AN INVESTIGATION OF THE RELATION BETWEEN TEN PER CENT FINES LOAD AND CRUSHING VALUE TESTS OF AGGREGATES (U.K.)

ÉTUDE SUR LES RELATIONS ENTRE DEUX ESSAIS UTILISÉS EN GRANDE-BRETAGNE POUR CARACTÉRISER LA RÉSISTANCE MÉCANIQUE DES GRANULATS

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Abstract

Ten per cent fines load and ACV tests are two well accepted tests for assessing the mechanical properties of aggregates. While the load producing ten per cent fines is determined in the former test, the amount of fines produced under 40 ton load is given as ACV in the latter test. Both tests are standardised in the U.K. and carried out in the same way, on the approximately same amount of aggregate.

Shergold and Hosking (1959) showed for a number of materials including two rock types that the fines versus load relation in the aggregate crushing test gave a non-linear relation. They also suggested that there was a linear relation between 7.5 to 12.5 % fines range, passing through the coordinates (0, -4) in the fines versus load diagram, irrespective of rock types. Based on this assumption, they proposed a means of estimating the ten per cent fines load of aggregate from the crushing test. This method was also accepted by the British Standards (BS 812 - 1975).

The analysis of experimental and published aggregate test results indicate that the fines versus load relation of aggregates is linear and has a varying intercept and slope in the fines versus load diagram. Based on this concept, a diagram was produced to determine the ACV of aggregates from the ten per cent fines load, or vice versa. In general, an acceptable fit was obtained between the best fitting line to the test results and the proposed relation except for the ACV greater than 30. The proposed relation is not only very simple to apply, but also enables the determination of any per cent of fines load from a minimum number of experiments. Additionally, the proposed relation between the ten per cent fines load and the ACV of aggregates increased the applicability of the specifications which are often given in terms of one of the aggregate test results or determination of an aggregate property from other known properties.

Introduction

The ten per cent fines load and the aggregate crushing value (ACV) tests are two well known and accepted aggregate tests for assessing the mechanical properties of aggregates. Both tests are standardised in the U.K. and carried out more or less in the same manner, on approximately same amount aggregate (BS 812 - 1975). These tests give an indication of the aggregate crushing behaviour. However, while the load required for producing the ten per cent fines is to be determined in the ten per cent fines test, the amount of fines produced at 40 tons is given as ACV, in the case of aggregate crushing value test. These tests have mainly been developed at the Road Research Laboratory, to meet the needs of the construction industry and to make a

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quick and simple assessment of aggregates for the specification requirement. The factors influencing these test results have been investigated by various researchers and a detailed review of these tests is given in the Engineering Group Working Party Report of the Geological Society of London on sand, gravel and crushed rock aggregates for construction purposes (Collis and Fox, 1985).

In the U.K. the aggregate crushing value test was initially adopted as a British Standard test for aggregates used in concrete and involved the use of \( \frac{1}{3} \) \( \times \) \( \frac{1}{3} \) inch size crushed stone or natural aggregate to which a load of 40 tons is applied at a uniform rate of 4 tons per minute (BS 812 - 1975). Later on this test was accepted as a standard test for road aggregates as Method 11B of BS 812 - 1943 (Markwick and Shergold 1945). In the present standard aggregate crushing tests, given in BS 812 - 1975, approximately 3 kg of standard size aggregate (14-10 mm) is placed in a 15 cm diameter cylindrical steel mould with closely fitting plunger and subjected to a continuous load transmitted through the plunger in a compression testing machine. A total load of 40 tons (400 kN) is achieved in 10 minutes. The fines passing the BS 2.40 mm sieve, is calculated as a percentage of the initial sample weight. The mean of two test results rounded to a whole number, is given as the ACV of the aggregate tested. The both test results should be within 1% of each other for acceptance in calculating the ACV. While a higher ACV indicates a weak aggregate, a low ACV indicates a more resistant aggregate.

Even through the aggregate crushing test was found to be a useful means of comparing the resistance to crushing of most aggregate types used in road surfacing, it was also found to be relatively insensitive to differences in the strength of weaker materials (Shergold and Hosking 1959). This it was suggested resulted from the fact that the weaker materials are compacted to a dense mass before the full load of 40 tons has been applied, thus reducing the amount of crushing that occurs in the later stages of the test. Since, the consolidation of material results from the filling of the voids by fines formed during the test, this difficulty could be overcome by selecting test conditions that would ensure the formation of only a relatively low proportion of fines during the test. Thus, Shergold and Hosking (1959), suggested the ten per cent fines load as an alternative aggregate test and this has been accepted by the British Standard as a standard aggregate test (BS 812 - 1975).

In the ten per cent fines test, the load required to produce ten per cent fines using the standard size equipment and sieve sizes as for the ACV test is determined. During the test, a uniform loading rate is applied to the standard size aggregate (14-10 mm) to cause a total penetration of the plunger of approximately 20 mm for the crushed rock in ten minutes. The percentage ratio of the fines passing the BS 2.40 mm sieve, to the initial sample weight is expected to fall between 7.5 to 12.5%. Otherwise, the test has to be repeated with an increased load. Then, the force required to produce the ten per cent fines is calculated from the following equation:

\[
10\% \text{ fines load} = \frac{14 \times \text{X}}{y + \text{X}}
\]

where: \( \text{X} \) is the maximum force (kN). \( y \) is the mean percentage fines from two tests at X kN force.

This equation was initially proposed by Shergold and Hosking (1959) based on the experimental relation established between the loads and the fines produced in the aggregate crushing tests carried out under differing loads. Even though this relation was found to be curvilinear in the majority cases, Shergold and Hosking (1959) suggested that for practical purposes, the relation could be considered a straight line over the 7.5 to 12.5 per cent fines range in the fines versus load diagram (Fig. 1), and the straight line passes through fixed coordinates (0.4), at zero load for all the aggregate types and could have differing slope angles for different aggregates. While a high ten per cent fines load value indicates a stronger aggregate, a low value indicates a weaker aggregate.

A brief review of the aggregate requirements for the construction industry has shown that while some specifications include the ACV, the others include the ten per cent fines load as one of the requirements. Although both tests have been known for a long time and are carried out more or less in the same manner, there have not been many studies made to investigate their interrelation (Shergold and Hosking 1959, Wehnert 1984). Additionally, there is no accepted or theoretically established relation between these two aggregate tests. If there was such a relation established, this would not only make the specifications more flexible, but would also make better use of the already existing test results on aggregates. For example, Road Note 59 gives a list of aggregate crushing value test results but not of the ten per cent fines load. Thus, such a relation would widen the application of the already available aggregate results.

In this paper, a relation has been proposed between the ACV and the ten per cent fines load of aggregates, based on the observations and assumption that there is a linear relation between the load and the fines produced in the ACV tests carried under different compressive loads. The linear relation between the load and fines of the ACV test, can have not only different slope angles but also different coordinates at zero load. The curves obtained between the ACV and the ten per cent fines load, based on the above assumption, have been compared with the laboratory and published test results and the reasons for the departure from the established curve have been given. Additionally, a general method of ACV test has been proposed based on the proposed relation and practical findings.

**Specification requirements**

A review of the aggregate requirements for constructional use has shown that either the ACV or the ten per cent fines loads are specified. Since the ACV test was the first to be standardized, (BS 812 - 1943), this test was included in the early specifications for roads and