Appendix U.1.1 – Fwa's Cube Tumbler

Generic Name of Test	*Impacting* Steel Drum : Abrasion Test
Principle of Test	Cubes tumbling in steel drum (i.e. Los Angeles machine)
Historic Development of Test	The test was designed by Fwa in 1990 to evaluate the relative surface-deterioration resistance of different concrete pavement materials.
Apparatus	The apparatus is a standard Los Angeles machine (see figure U.1.1.1). It has a large rotating steel drum, which contains a shelf that lifts and drops the internal contents. No abrasive charge is used for this test.

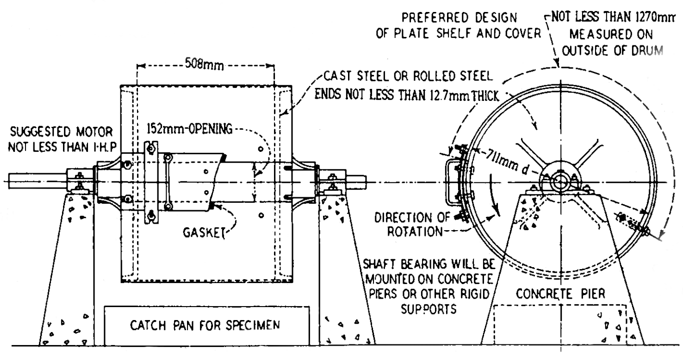


Figure U.1.1.1 The Los Angeles Machine [ASTM C131]

Test Method	Two concrete cubes of 100mm are inserted into the drum of the machine, which is rotated at 32 rpm. The test duration is 2000 revolutions. Abraded material is removed from the drum at intervals of 200 revolutions.
Abrasion Wear	The percent of abrasion wear is calculated from: $W = (m_o - m/m_o) \times 100\%$ Where: W = wear in percent by mass, m_o = initial total mass of specimens tested and m = remaining mass of specimens after wearing treatment

Wear Mechanisms according to Author

(i) Fwa (1990): In general abrasive wear is caused by horizontal loads while fatigue wear is caused by repeated vertical loads.

(ii) Visual Effects: (See Figure U.1.1.2 and U.1.1.3)

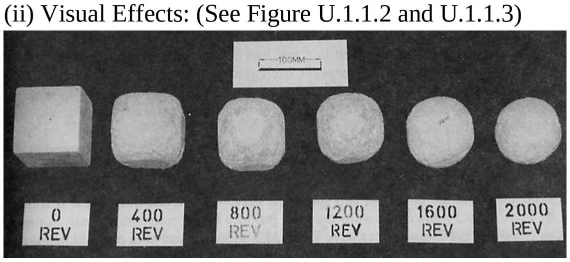


Figure U.1.1.2 Shape of cement mortar specimen at different stages of rotating-drum test on 100mm cubes [Fwa (1990)]

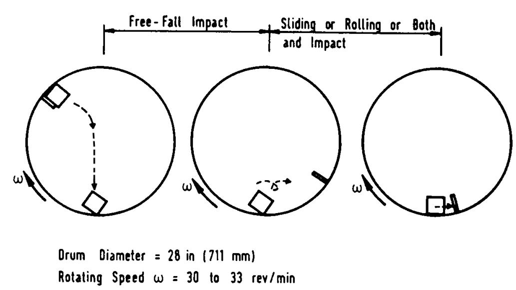


Figure U.1.1.3 Schematic representations of apparatus and wearing actions, respectively showing impact, rolling and sliding

References

Author	Comment
Fwa (1990)	Source document
Hutching (1992)	Source document
ASTM C131	Source document

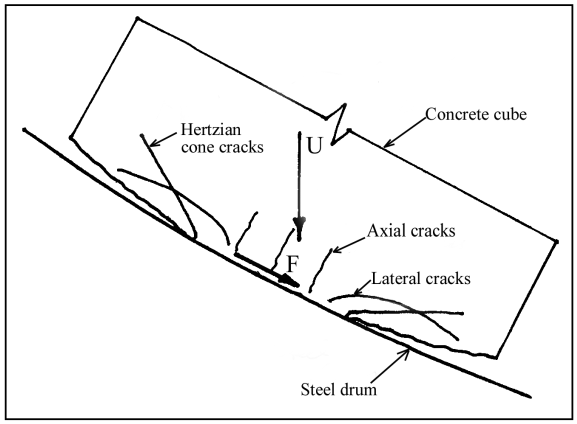
APPENDIX U.1.1

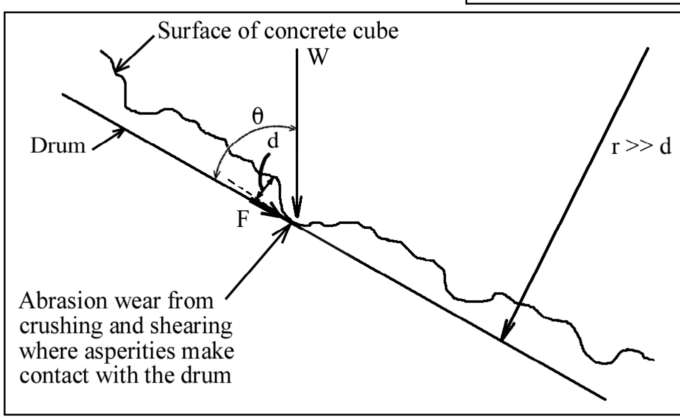
Wear Mechanisms according to writer [R2 S2 I4]

The concrete cubes are lifted by the shelf inside the drum. At a certain height they slide out and fall against the drum below. On landing the cubes will both roll and slide until they are lifted again. (The combined actions of falling together with rolling and sliding is referred to as 'tumbling'). Impact wear is likely to be an order of magnitude greater than rolling and sliding induced wear. These mechanisms are considered in more detail below.

(i) Impact: The abrasion wear Q arising out of the initial impact of the cube against the drum may be quantified by the expression $Q \propto \frac{m.U^2}{H}.f(\theta)$ in mm^3 [Hutchings (1992)]. Clearly the velocity at impact, U, is the most dominant factor, while the mass of the cube, m, the hardness of the concrete, H, and a factor $f(\theta)$ based on the angle of impact θ are also important. The severe impact in this test very likely leads to forms of sub-asperity cracking including Hertzian cone cracks, lateral cracks and axial cracks indicated in figure U.1.1.4

Figure U.1.1.4 Presentation of different crack mechanisms occurring on impact





The radius of the drum, r, is a few orders of magnitude greater than the average height of the asperity, d.

Figure U.1.1.5 Microscopic abrasion mechanism for rolling and sliding

(ii) Rolling and sliding: The abrasion wear corresponding to rolling and sliding may be limited to the asperities and may respectively be quantified by the expressions:

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

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

Where $Q_{Crushing}$ and $Q_{Shearing}$ represent the loss of material owing to crushing and shearing (See figure U.1.1.5) at the microscopic asperities where contact is made. W and F are respectively the weight of the cube and the frictional drag from sliding, and μ is the coefficient of friction between concrete and steel.

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