Towards standard tests for abrasion resistance of concrete
Report on a limited number of tests studied, with a critical evaluation (1)

M. G. Alexander

Department of Civil Engineering, University of the Witwatersrand, South Africa
(prepared while a temporary visitor at the Building Research Station Technion, Haifa, Israel, January 1983)

A comparative study on a limited number of existing abrasion tests for concrete has been done, with the intention that it should serve as a basis for the preparation of a recommendation for a standard test or tests. A summary and classification of the tests is presented, together with a critical evaluation. In view of the number of different tests currently being used in various countries, it is clear that no single test has yet been devised that adequately measures the wear resistance of concrete under all conditions. Since concrete is subjected to different kinds of wear, it seems likely that a number of tests, each suited to a particular mode of abrasion, will be required. Further experimental evidence on the correlation of test data with practical performance is required before firm recommendations can be made.

1. INTRODUCTION: OBJECT OF STUDY, DEFINITIONS, LIMITATIONS

The resistance of concrete surfaces to various types of wear has been the subject of study for a considerable time [1]. Many concrete structures are required to be abrasion-resistant, among them dams and canals, roads, and floors. Attempts have been made over the years and in various countries to characterise and measure concrete abrasion resistance by means of different tests, so that at present there is an almost bewildering array of tests in use. While the objective of this study was not to exhaustively examine all available tests, it was intended that a sufficient number of tests should be covered so as to represent the range of different types.

The determination of the abrasion resistance of concrete falls generally under the subject of concrete durability. In the context of the requirements of RILEM Committee CPC-14, this study is an endeavour to ascertain the types of concrete abrasion tests that are available and how well they produce results that are meaningful and reliable. The ultimate object of the exercise could be stated as: To discover, or to select from existing procedures, a test (or tests) that could be generally accepted for determining the resistance of concrete to all kinds of wear. Concrete is subjected to many kinds of wear, and for the present purposes the abrasion resistance of concrete may be defined as: the ability of concrete to withstand abrasive forces, whether these be due to friction, attrition, grinding, rolling, impact, high local stresses, or the action of fluids containing abrasive media. Only the normal contexts of hydraulic structures, floors, roads and other surfaces subjected to traffic will be considered. Of necessity, the abrasion resistance of concrete must be evaluated relative to the operational purpose for which it is intended. (Two categories of abrasion-type tests that are excluded in this report are wear tests of aggregates, and skid resistance-type tests for roads, since these are considered to be special aspects of the abrasion problem. Refer to the appendix.)

2. BRIEF NOTES ON ABRASION OF CONCRETE

Modes of wear on concrete surfaces

Mindess and Young [2] use the general term “wear resistance” to identify three distinct types of concrete surface wear:

(a) Abrasion: wearing by repeated rubbing or frictional processes (attrition).

(b) Erosion: wearing by abrasive action of fluids containing suspended solids (a special case of abrasion).

(c) Cavitation: wearing by implosion of vapour bubbles in high-velocity fluid flow.

Type (a) applies in general to trafficked surfaces such as floors and roads. Under this general heading, however, various modes of abrasion are possible, and these are identified later in the text. Types (b) and (c) apply mainly to hydraulic structures subjected to moving water. The mode of wear in this case will depend on the water velocity and sediment load.

(1) Prepared for submission to RILEM CPC-14 Concrete Permanent Committee, June 1984.
Factors affecting the abrasion resistance of concrete

These are briefly mentioned, since a fuller treatment can be obtained in the references. (In particular, refer to appendix of reference [3], and reference [4].) The main factors are:

(i) Compressive strength, or more correctly the strength of the paste; hence the w/c ratio.

(ii) Aggregate type. Hard aggregates give better abrasion resistance than soft aggregates. Coarser aggregates are generally superior to finer aggregates (except for cavitation).

(iii) Finishing procedures. Abrasion is a surface phenomenon, and attention should be given to the different surface finishes that can be obtained by means of floating and trowelling, abrasion-resistance toppings, chemical surface treatments, polymer impregnations, etc.

(iv) Curing of the concrete. This is an extremely important factor, and is often neglected in practice.

Clearly, abrasion resistance of concrete is affected by very much the same factors as determine the compressive strength of concrete. In general, it is true to say that measures which improve the strength, impermeability and density of the concrete will also improve the abrasion resistance. This means that attention should be paid to low w/c ratios, adequate cement content, proper mix design, use of drier mixes consistent with full compaction, and proper curing.

3. COMPARISON OF ABRASION TESTS

A total of eight standard tests from various countries were studied and compared according to the format outlined below:

Details of tests:

(1) Test reference, title, and country of origin.
(2) Type of test; laboratory/site.
(3) Type of abrasive effort applied.
(4) Apparatus and materials required, 1 Readily available in most laboratories, 2 Specialized items.
(5) Details of test specimen.

Evaluation of tests:

(6) Object of test.
(7) Ability of test to simulate practical conditions.
(8) Degree of sophistication of test.
(9) Available results - precision and reproducibility.
(10) General - salient comments.

The comparison is contained in tables I (a) and (b) under the headings given above. The tests selected are considered to represent a reasonable range of the different types available. The appendix refers to a few additional selected tests, and to a comprehensive European publication from CERIB [5].

General comments on the tests are:

(1) The European tests involve, in general, relatively small specimens of concrete or tiles (terrazzo, etc.) which are subjected to frictional abrasion against a revolving wheel, with or without an abrasive medium. These tests are not suitable for direct in situ measurements of wear.

(2) No British Standard (BS) is currently available for abrasion testing of concrete. However, the UK Department of Transport has an accelerated wear test for concrete roads (see Appendix). In addition, the Cement and Concrete Association (UK) have been doing work aimed at correlating the Schmidt Rebound Hammer Index with abrasion resistance. An apparatus consisting of three hardened steel wheels which are rotated under load on an in situ surface is being used to assess abrasion resistance [6].

(3) The USA tests require larger specimens, and represent a greater variety of modes of abrasion, than the European tests. They are better suited to in situ applications.

(4) The variations between the standard tests in different European countries are often simply related to size of specimen, contact pressure, and total length of time of test. This reflects allowances for local materials and conditions.

(5) Very little is available by way of precision results. This hampers a comparison of the tests.

(6) The tests measure abrasion values in terms of mass or volume loss, sometimes converted to a lineal measure, or directly by means of depth of wear readings. A useful variation is the recording of wear-time curves.

4. CLASSIFICATION OF ABRASION TESTS

Two types of classification have been considered:

(i) classification according to the type of wear, and
(ii) classification according to the type of practical application.

These two types are interrelated and have been combined in figure 1, which indicates the suitability of the standard tests for the different applications.

A rigid separation between the categories is not possible and certain tests might serve to evaluate abrasion resistance for a number of different practical applications. Notes on the figure are:

(a) The "Böhme" test is the German Standard DIN 52108. It is taken to cover all the tests which use the basic principles of the Böhme method.
(b) Those tests which are underlined are the preferred tests for the particular application considered. However, this judgement is somewhat subjective, and further comparative testing may show a different rating.
(c) There is a fairly fundamental difference between the European and American approaches to abrasion testing. The European tests are designed primarily for testing smaller precast flooring elements, while the American tests are designed with in situ testing of large elements, both floors and roads, in mind, although laboratory testing may be more commonly done. The American tests are generally not suitable for smaller precast flooring elements, such as terrazzo tiles. This may reflect the different flooring practices in Europe and America.

5. CRITICAL EVALUATION OF ABRASION TESTS

(1) A distinction must be made between abrasion tests for concrete floors (including tiles), concrete roads, and hydraulic structures. The type of wear and abrasion tests related to different concrete surfaces can be described as follows: