

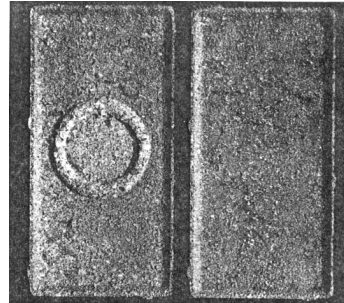
Appendix U.2.14 – CCA:TM6

Generic Name of Test	Rolling Steel Balls : Abrasion Test	
Principle of Test	Loaded orbiting steel balls	
Historic Development of Test	When it became apparent that the variability of the Australian MA-20 test was high, the Concrete Association of New Zealand made several modifications. The resultant test became 'Cement & Concrete Association of New Zealand Test Method: CCA:TM6:1991 Determination of Abrasion Index for Concrete Paving Units'. [Hudson (1991)] However this test has subsequently been discarded (as the official test for testing concrete pavers) in favour of AS/NZS 4456.9.	
Apparatus and Abrasives	The test apparatus is similar to the MA-20 test except where noted in the diagram below. The main differences include the use of a micrometer to measure the wear depth and the uses of a drill press rather than a drill on a stand.	
		<p style="text-align: center;"><u>Modifications made to MA-20</u></p> <ol style="list-style-type: none"> 1) The drill and drill stand are replaced with a drill press. 2) The dial gauge is omitted, in favour of measuring depth of wear with a micrometer. 3) The electronic revolution counter is replaced by a magnetic counter. 4) The concrete block is clamped by a bar screwed down across the top, to ensure that the test specimen is perpendicular to the axis of the drill press. 5) The water flow rate is controlled.
Test Method	<p style="text-align: center;">Figure U.2.14.1 The MA20 Abrasion Apparatus</p> <p>The CCA:TM6 test requires that the ball race be warmed up prior to the first test of the day by running the ball race for 1000 revolutions. The concrete test specimen is secured; the flow of water adjusted to 1.5 l/min and a load of 14.5 kg is applied. The duration of the test is 5000 revolutions at an unspecified speed. The test specifies that the steel balls be replaced after every 13 tests and the entire ball race assembly replaced after 260 tests. [CCA:TM6: 1991]</p>	
Abrasion Wear	<p>This is measured in terms of the average depth of abrasive wear by using a micrometer with a rounded tip from which an abrasion index I_a is calculated, where:</p> $I_a = \frac{\sqrt{5000 \text{ revs} / 1000}}{\text{depth (mm)}} \quad \text{[CCA:TM6: 1991]}$	
References	<p><u>Author</u></p> <p>CCA:TM6:1991 Rocha (1994) Doulgeris (1995)</p>	<p><u>Comment</u></p> <p>Source document Source document Source document</p>

Wear Mechanisms according to Author

- (i) No comments by the author
- (ii) Visual Effects: See figure U.2.14.2

Figure U.2.14.2 Abrasion wear of concrete paving block (that was subjected to the similar ASTM C779 Proc C test) [Ghafoori (1995)]



Wear Mechanisms according to writer [R3 S1 I2]

(i) **Rolling:** As the ball-race rotates under the action of the drill, the individual balls roll over the surface resulting in crushing effects. In the initial phase of the test the contact area between ball and concrete surface is very small, resulting in high compressive stresses, particularly at the asperities, leading to rapid abrasion. If the load W is sufficiently high relative to the tensile strength of the concrete, then sub-asperity cracking will develop in the form of Hertzian cone cracks will develop, and quite likely also 'lateral' and 'axial' cracks will also develop as indicated in figure U.2.14.4.

(ii) **Impact:** There is a degree of vibration inherent in the drill machine, which results in some bouncing and consequent impact. Bouncing may increase as the balls penetrate deeper into the surface, owing to a roller-coaster-like profile developing, given that the harder aggregate particles in the wear path abrade at a slower rate relative to the mortar matrix. However, this undulation will be relatively shallow owing to the levelling effect of having the lower six balls in the brass ring at the same level. (The upper six balls of the brass ring are in contact with the raceway). Impact will accentuate the compressive stresses described in (i), thus increasing abrasion-wear.

(iii) **Sliding:** Spheres rolling on a surface experience 'Reynolds' slip due to the progressive stretching of the surface within the contact region. As the groove deepens 'Heathcote' slip also occurs, as a result of variations in circumferential contact depending on sectional position of the ball in the groove. Finally there is also a degree of frictional resistance between balls and ball race that translates to friction at the concrete/ball interface. These concepts are more fully explained in chapter 3 but the net effect is frictional force (see F_n and F below) and sliding leading to shearing effects.

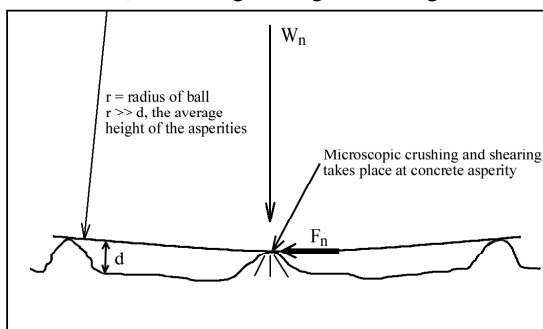


Figure U.2.14.3 Microscopic rolling and sliding wear mechanism

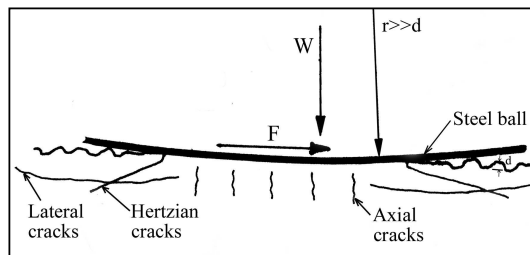


Figure U.2.14.4 The geometry of a Hertzian cone crack formed by a sphere loaded normally on the plane surface. Note also 'lateral' and 'axial' crack formations

- (iv) **Adhesion and deformation:** See note 1 in introduction to appendix U