Appendix U.2.1 – Abrams's Tumbling Balls

Generic Name of Test	*Impacting* Steel Balls : Abrasion Test
Principle of Test	Steel balls tumbling in a rotating drum (Talbot Jones Rattler) lined with concrete blocks.
Historic Development of Test	The Talbot-Jones rattler was designed for testing paving brick and is an adaptation of the ordinary foundry rattler (the original brick rattler was introduced at Purdue University in 1889). It has been used for the testing of concrete since 1913. [Abrams (1916)], [Crepps (1920)]
Apparatus and Abrasives	The Talbot-Jones rattler consists of a large steel drum mounted on a horizontal axis, which revolves at a fixed rate. The concrete specimens are arranged around the perimeter of the drum and are clamped in place with wedge shaped wooden blocks. (See Figure U.2.1.1 and U.2.1.2) [Abrams (1916)]

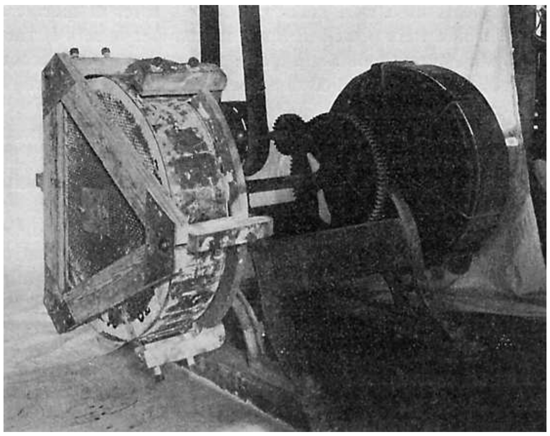

Figure U.2.1.1 The Talbot-Jones Rattler in operational mode. [Abrams (1916)]

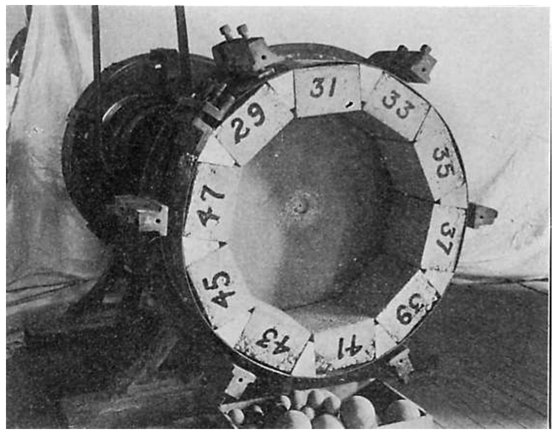

Figure U.2.1.2 View of blocks before test. Note the balls in the foreground. [Abrams (1916)]

Test Method	The test pieces consist of blocks 203mm square and 127mm thick. The blocks are arranged around the perimeter of the drum as shown in Figure U.2.1.2. The abrasive charge consists of 91kg of cast iron balls, about 135 balls 48mm in diameter and 10 balls 95mm in diameter. The drum is rotated at 30 rpm for 1800 revolutions with the front of the chamber closed by means of a heavy wire screen. The direction of rotation is reversed 2 or 3 times during the test. [Abrams (1921)], [Crepps (1920)]
Abrasion Wear	The abrasion wear is measured as the loss in weight, which may be converted to a percentage of the original weight or expressed as the depth of wear. [Abrams (1916)]
References	<u>Author</u> <u>Comment</u> Abrams (1916) Source document Abrams (1921) Source document Crepps (1920) Source document Hutchings (1992) Source document

APPENDIX U.2.1

Wear Mechanisms according to Author [R2 S2 I4]

(i) Abrams (1921): The blocks are subjected to the tumbling action and impact of the balls.
Abrams (1921): The test gives a combined abrasion and impact action.
(ii) Visual Effects: See Figure U.2.1.3 and U.2.1.4

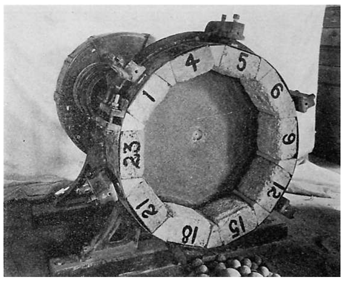

Figure U.2.1.3 View of blocks after test [Abrams (1916)]

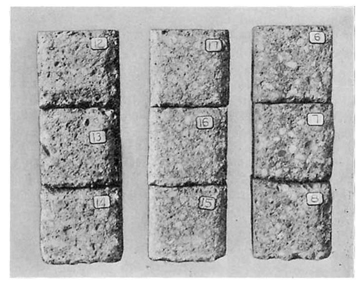

Figure U.2.1.4 Concrete blocks after test [Abrams (1916)]

Wear Mechanisms according to writer [R2 S2 I4]

As the drum rotates the balls will fall roll, slide and bounce, which collectively may be referred to as tumbling. (Bouncing will be accentuated as the concrete's surface becomes rougher). Rolling will result in crushing effects, sliding in shearing, while falling and bouncing result in impact. These mechanisms are considered in more detail below.

(i) <u>Impact:</u> The abrasion wear Q arising out of the impact of the ball against the concrete may be quantified by the expression $Q \propto \frac{m.U^2}{H}.f(\theta)$ (mm^3) [Hutchings (1992)]. Clearly the velocity at impact, U, is the most dominant factor, while the mass of the ball, m, the hardness of the concrete, H, and a factor $f(\theta)$ based on the angle of impact θ are also important.

(ii) <u>Rolling and sliding:</u> The abrasion wear corresponding to rolling and sliding may respectively be quantified by the expressions:

$$Q_{Crushing} \propto W \text{ (for rolling)}$$

$$Q_{Shearing} \propto F = \mu W \text{ (for sliding)}$$

Where $Q_{Crushing}$ and $Q_{Shearing}$ represent the loss of material owing to crushing and shearing (see figure U.2.1.5) at the microscopic asperities where contact is made. W and F are respectively the weight of the ball and the frictional drag from sliding, and μ is the coefficient of friction between concrete and steel.

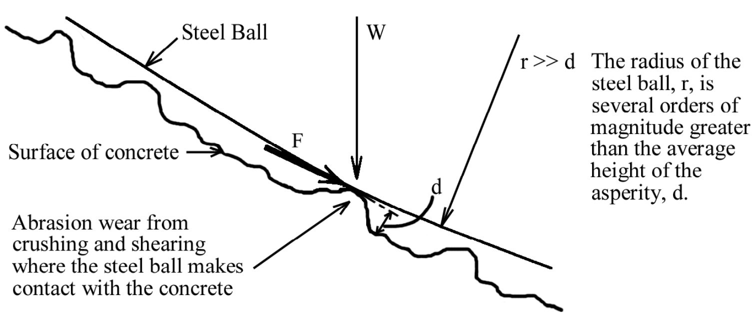

Figure U.2.1.5 Microscopic wear mechanism for rolling and sliding

<u>Relative severity:</u> Impact will result in substantially more severe crushing and shearing than rolling and sliding, as well as various types of sub-asperity cracking, such as Hertzian cone cracks, lateral cracks or axial cracks (discussed in detail in chapter 3.)

(iii) <u>Adhesion and deformation:</u> See note 1 in introduction to appendix U