The measurement of particle elongation and flakiness: a critical discussion of British Standard and other methods*

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Contribution by F. A. Shergold

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Mr Lees has made a most useful contribution to knowledge on the subject of particle shape. The methods for measuring particle shape that he suggests will certainly give more accurate results than the present British Standard methods and should be invaluable in research on the subject, where a high degree of accuracy is required. There is one aspect of the subject, however, that Mr Lees does not deal with, namely, the degree of accuracy required in routine testing where often large numbers of samples have to be tested and time is an important factor. This omission has led him to make a number of criticisms of the British Standard shape tests, with which we cannot agree. The need for routine tests to make no more demands on time than is consistent with achieving the required level of accuracy was very much in mind when the British Standard tests for the shape of aggregates were developed, as can be seen from the reports on the extensive research carried out before the war by the Road Research Laboratory on which the tests were based[1-3], and to which Mr Lees unfortunately does not refer.

His first main criticism is that the tests are based on the assumption " that the average intermediate diameter of the particles between the two sieves is equal to the arithmetic mean of their rated openings ". In the development of the tests, however, this assumption was made for round-holed sieves only, where Mr Lees agrees it is correct. For square-holed sieves the report[1] says: " Experience shows that the use of sieves having square openings does not affect the truth of this argument, although in this case the ' intermediate dimension ' cannot be so simply defined. For such sieves the ' intermediate dimension ' is approximately 1·2 times the mean sieve size ". Mr Lees finds values for this ratio which range from 1·18 for uncrushed gravels to 1·29 for crushed rock, so there is no serious disagreement here. The assumption made in the tests is that this ratio of the intermediate dimension to the mean sieve size is the same for all aggregates, and can therefore be neglected. We think this assumption is justified and that the variation from 1·18 to 1·29 is not significant in routine testing.

Mr Lees' second main criticism is that the tests are based on the assumption " that the intermediate diameter of most of the particles will be close to the average ", and he has shown convincingly that where accurate information on the shape of each particle is required this assumption leads to error. In routine testing, however, accurate information is not required on the shape of each particle; all that is required is a measure that will give a valid comparison of the flakiness, elongation or angularity of different samples of aggregate. In the British Standard tests the assumption made is not so much that the intermediate diameter of most of the particles will be close to the average as that the distribution of the intermediate diameters of particles about the average will be similar in different samples of single-sized aggregate. This assumption has been shown to be true for most single-sized aggregates.[4]

Mr Lees quotes a paper by Shergold and Manning in support of his statement that " Even judgement by eye, when trained observers are employed, is considerably superior to the use of gauges in classifying particles into shape categories ". There is nothing in the paper quoted to support this statement. The work described in the paper showed that there was general agreement between different observers and between the observers and the results of the British Standard flakiness and elongation tests, but there was nothing to suggest that the judgement of the observers was superior to the use of gauges in classifying particles.

As an example of the type of gauge that he thinks should be used in shape measurements, Mr Lees quotes the adjustable gauge used by Rösslein in one investigation only (this gauge suffers from the disadvantage that the measuring surfaces are not parallel), but fails to mention the more practical gauge devised by Schulze,[5] which is now used in the German standard method for measuring the shape of aggregates.

The British Standard shape tests have been in use for nearly thirty years, but it is only in the last year or two that criticisms have been raised against them. These criticisms result partly from a misunderstanding of the purpose of the tests and partly from unawareness of the considerable amount of research on which the tests were based. It is our opinion that the tests provide a satisfactory routine means for comparing the particle shape of different samples of aggregate. Until evidence is produced that they place aggregates, as distinct from particles, in the wrong order of merit, we see no reason for replacing them by more accurate and time-consuming methods.

REFERENCES

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Reply by the author

Before replying in detail to Mr Shergold's comments, the author notes that the major disagreement seems to be not whether the present methods of determining the flakiness index and elongation index by means of the British Standard gauges contain some inaccuracies, but whether it is worth attempting to remove or reduce these inaccuracies.

Mr Shergold's attitude is that, because the tests have proved useful for nearly 30 years, no improvements are necessary in routine testing, although he admits that greater accuracy may be " invaluable in research on the subject ".

The author's view is (1) that any increase in accuracy is worth while, even in routine testing, if it can be achieved at no further cost in time or money and (2) that if the standard of accuracy of the routine test can be increased to a level which makes it acceptable in research, then the same methods can be used for both, and the chances of the research yielding useful results are increased. In this particular aspect of the measurement of particle elongation and flakiness it is possible to improve the techniques for measurement without making any increased demand on time, thus satisfying at the same time the needs of both research and routine testing.

I will now reply specifically to some of the points raised. Mr Shergold's second and third paragraphs apparently concede the main points made in the paper regarding the inaccuracies arising out of the assumptions made in the construction of the British Standard flakiness and elongation gauges. He finds " no serious disagreement " with the findings that the average intermediate diameter can be as much as 1·29 times the mean sieve size for crushed aggregate and 1·18 times this size for uncrushed gravel (the effect of which is to base the flakiness index calculation on a flatness ratio of approximately 0·47 for gravels compared with a flatness ratio of 0·51 for crushed rock) or with the statement that the assumption that " the intermediate diameter of most particles will be close to the average . . . leads to error ". With regard to the first of these, the statement, derived from Road Research Bulletin No. 2, that " the assumption that the average intermediate diameter is equal to the arithmetic mean of the two rated sieve sizes was made for round-holed sieves only " is irrelevant, since all specimens to be applied to the flakiness and elongation gauges are required by B.S. 812:1960 to have been initially screened out on square-mesh sieves conforming to B.S. 410, *Test sieves*. The further statement that " experience shows that the use of sieves having square openings does not affect the truth of this argument " is demonstrated to be false by Figure 2 of my paper.

To summarize the position, the question of whether the inherent inaccuracies in the gauges can be tolerated in routine testing, hinges, as Mr Shergold suggests, on their significance and on the time factor. With regard to significance, the author's view is that our knowledge on the relationships between particle shape and behaviour is insufficient for us to know just what is significant. The question is not whether the tests " place aggregates in the wrong order of merit " but whether different types of aggregate are being tested by reference to a single standard of flakiness and elongation, whether they are being tested in accordance with the criteria of particle flakiness and elongation stated in B.S. 812:1960 and whether aggregates so tested are being properly rejected or properly accepted in consideration of their shape properties relevant to the use to which they are to be put.

With regard to the time factor, it does not follow that methods which are more accurate are necessarily more time-consuming. For example, it takes no longer to apply 200 particles to a slot cut to a certain ratio of the mean sieve size than it does to apply them to a slot cut to a different ratio. And if adjustable gauges of the Rösslein (or Schulze) type are used, even supposing the determination of each particle took twice as long, it is arguable either that the increase in time is worth while or, if it is not, that 100 particles accurately gauged give a better indication of aggregate shape than 200 particles gauged only approximately. (Gauging by eye, mentioned in the paper as being superior to use of the standard gauges, where trained observers are employed, would certainly be more rapid, but is not recommended in routine testing since it would introduce an unwelcome human element. The reference to the paper by Shergold and Manning was not intended to claim their support for the statement which preceded it, which in fact refers to an opinion formed during work in our own laboratories, but was included as a general reference on the subject of judging aggregates by eye and to show that others had found the method satisfactory. I apologize to Messrs Shergold and Manning if another interpretation was possible.)

In conclusion, the paper under discussion did not set out to supply the final answer to the problem of measurement technique, but rather, by drawing attention to the inaccuracies which exist and to possible alternative solutions, tried to promote an awareness of the problem and provide a basis for discussion.