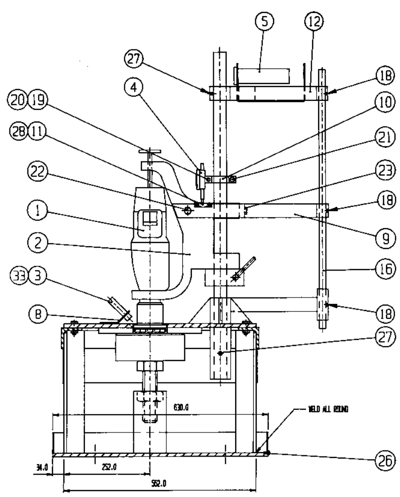
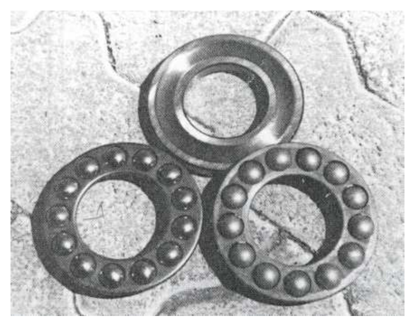
Appendix U.2.16 – CMA20

Generic Name of Test	*Rolling* Steel Balls : Abrasion Test
Principle of Test	Loaded orbiting steel balls
Historic Development of Test	This proposed abrasion test was designed to improve the variability of the MA20 test, although to date the apparatus has not been manufactured. These modifications included testing wet, a local bearing consisting of 13 rather than 12 balls with a thin steel locating ring, a very secure guiding system and a clamping system that ensures the correct orientation of the paver to the axis of the drill. It may be regarded as a further improvement of the MA20SA test. [Papenfus (1994)]
Apparatus and Abrasives	A vertically mounted electric drill drives a raceway, which in turn bears on 13 balls running on the paver surface. Water is run through the bearing whilst the equipment is running. A dial gauge provides an abrasion depth reading. See figures U.2.16.1 and U.2.16.2. [Papenfus (1994)]
 **Figure U.2.16.1** CMA20 Apparatus	 **Figure U.2.16.2** Bearing and ball raceway used in MA20SA test
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 2000 revolutions of the ball race after which the final depth of penetration is read off the dial gauge. [Papenfus (1994)]
Abrasion Wear	This is measured in terms of the average depth of abrasive wear from which an abrasion index I_a is calculated, where $I_a = \frac{\sqrt{2000\,\text{revs}/1000}}{\text{depth}\,(\text{mm})}$ [Papenfus (1994)]
References	Author / Comment Papenfus (1984) — Source document Doulgeris (1995) — Source document Rocha (1994) — Source document Liu (1991) — Source document

APPENDIX U.2.16

Wear Mechanisms according to Author

(i) There are no referring authors, as the apparatus has not been made, but the same comments as in MA20SA, ASTM C779 Proc. C and MA20 will apply equally here.

(ii) Visual Effects: (See figure U.2.16.3)

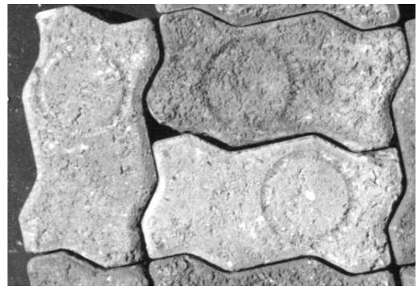


Figure U.2.16.3 Wear patterns on paving blocks from MA20SA apparatus, which uses the same bearing [Holland (1991)]

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.2.16.5.

(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 13 balls at the same level. 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. These concepts are more fully explained in chapter 3 but the net effect is frictional forces (see Fn and F below) and frictional slip leading to shearing effects.

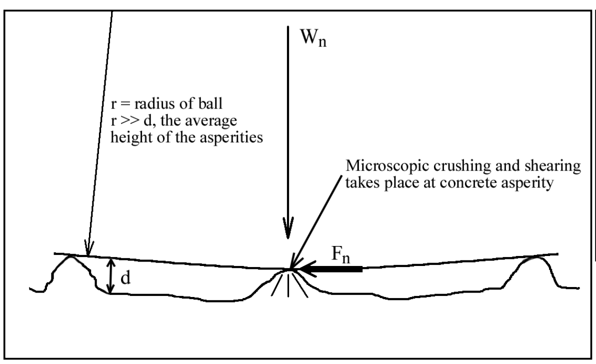


Figure U.2.16.4 Microscopic rolling and sliding wear mechanisms

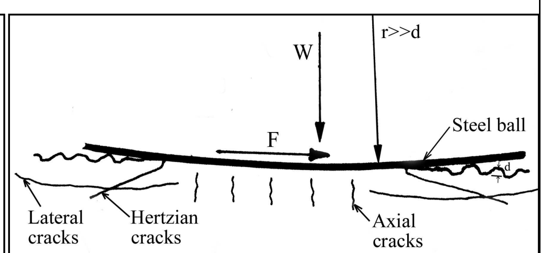


Figure U.2.16.5 The geometry of a Hertzian cone crack formed by a sphere loaded normally on the plane surface. Note also 'lateral' and 'axial' crack formations

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