Appendix U.2.9 – DIN51951

Generic Name of Test	*Rolling* Steel Balls : Abrasion Test
Principle of Test	Loaded orbiting steel balls also moving in a planetary circuit
Historic Development of Test	In Germany wear tests have been investigated since 1936 to set up standards for hard concrete surfaces. This led to the Standard Specification DIN 1100 being published in 1941. Fritz Ebener developed this testing apparatus and after comparative tests in 1953 a new standard, DIN 51951 was published. [Sawyer (1957)]
Apparatus and Abrasives	The apparatus is shown in figures U.2.9.1 and U.2.9.2 and consists of a horizontal turntable (on which the specimen is placed) and a loading press (installed vertically in the head of the machine). A spherical head is attached to the loading press in such a way that the head can be rotated. The centres of the turntable and head are displaced in relation to each other by 40mm. The turntable and spherical head are contra-rotating and geared to a ratio of 1:35. The spherical head holds five 18mm ball bearings running in a hardened raceway 33mm in diameter. A suitable clamping mechanism is used to hold the test specimen. A vacuum removes abraded particles from the wear path. [Sawyer (1957)]

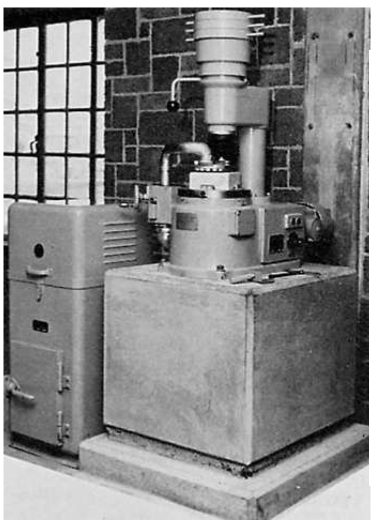

Figure U.2.9.1 Wear Testing machine with test specimen in place [Sawyer (1957)]

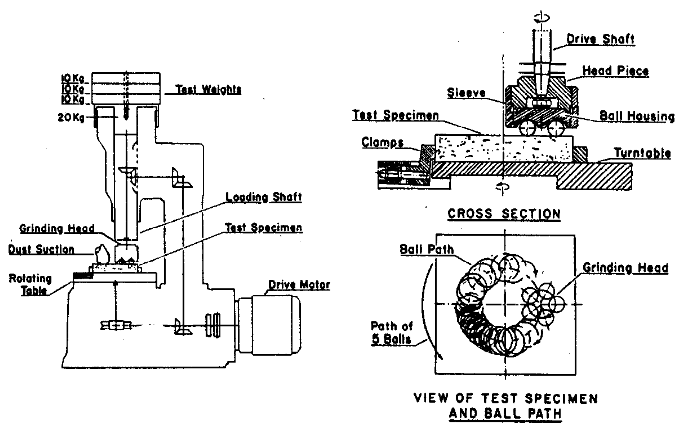

Figure U.2.9.2 Details of the Fritz Ebener wear machine [Sawyer (1957)]

Test Method	The test specimen of dimensions 152 x 152 x 50mm is weighed, clamped to the turntable and a load of between 20kg and 50kg is applied. The test consists of ten periods of 40 rotations of the base table (1400 rotations of the ball holder) after which the specimen is weighed and the dimensions of the abraded groove measured. New balls are used at the beginning of each test. [Sawyer (1957)]
Abrasion Wear	This is measured as the mass loss due to abrasion wear. The dimensions of the abraded grooves are also noted. [Sawyer (1957)]
References	<u>Author</u> <u>Comment</u> Sawyer (1957) Source document

APPENDIX U.2.9

Wear Mechanisms according to Author

(i) Sawyer (1957): The concrete specimen is subjected to abrasion caused mainly by rolling pressure and sliding friction accompanied by some pounding or beating force.

(ii) Visual Effects:

Figure U.2.9.3 Worn test specimen after one test period (left) and 10 test periods (right) [Sawyer (1957)]

Note: Clearly the balls are capable of wearing well into the 'core' concrete but can also measure 'surface' abrasion resistance. Notice too that the greater exposed surface of the coarse aggregate makes it the primary determinant of 'core' abrasion resistance, particularly if it is harder than the paste. Therefore the primary function of the paste is to bond the harder aggregate securely in the matrix.

Wear Mechanisms according to writer [R3 S1 I2]

(i) Rolling: As the ball-race rotates under the action of the rotating head, the individual balls roll over the surface resulting in crushing effects. The contact area between ball and concrete surface is very small, resulting in high compressive stresses, particularly at the asperities (see figure U.2.9.4), 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, as indicated in figure U.2.9.5.

(ii) Impact: There is a degree of vibration inherent in the drill machine that results in a measure of impact. Vibration and impact may increase as the balls penetrate deeper into the softer mortar constituent relative to the harder course aggregate constituent, resulting in a roller-coaster-like profile developing. However this undulation will be relatively shallow owing to the levelling effect of having 5 balls in the raceway, as well as the effect of the superimposed planetary motion. 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. There is also a degree of frictional resistance between balls and ball-race that translates to horizontal drag at the concrete/ball interface. These concepts are more fully explained in chapter 3 but the net effect is frictional force and sliding leading to shearing effects, as indicated below.

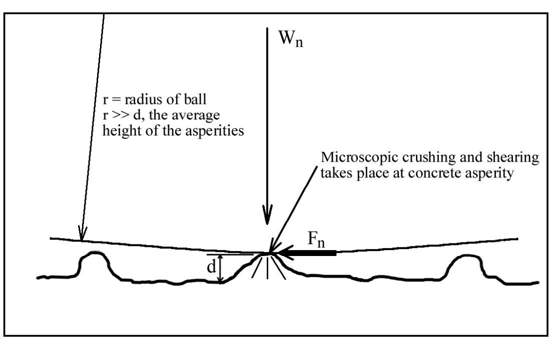

Figure U.2.9.4 Microscopic rolling and sliding wear mechanism

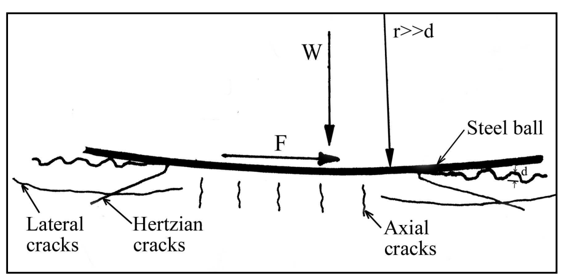

Figure U.2.9.5 The geometry of a Hertzian cone crack formed by a sphere loaded normally on the plane surface. Note also lateral and axial crack formations.

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