonstrates the testing set-up for pavements according to the BS EN 1338:2003 standard. This testing procedure will result in a more realistic failure mode when compared to the testing method used up till now.

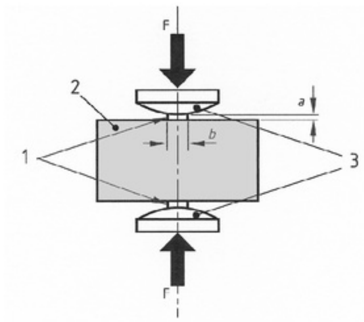

Figure 6. Principle of Testing from BS EN 1338

Notation:
1 = Packing pieces
2 = Paving block
3 = Rigid bearers with a contact surface of (75±5) mm
b = packing width of (15±5) mm
a = Packing thickness of (4±5) mm

Testing procedure is as following:

- Paving blocks are immersed in water 24 hours prior to testing, removed and wiped dry.
- The load shall be applied along the *longest splitting section* of the block, and parallel to the block's edges.
- For square blocks, the load shall be applied *to the shortest length passing through the centre* of the surface.

The strength of the paving block is calculated based on section F.4 of the code;

$$T = 0.637\ x\ k\ x \frac{P}{S}$$

Where:
T = Paving Block Strength, in Megapascal
P = Measured load at failure in Newton
S = Area of failure plane in square millimeters, equal l x t
l = The mean of two measured failure lengths, in millimeters
t = Paving block thickness at the failure plane
k = correcting factor (see table 2)

Table 2. Correction factor k

t (mm)	**40**	**50**	**60**	**70**	**80**	**90**	**100**	**110**	**120**	**130**	**140**
k	0.71	0.79	0.87	0.94	1.00	1.06	1.11	1.15	1.19	1.23	1.25

The *failure load* per unit length in N/mm is calculated from equation:

$$F = \frac{P}{l}$$

Paving blocks are acceptable based on clause 6.3.8.3 of the code, being:

- The *strength T* of eight blocks or fewer shall not be lower than 3.6 Mpa.
- The *failure load F* of eight blocks or fewer shall not be lower than 250 N/mm
- If the specimens consist of 16 blocks, not more than one block can have a *strength T* lower than 2.9 Mpa
- If the specimens consist of 16 blocks, not more than one block can have a *failure load F* lower than 250 N/mm

Testing Aspects of BS EN 1338

Beside from the strength evaluation, the BS EN 1338 standard also incorporate issues as *weathering resistance; abrasion resistance, slip/skid resistance and thermal conductivity*.

Weathering resistance is aimed predominantly to the thaw and freeze resistance which accordingly does not apply to Indonesia's tropical weather. The thaw and freeze response is determined based on the response to de-icing salt. Another method provide by the standard is the total water absorption test. This test is done by immersing the blocks till constant weight, dried in an oven for 24 hours and the absorption W_s calculated as following.

$$W_s = \frac{M_1 - M_2}{M_2} x100\%$$

Where:
M_1 = Submerged specimen weight in grams
M_2 = Dry specimen weight in grams

The abrasion resistance is measured by the *Wide Wheel Abrasion Test* or the *Böhme Test*. The test is similar as was assigned in the BS 6717 standard. The SNI 03 – 0691 -1989 has no clausal on this issue.
The skip/skid regulations are straight forward. The paving blocks are accepted provided that the whole upper surface has not been grounded or polished.

Test Results

The Structural and Material Laboratory, Diponegoro University in cooperation with *PT PROKON Concrete Industry* investigated the behavior of paving blocks subjected to the two different test methods.

Two types of paving blocks were test, specimen Group I was designed with compression strength of 400 kg/cm^2 and Group II was designed with compression strength of 500 kg/cm^2. Each and every group was consisting of 32 specimens. The paving blocks were then tested in accordance to the BS 6717 and BS EN 1338 code.

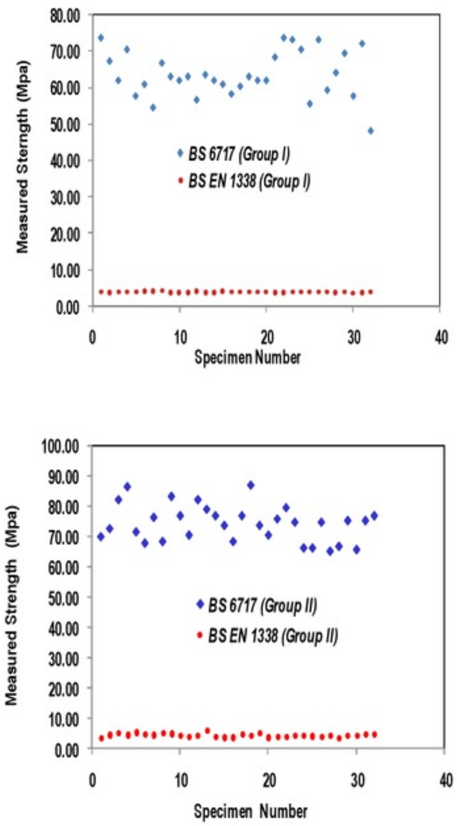

Figure 7. Test Results

The comparison between the *Compressive Strength* to the *T Strength* can be seen in Figure 7.
From the two populations, the relationship between the measured *T Strength* from the BS EN 1338 standard to the compression strength based on the BS 6717 can be generated (Figure 8).

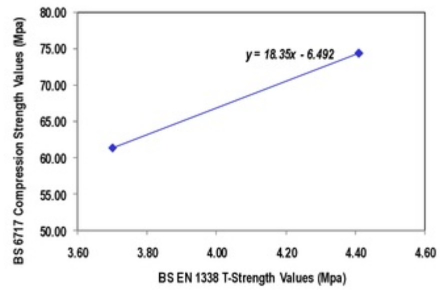

Figure 8. BS EN 1338 to BS 6717 Relationship

When expressed as a linear function, the relation of the compression strength to the T test will be;

$$f_{paving} = 18.35\,T - 6.492$$

Where:
T = is the paving block strength based on the BS EN 1338 code in Mpa
f_{paving} = is the paving blocks compression strength based on the BS 6717 in Mpa

This expression is based on the data that consist only of two populations. When the relationship of the compressive strength to the so called *Modulus of Rupture* f_M is used to re assembling the mathematical expression, a power function is used giving the following relationship.

$$f_{paving} = 14.63\,T^{1.096}$$

When covert to the *modulus-of-rupture-to-compression-strength* equation this will give us:

$$f_{MR} = 0.086\sqrt[0.912]{f_c}$$ or

$$T = 0.086\sqrt[0.912]{f_{paving}}$$

Conclusion and Recommendation

The experimental model showed that a fairly simple conversion from the BS EN 1338 to the BS 6717 standard can be generated.
The data also demonstrated that the behavior of paving blocks is similar to concrete and that the T value actually can be regenerated from the modulus of rupture concept.
However, wider ranges of paving blocks with various strengths should be tested to ensure the reliability of the regenerated equations.
Further, the expression of failure load F as mentioned in the BS EN 1338 standard should be studied more in depth to provide a better understanding to the failure behavior of paving blocks.

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