Appendix U.2.11 – Davis Modified Rolling Balls

Generic Name of Test	*Rolling* Steel Balls (in Water) : Abrasion/Erosion Test
Principle of Test	Loaded orbiting steel balls submerged in water.
Historic Development of Test	The test apparatus was developed by Raymond E. Davis of the University of California. Smith used this test in 1958, modified from the original Davis test, as detailed below. Little else is known about the history of this test. [Smith (1958)]
Apparatus and Abrasives	The apparatus shown in figure U.2.11.1 and U.2.11.2 consists of 41 (reduced from 62) steel balls with a diameter of 25mm, which are placed on top of the concrete test specimen. The concrete test specimen is housed in a cylindrical container, which serves to retain the steel balls and provide for water inlet and outlet pipes. A 305mm diameter rubber covered rotating head is driven by an electric motor and places a 450kg load on the steel balls. Another modification was to place a 76mm diameter by 19mm thick steel disk beneath the centre of the rotating head and thus exclude steel balls from the central zone. [Smith (1958)]

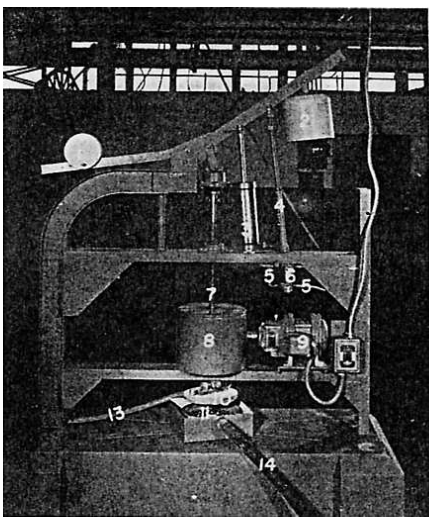

Figure U.2.11.1 The Davis steel ball abrasion apparatus [Smith (1958)]

1-6) Loading mechanism (450kg)
7) Drive shaft
8) Gearbox
9) Electric motor
10) Rotating head
11) Steel balls
12) Concrete specimen
13) Water inlet pipe
14) Water outlet pipe

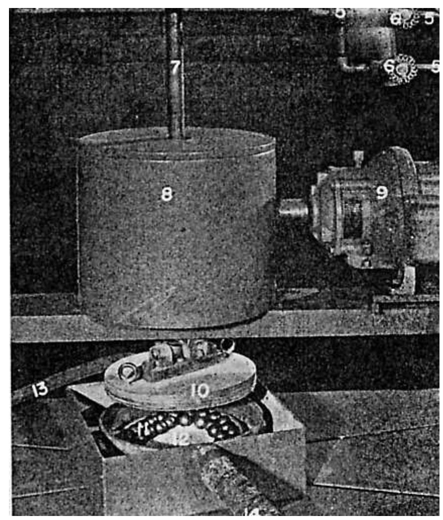

Figure U.2.11.2 Steel balls (41) and rotating head [Smith (1958)]

Test Method	Before testing, the specimens are placed in water for 24 hours and dried for 1 hour after which they are weighed. The specimen is placed in the housing, the 41 steel balls added and the rotating head lowered onto the steel balls. The head rotates at 60rpm while a constant supply of water is provided to wash away abraded particles. The test duration is approximately 5 minutes. After being tested, the specimens are dried for 1 hour and weighed again. [Smith (1958)]
Abrasion Wear	This is measured as the mass loss of the test specimen. [Smith (1958)]
References	<u>Author</u> <u>Comment</u> Smith F.L (1958) Source document

APPENDIX U.2.11

Wear Mechanisms according to Author
(i) Smith (1958): No comments on the wear mechanism
(ii) Visual Effects: None available

Wear Mechanisms according to writer [R3 S1 I2]

(i) Rolling: As the head rotates under the action of the motor, the individual balls roll over the surface resulting in crushing effects. The test the contact area between ball and concrete surface is very small, resulting in high compressive stresses, particularly at the asperities (see figure U.2.11.3), 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 also 'lateral' and 'axial' cracks will develop as indicated in figure U.2.11.4.

(ii) Impact: There is a degree of vibration inherent in the Davis machine, which results in a measure of impact. Vibration and impact 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. On the other hand, the rubber lining on the rotating head serves to reduce vibration and impact, to a degree. Impact will accentuate the compressive stresses described in (i), thus increasing abrasion-wear.
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(iii) Sliding: Spheres rolling on a surface experience 'Reynolds' slip due to the progressive stretching of the surface within the contact region. This results in a small frictional force F, leading to a slight amount of shearing. 'Heathcote' slip [Hutchings (1992)] is not expected, since the double row of balls do not run in two clearly defined concentric circles (of the kind in ASTM C779 Proc C).Shearing effects are indicated below.

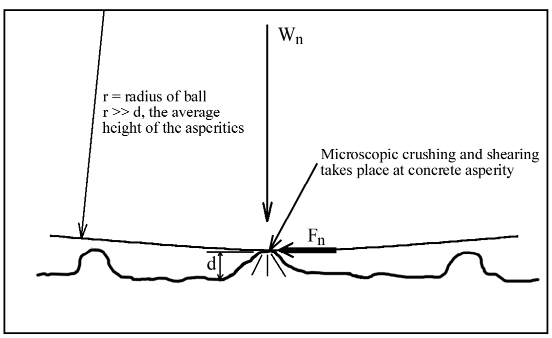

Figure U.2.11.3 Microscopic rolling and sliding wear mechanism

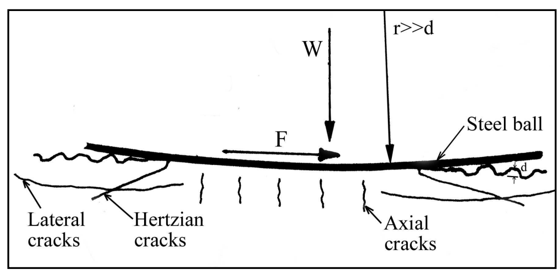

Figure U.2.11.4 The geometry of a Hertzian cone crack formed by a sphere loaded normally on the plane surface. Note also 'lateral' and 'axial' crack formations.

The abrasion wear from the crushing and shearing force (shown in figure U.2.11.3) acting on an asperity will be proportional to W_n, and may be stated as:

$$Q_{Crushing} \propto W_n$$

$$Q_{Shearing} \propto F_n = \mu W_n$$

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