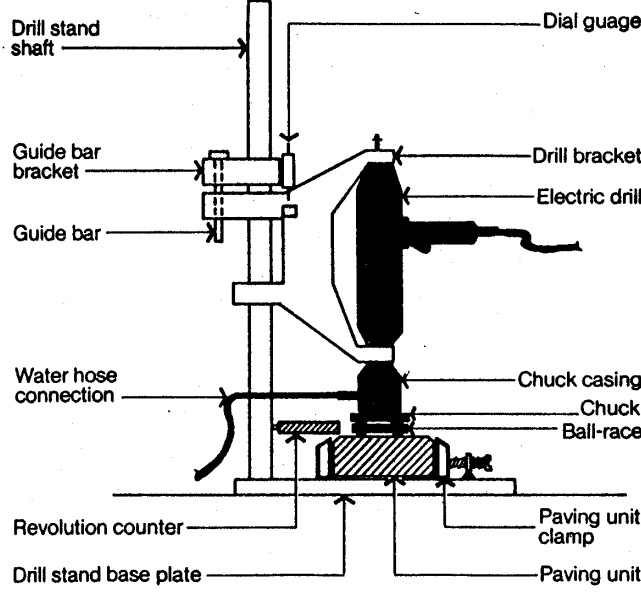


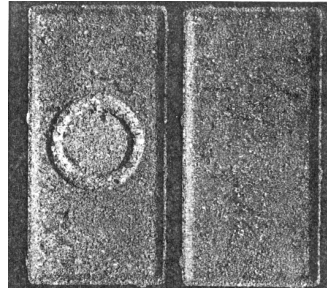
Appendix U.2.13 – MA20

Generic Name of Test	Rolling Steel Balls : Abrasion Test								
Principle of Test	Loaded orbiting steel balls								
Historic Development of Test	In Australia an equivalent version of the ASTM C779-82 Proc C test was developed for the testing of concrete pavers. The test was included as a provisional abrasion test in the paving specification. <i>MA20-1986 Specification for Concrete Segmental Paving Units</i> . It was later discarded in favour of a tumbling test, AS/NZS 4456.9:1997 described in U.2.3. [Doulgeris (1995)]								
Apparatus and Abrasives	A vertically mounted electric drill drives a bearing raceway, resting on 6 x 15.8mm steel balls, that in turn rest on a brass disc that positions the balls, and this disc in turn rests on 6 other balls that finally make contact with the concrete surface. Water is run through the bearings whilst the equipment is running. A dial gauge provides an abrasion depth reading. See figure U.2.13.1. [MA20 (1986)]								
 <p>Figure U.2.13.1 Schematic of the MA20 Abrasion Apparatus</p>									
Test Method	The concrete specimen being tested is clamped to the horizontal surface. A sufficient flow of water should be present to clear grinding debris. The drill is run at a speed of 1000-1050 rpm. The test specifies 5000 revolutions of the ball race after which the final depth of penetration is read off the dial gauge. [MA-20 (1986)]								
Abrasion Wear	This is measured in terms of the average depth of abrasive wear from which an abrasion index I_a is calculated, where $I_a = \frac{\sqrt{5000 \text{ revs}/1000}}{\text{depth (mm)}}$ [MA20 -1986]								
References	<table border="0" style="width: 100%;"> <thead> <tr> <th style="text-align: left; border-bottom: 1px solid black;">Author</th> <th style="text-align: left; border-bottom: 1px solid black;">Comment</th> </tr> </thead> <tbody> <tr> <td>MA20 (1986)</td> <td>Source document</td> </tr> <tr> <td>Rocha (1994)</td> <td>Source document</td> </tr> <tr> <td>Doulgeris (1995)</td> <td>Source document</td> </tr> </tbody> </table>	Author	Comment	MA20 (1986)	Source document	Rocha (1994)	Source document	Doulgeris (1995)	Source document
Author	Comment								
MA20 (1986)	Source document								
Rocha (1994)	Source document								
Doulgeris (1995)	Source document								

Wear Mechanisms according to Author

- (i) Doulgeris (1995): The abrasive action is believed to be one of micro crushing occurring under high compressive and perhaps some impact stresses exerted by the steel balls.
- (ii) Rocha (1994): The ball bearings cause impact as well as sliding friction.
- (iii) Visual Effects:

Figure U.2.13.2 Abrasion wear of a 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 and quite likely 'lateral' and 'axial' cracks will also develop as indicated in figure U.2.13.4.

(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.

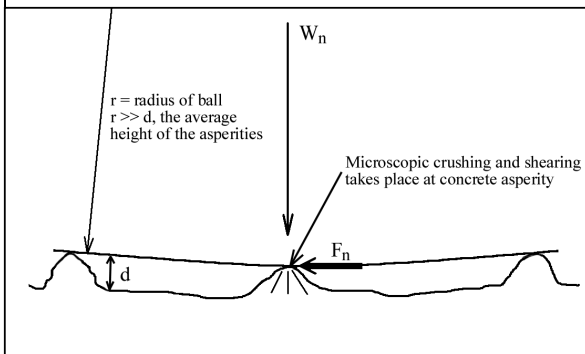


Figure U.2.13.3 Microscopic rolling and sliding wear mechanism

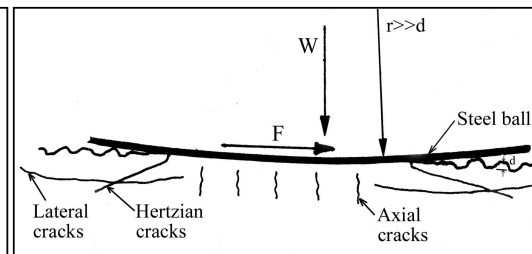


Figure U.2.13.4 The geometry of a Hertzian cone crack formed by a sphere loaded normally on the plane surface. Note also 'lateral' and 'axial' cracks

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