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Studies of the texture of some roadstone materials by scanning electron microscopy

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The surface texture of roadstones made from blastfurnace slag and mixtures of other waste materials has been studied by means of the scanning electron microscope. The importance of considering more than one level of texture when assessing the resistance to skidding of the roadstone has been confirmed and a correlation between levels of the surface texture as observed by scanning electron microscopy and the polished stone value of the roadstone has been established.

1. Introduction

The skid resistance of modern roads, subjected to heavy traffic, has become of increasing importance. The skid-resistant properties must be retained during wear and this limits the materials which are available for surfacing. The relationship between the skidding resistance of bituminous road surfaces and the incidence of accidents has been established by Giles and Sabey [1] while, more recently, Hatherley and Lamb [2] have shown that the frequency of road accidents at locations with high accident rates can be significantly reduced by improving the skidding resistance of the road surface.

It has also been established [3] that the most important factor in determining the resistance of a bituminous road surface to skidding is the nature of the exposed aggregate. The best laboratory assessment of the aggregate is provided by its Polished Stone Value (PSV) [4] which is a frictional parameter of the aggregate determined after a prescribed polishing routine. This has been found to correlate reasonably well with frictional coefficients measured on the trafficked road surface and which are acknowledged to give a more realistic assessment of the resistance to skidding of the surface.

A considerable amount of research has been undertaken in recent years with the object of supplying aggregates of high polished stone value. Calcined bauxite was found by James [5] to have an exceptionally high resistance to polishing while in the same publication the possibilities of producing other aggregates with similar or better properties were discussed. The progress made in synthesizing such aggregates is reported by Hosking [6].

In work which commenced in 1966 at the Building Research Station attempts have been made to devise a method of manufacturing a roadstone of improved skid resistance from blastfurnace slag. To achieve this, however, it has been essential to identify those properties of blastfurnace slag which govern its PSV. It was found [7] that compounds present in the slag have differing PSV's and that the PSV of slag depends predominantly on the crystalline texture and porosity. It was established that both increased crystal size and increased porosity improved the PSV but that too high a porosity degraded the wearing properties of the slag. High temperature microscopy was used to devise heating cycles which would enlarge the crystal size and these cycles were reproduced in a furnace on a pilot scale. In this way the PSV of the slag was improved from 52 to 62.

More recently research has been undertaken to study the synthesis of roadstone of high PSV from mixtures of waste materials [8].

During the investigation of the blastfurnace slag a preliminary assessment of the texture of the slag specimens was made by means of the scanning electron microscope. This aspect of the work has now been expanded and a detailed study has been made of the surface texture of both the blastfurnace slag and other roadstone materials. This is the subject of the present paper.

2. Experimental

The composition of the blastfurnace slag and

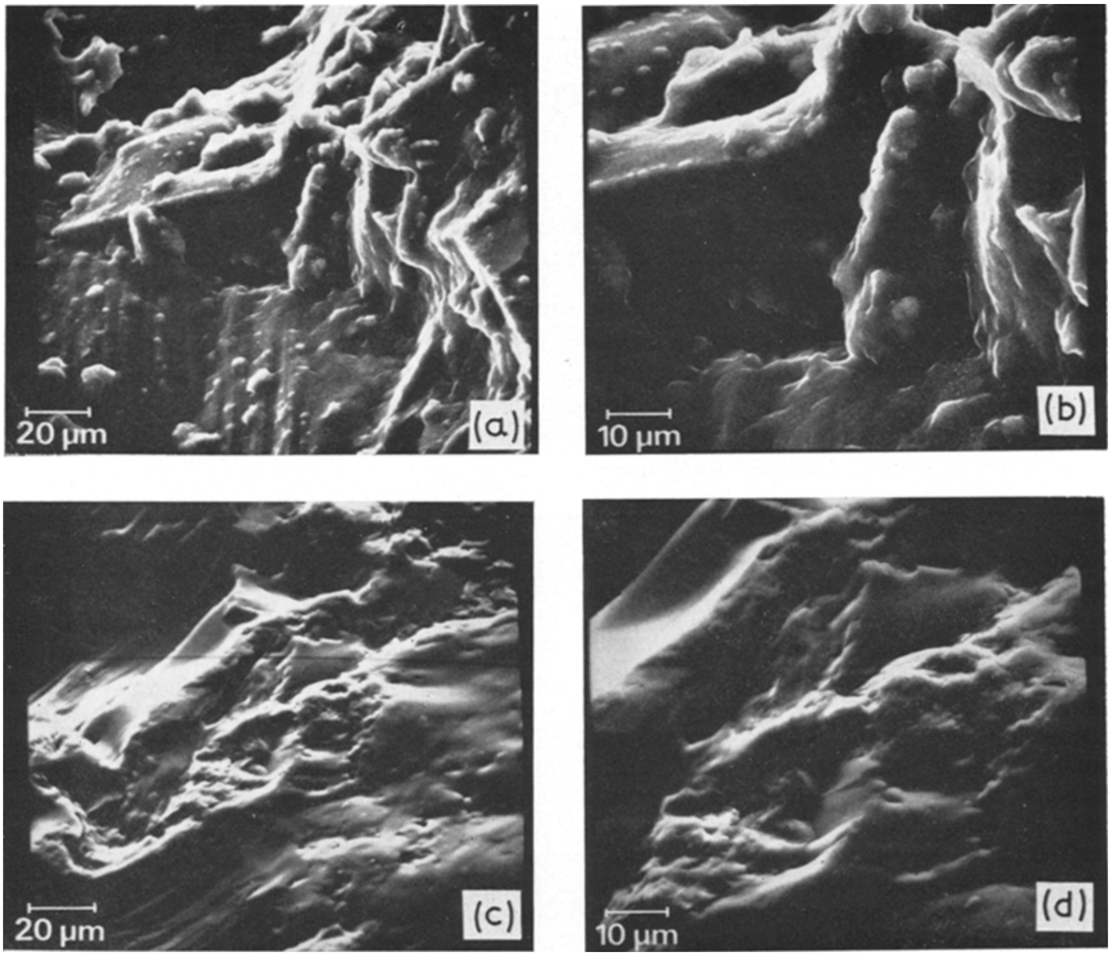


Figure 1 Scanning electron photomicrographs of the surfaces of the original slag aggregate. (a) and (b) before polishing, (c) and (d) after polishing.

the heat-treatments which were used to improve its PSV are described by Gutt and Hinkins [7]. The manufacture of the synthetic slag aggregates will be discussed in a later paper.

The polished stone values of the aggregate were determined in accordance with BS 812:1967 [4]; the description "polished" in this paper refers to an aggregate which has been subjected to the accelerated polishing procedure detailed in the standard.

The aggregate surfaces were studied using a Cambridge Instruments "Stereoscan" Scanning Electron Microscope. Before examination the specimens were cleansed in an ultrasonic bath of distilled water and were coated with a thin film of carbon in order to make their surfaces conducting.

3. Results

3.1. Blastfurnace slag aggregate

The photomicrographs in Figs. 1a to d show the polished and unpolished surfaces of the original slag aggregate which had a PSV of 52. After heat-treatment its PSV was improved to 62 and Figs. 2a to d show the polished and unpolished surfaces of the improved aggregate. It can be seen that the unpolished surface of the improved aggregate has texture on two scales. Firstly there is texture on a scale of 10 to 50 μm. This may be termed the primary micro-texture. Superimposed on this is a finer texture on a scale of 1 to 5 μm which may be termed the secondary micro-texture. In contrast the unpolished surface of the original aggregate exhibits only the primary microtexture to any marked degree. This can best

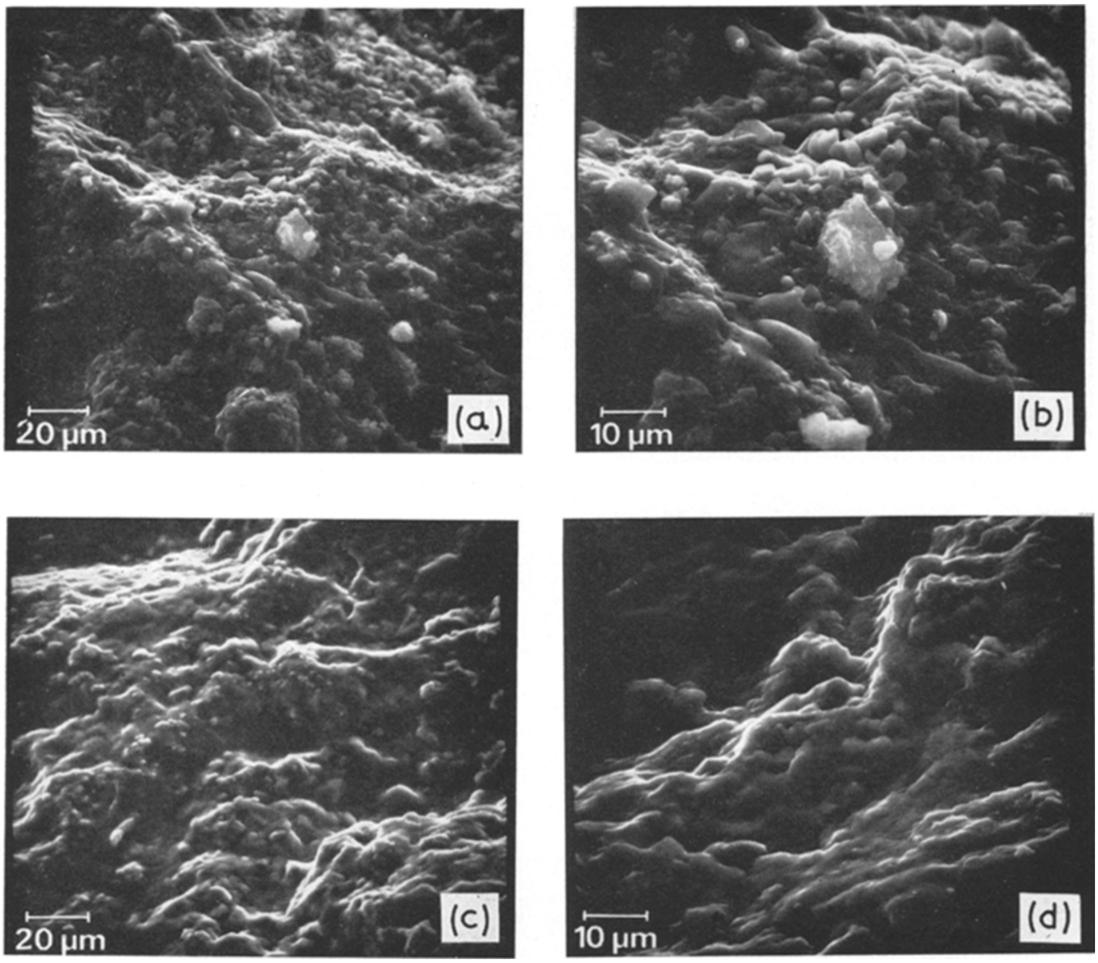


Figure 2 Scanning electron photomicrographs of the surfaces of the improved slag aggregate, (a) and (b) before polishing, (c) and (d) after polishing.

be seen by comparing the high magnification micrographs (Fig. 3).

During the polishing process the surfaces of both the original and the improved aggregates suffered considerable loss of texture. However, the secondary micro-texture of the improved aggregate is still clearly visible while at the 1 to 5 μm scale the surface of the original aggregate appears quite smooth.

Fig. 4 shows the unpolished surface of a blast-furnace slag aggregate from a different source. This aggregate had an initial PSV of 60 but was not susceptible to significant improvement by heat-treatment. It can be seen that it has considerable secondary micro-texture in the form of plate-shaped crystals, probably crystals of rankinite. The crystals in the hollow of the surface are particularly well developed and probably originated in vesicules of the porous slag. The surrounding material has a much more broken appearance.

3.2. Synthetic aggregates

Figs. 5 to 9 show the unpolished surfaces of four synthetic aggregates which have polished stone values of 50, 63, 68 and 90. The first three have the same overall chemical composition. Two micrographs of calcined bauxite (PSV 75) are included for comparison.

The aggregate having the low PSV of 50 (Fig. 5) can be seen to have relatively little of either primary or secondary micro-texture. The lack of secondary micro-texture is shown well by the almost featureless micrograph at a

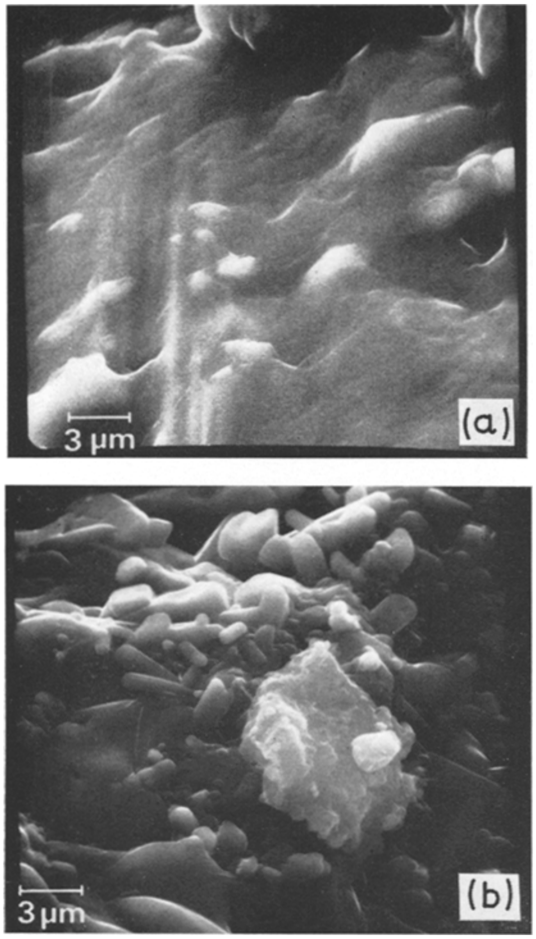


Figure 3 Scanning electron photomicrographs of the unpolished surfaces of the improved and original slag aggregates, (a) original (b) improved.

magnification of 6000. The surface of the aggregate of PSV 63 (Fig. 6) has considerable primary but little secondary micro-texture, while the aggregate having the best PSV in this series (Fig. 7) has both good primary and good secondary micro-texture. Fig. 8 shows the surface of the material of PSV 90. Again this has well developed primary and secondary micro-texture. The calcined bauxite has extremely good secondary micro-texture but relatively poor primary micro-texture.

4. Discussion

It has been recognized previously that the texture of the road surface is important. Sabey [9] considered that both the macro-texture, formed by the projection of the aggregate particles from the binder, and the micro-texture, influence the skidding resistance. The macro-texture prevents the formation of continuous fluid films between the tyre and road in wet conditions and provides channels for the water to drain away. This is particularly important at high speeds. The micro-texture contributes to the adhesion between the tyre and the road surface and is the dominant factor determining low-speed skidding resistance. More recently, however, it has been recognized that at least two levels of micro-texture can be usefully specified in high performance aggregates. Williams and Lees [10], from an examination of calcined bauxite, considered three levels of texture: (a) A surface made up of unit aggregates approximately 7.5 mm in diameter. (b) The conglomerate of smaller grains, size approximately 100×10^{-3}

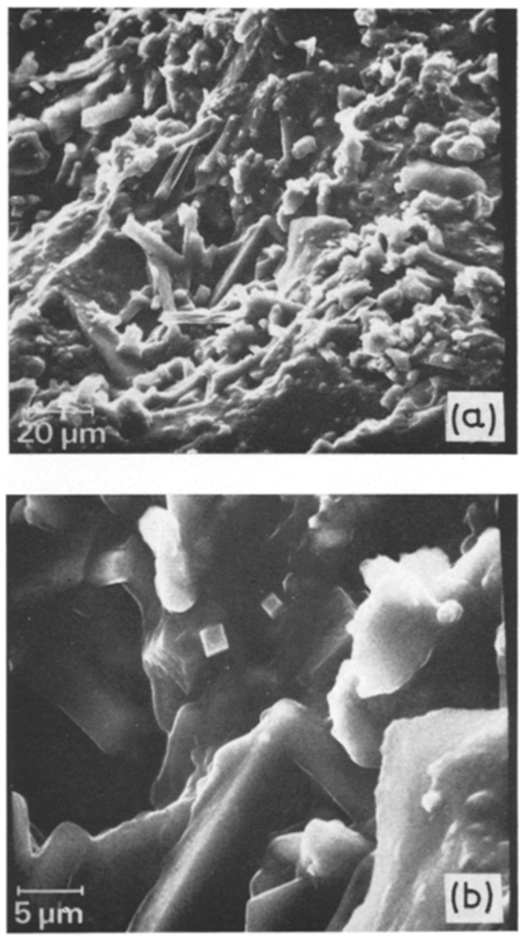


Figure 4 Scanning electron photomicrographs of the unpolished surface of slag aggregate which had a high initial PSV.

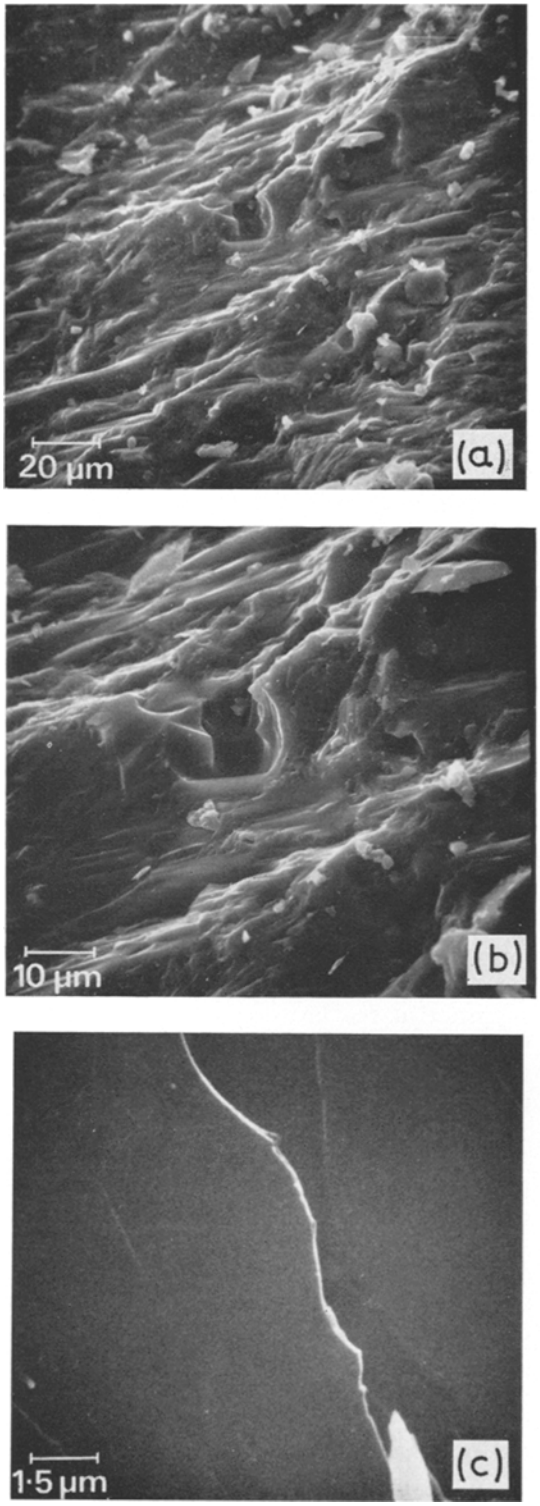


Figure 5 Scanning electron photomicrographs of the unpolished surface of the synthetic aggregate having a PSV of 50.

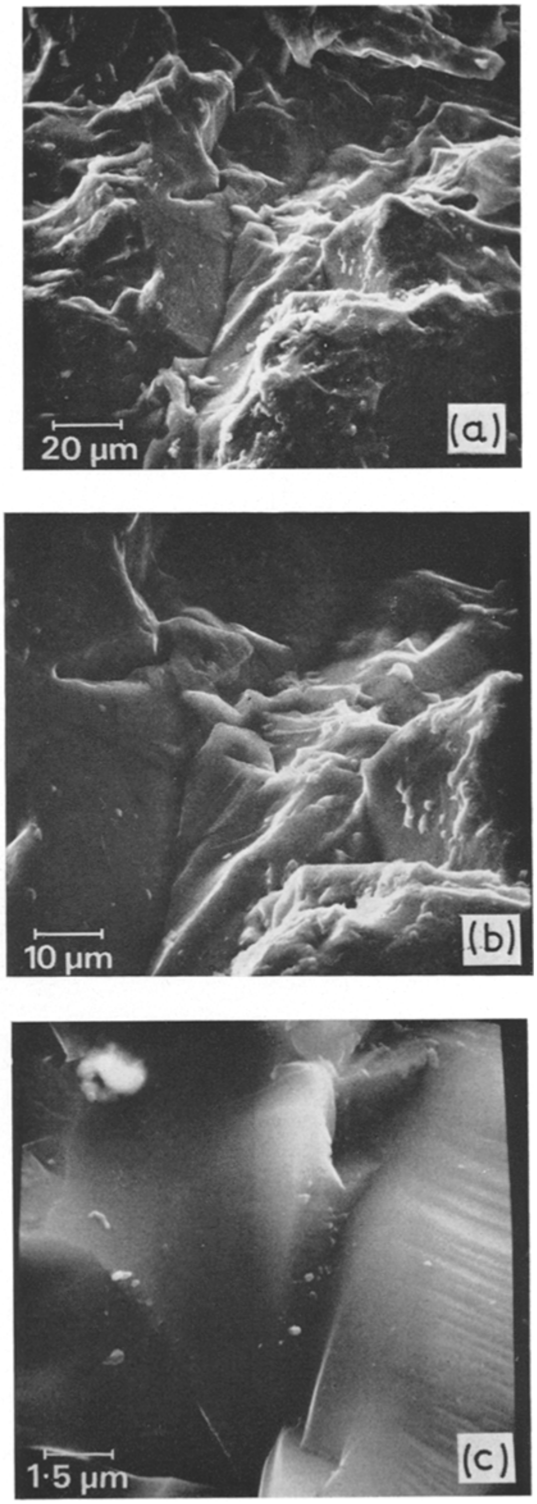
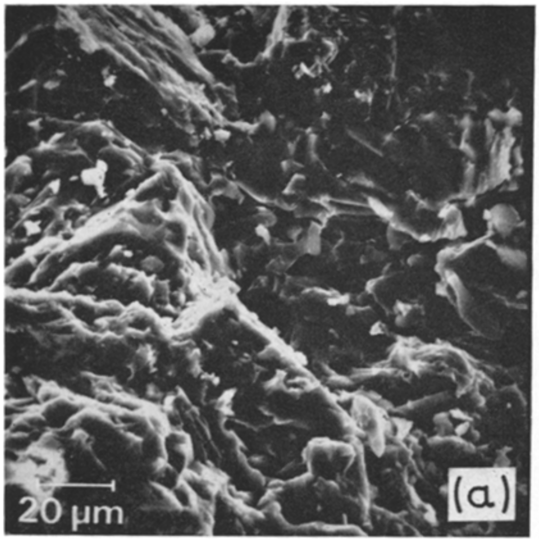
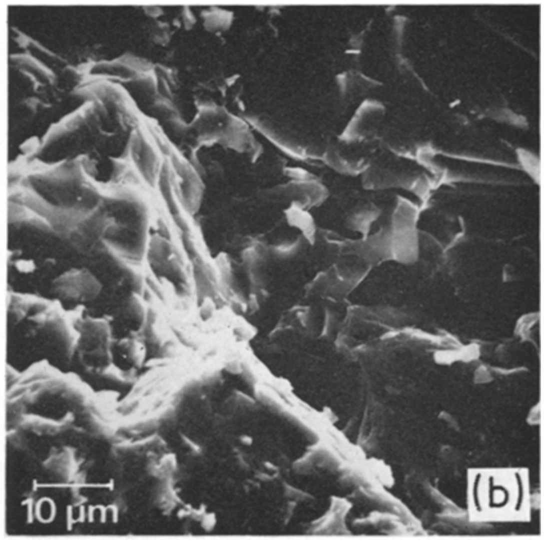


Figure 6 Scanning electron photomicrographs of the unpolished surface of the synthetic aggregate having a PSV of 63.





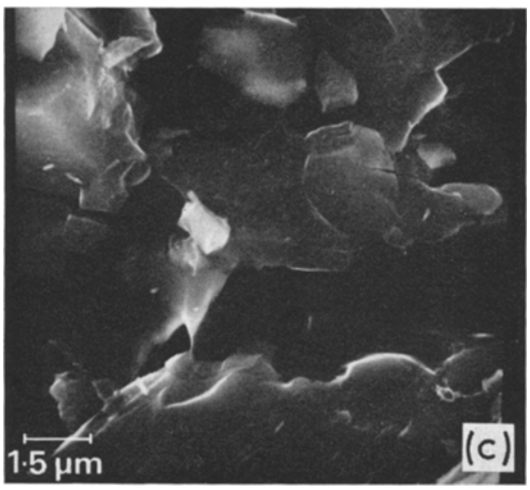


Figure 7 Scanning electron photomicrographs of the unpolished surface of the synthetic aggregate having a PSV of 68.

mm across, which comprise the unit particles. (c) The conglomerate of individual crystals of sub-angular nature, approximately 10^{-3} mm long and 5×10^{-3} across which comprise the small grains. They also found that scratch marks of nominal length 5×10^{-3} mm and depth approximately 0.2×10^{-3} mm, caused by the use of a coarse emery abrasive, raised the wet skid resistance values by 8%, emphasizing the importance of the fine micro-texture.

The results reported here confirm the necessity of considering more than one level of micro-texture when assessing the surface of a roadstone and they also show that a correlation can be established between micro-texture and PSV.

The micrographs of the blastfurnace slag aggregate show that where secondary micro-texture on a scale of 1 to 5 µm has developed on heat-treatment, an increase of PSV has resulted. This texture is retained to a considerable degree during the polishing process and is comparable to the smallest level of texture recognized by Williams and Lees. The aggregate which had a good initial PSV also had a well developed micro-texture but its PSV was not significantly improved on heat-treatment. These results suggest that the heat-treatment process leads, simultaneously with the enlargement of crystals [7], to the formation of the secondary micro-texture and that this secondary micro-texture is an essential feature of slags of improved PSV. Where the mineralogy of the original slag is such that it has a good secondary micro-texture, its PSV is probably an optimum and cannot be improved without altering the chemical composition.

The micrographs of the synthetic aggregates support the view that within a system of a particular chemical composition the best PSV is obtained when the surface has a good secondary micro-texture (of the order of 1 to 5 µm) superimposed on to a good primary micro-texture (of the order of 10 to 50 µm). A good primary micro-texture alone will give a moderately good PSV as is illustrated by the aggregate of PSV 63. Similarly it would appear likely that

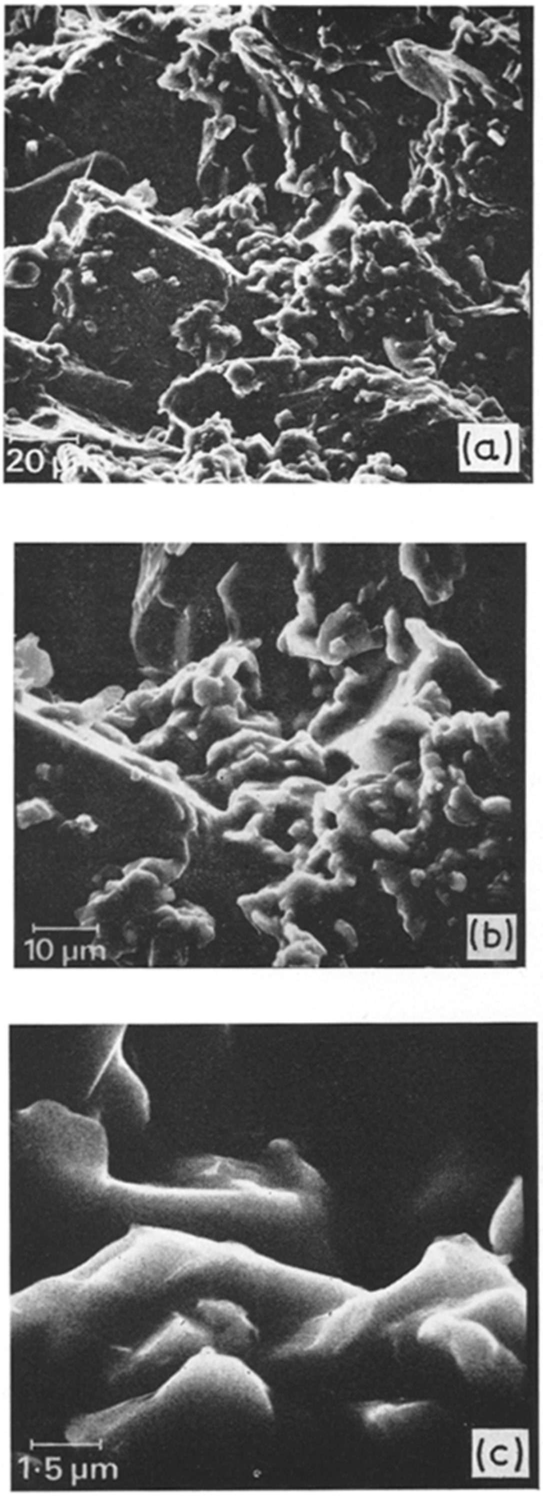


Figure 8 Scanning electron photomicrographs of the unpolished surface of the synthetic aggregate having a PSV of 90.

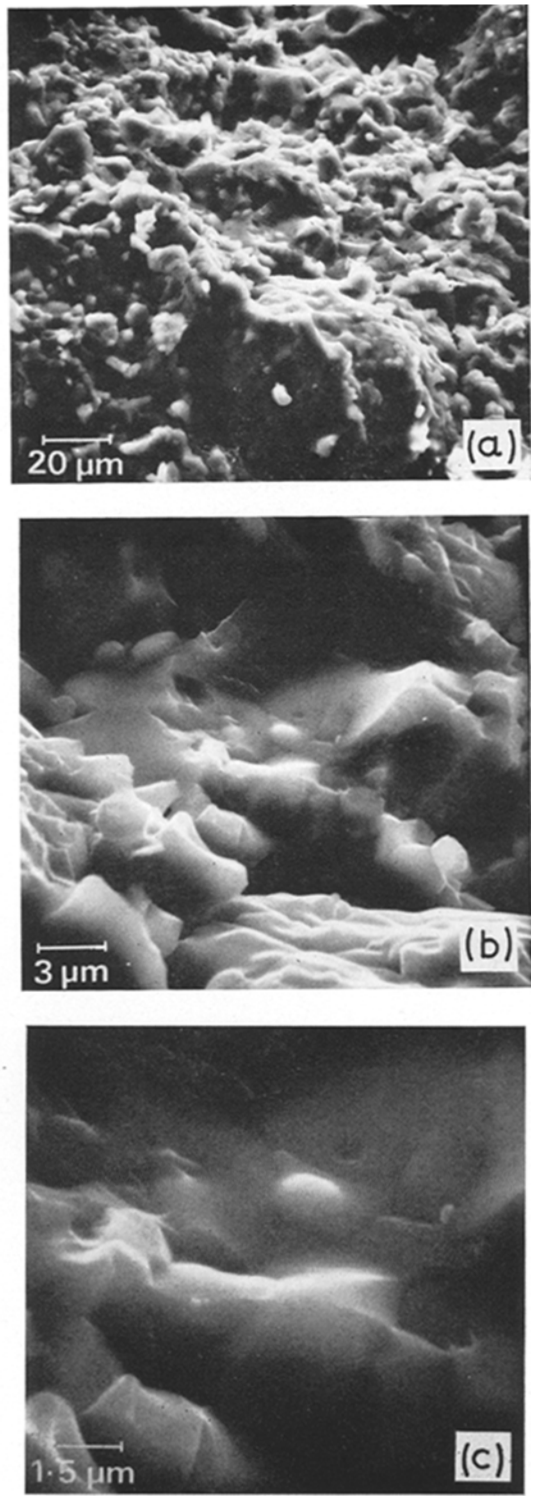


Figure 9 Scanning electron photomicrographs of the unpolished surface of calcined bauxite.

the PSV of calcined bauxite could be increased by a treatment to develop its crystal size and so improve its primary micro-texture. Systems of different chemical composition will have different ranges within which the PSV will vary because of the physical properties of the phases within the system, the most important of which is probably hardness. Thus the very high PSV of 90 occurs in a material where a good secondary micro-texture is superimposed on a good primary micro-texture and when the material itself is inherently very hard. It should be emphasized that for a material to be offered as a durable roadstone, properties other than PSV, for instance, the Aggregate Abrasion Value, would need to be determined.

These effects have proved sufficiently predictable for it to be possible to forecast the PSV of a new synthetic aggregate to within 5 units from stereo-micrographs provided the observer has experience of the microscopic appearance of the type of aggregate being examined and provided the range over which the PSV of the particular system can vary is known.

Acknowledgement

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