Properties and performance of recycled aggregates

by Dr M Mulheron and M M O'Mahony

The authors review recent research on the recycling of crushed aggregates, examining their physical and mechanical properties and gauging their suitability as sub-base materials for roads

The research work reported here[1] was carried out in 1987 as part of a four-year programme sponsored in part by the Institute of Demolition Engineers on the recycling of demolition debris.

The physical and mechanical properties of crushed concrete and demolition debris from a variety of sources were examined to assess the suitability of these aggregates for use as Type 1 or Type 2[2] granular sub-base materials. In particular, sieve analyses and compacted density tests were conducted, during the construction of a road in Portsmouth, to compare the use of crushed concrete and limestone as the upper part of the capping layer. The tests were carried out in accordance with British Standards[3,4] and the Department of Transport Specification for Highways Works[2]. A significant part of the work consisted of sieve analyses of the material to assess the ability of recycling plants, currently in operation, to produce well graded material.

The object of the research project is to produce draft specifications and standards for the use of recycled aggregates obtained from demolition debris. The project has been divided into three phases, and this report deals with Phase 1, the objects of which are (i) to assess the ability of recycled aggregates, currently in production, to meet existing specifications and standards for Type 1 and Type 2 granular sub-base material, and (ii) to monitor the performance of recycling plants in operation in the UK and investigate the sources of any variation in the recycled aggregates produced by such plants.

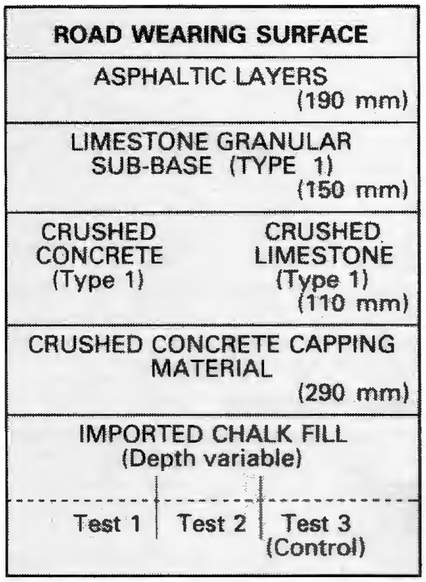

Figure 1. Details of test lengths for Portsmouth field trial.

The aim of the field trial in Portsmouth was to observe the differences between crushed concrete of Type 1 particle grading and Type 1 limestone as capping layers in the construction of two lengths of road. A layer of crushed concrete capping material was placed to a depth of 180 mm above the chalk fill. For the remaining 110 mm of the capping layer, Type 1 limestone was placed on a 50 m length of road and crushed concrete having a Type 1 grading was used on the other test length. Test details are given in Figure 1.

The demolition debris which was provided for testing was a crushed concrete produced in a single crusher operation and demolition debris from a double crusher operation. Crushed concrete, crushed brick and a mixture of both, originating from a plant in Holland, were also tested. As recycling of crushed aggregates is at a more advanced stage in Holland, where recycled products are currently used as road sub-base, it was interesting to note if similarities existed between Dutch and British products. The crushed concrete used in the

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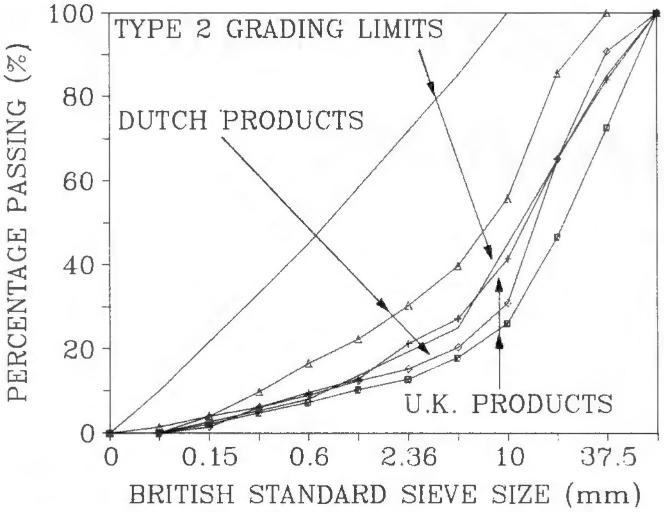

Figure 2. Particle gradings of British and Dutch materials.

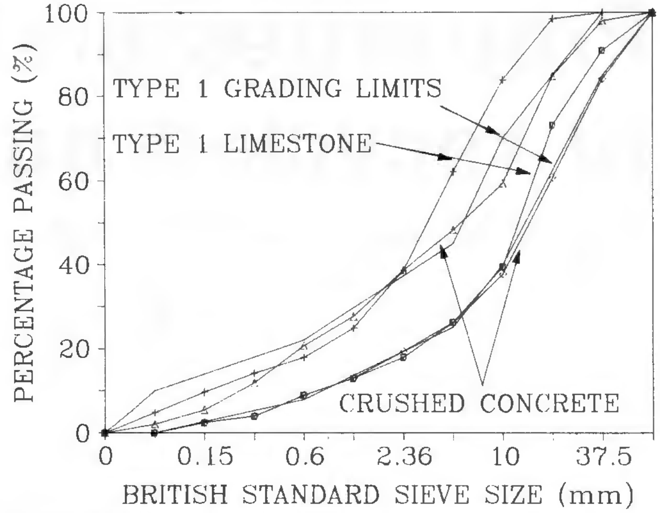

Figure 3. Particle gradings of materials used in Portsmouth trial

Portsmouth field trial was specified as having Type 1 particle grading and the limestone was specified as being a Type 1 material.

Particle grading

Type 2 graded British products had coarser particle gradings than required to comply with the Specification for Highway Works. This can be seen in Figure 2. Dutch products were less coarse, and therefore had gradings which were for the most part within the Type 2 grading envelope. The particle grading of the Dutch crushed brick fell almost centrally between the limits of the Type 1 grading envelope.

Particle grading of the Type 1 graded crushed concrete, used for the Portsmouth field trial, fell within the Type 1 specified grading for the most part, as is clear from Figure 3. During the screening in this particular crushing operation, variations in the volumes of material passing 6 mm and 10 mm screens dictate whether the material is to be Type 1 or Type 2 graded granular sub-base material. The grading of this crushed concrete compares favourably with the grading of the limestone material which is included in Figure 3. It is noticeable that the limestone falls well outside the Type 1 grading limits in the 5 mm-20 mm range and exhibits a greater variability compared to the crushed concrete.

Compacted densities

The method for determining *in situ* densities was conducted in the following manner. The capping layer and sub-base layer of the road were first laid and compacted using a standard vibrating roller. The roller had a weight of 3600 kg/m width. A hole of diameter 300 mm was then dug, to a depth equivalent to that of the top layer. The material was collected, stored in that condition and later weighed. The hole was lined with a thin polythene sheet and subsequently filled with water, the volume of which was known. Using the volume of water required to fill the hole and the weight of material collected, the compacted density of the layer could be calculated. The same procedure was conducted on the lower layer.

It is apparent in Figure 4 that the crushed concrete had lower compacted densities than the limestone, but the density of the crushed concrete is more consistent. As the compacted density of the material is dependent on the particle grading, this shows that recycling plants can produce material of consistent particle grading.

Other tests

Plasticity tests carried out on crushed concrete in accordance with BS 1377[3] revealed the material was non-plastic. It was clear, from examination of the material, that it was pure and did not contain much brick. This is perhaps the reason for lack of plasticity in the samples.

The 10% fines test measures the resistance of an aggregate to crushing. The test was conducted in accordance with BS 812[4]. The test consisted of applying an incremental load to the aggregate and measuring the percentage fines for each increment. The test was carried out on crushed concrete. Thames valley aggregate and Dutch Brick, the results can be seen in Figure 5. The natural aggregate had almost double the resistance to load of the Dutch brick. The crushed concrete is also somewhat stronger than the brick. The fact that 10% fines is produced at lower load for the crushed

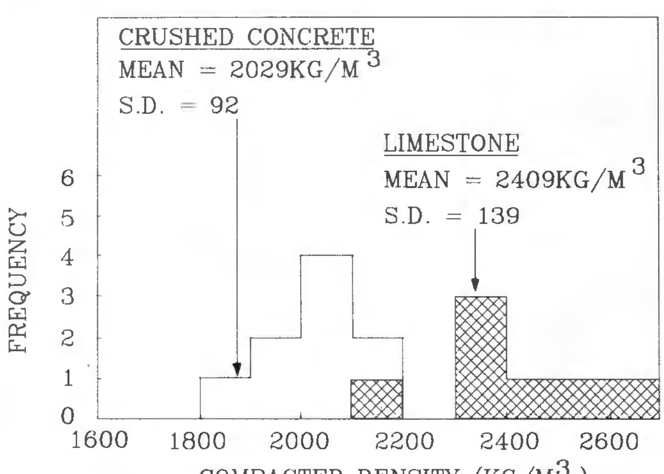

Figure 4. Histogram for compacted densities of materials used

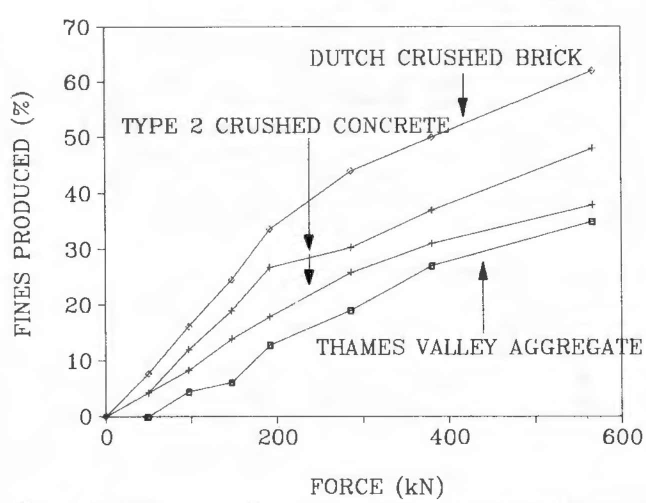

Figure 5. Percentage fines produced in aggregates under

concrete and crushed brick is due to the mortar coating on the particles of these products. However, all materials had 10% fines values greater than the required 50 kN for Type 1 and Type 2 material.

Relative densities of the crushed concrete ranged between 2.29 and 2.34 which corresponds well with values obtained on other studies[6,7]. Moisture contents were in the range of 7.7 and 10.8 depending on stockpile conditions. The water absorption of the crushed concrete tested ranged from 6.43% to 7.9% in comparison with 7% to 8.7% found by Hansen and Narud[7]. Water absorption is greater in recycled aggregates because of high water absorption of the old mortar coating the original aggregate particles.

Conclusions

The conclusion arising from the work so far can be divided into two sections, relating to the materials currently produced by recycling plants and the Portsmouth field trial.

First, assessment of the recycled aggregate production with respect to granular sub-base requirements.

It is obvious that crushed concrete, having a particle grading of Type 1 or Type 2, can be produced from both single crusher and double crusher operations. However, the consistency at which such a material is produced, depends mainly on the crusher setting and sieving process conducted after crushing.

The plasticity of the material depends largely on the brick content. An input of pure concrete will produce a non-plastic material which fulfills the DTp requirement for a type 1 or Type 2 material.

The 10% fines value for crushed concrete was well above the value of 50 kN required for Type 1 and Type 2 materials. Therefore, with respect to this specification, crushed concrete can be considered as a suitable granular sub-base material.

The crushed concrete and demolition debris were produced by single crusher and double crusher operations respectively. Therefore it was difficult to compare the two types of production. However, it seems the double crusher is the more efficient, as oversized particles do not need to be recrushed or discarded, for use as a different product.

Second, the Portsmouth field trial.

The crushed concrete and limestone provided as Type 1 material for the upper layer generally fell within the Type 1 specifications. Therefore, with respect to particle grading, it is clear that crushed concrete can be considered for use as a Type 1 granular sub-base material. In this field trial, both materials were used for the upper 110 mm of the capping layer below the limestone sub-base, as use of crushed concrete in a sub-base layer was not allowed.

The limestone when laid had a higher compacted density than the crushed concrete but exhibited a wider range of values. This variation appears to result from the variable range of particle gradings detected in the limestone samples. The higher densities achieved with the limestone are likely to be partly due to the higher relative density of the material. The densities obtained with the crushed concrete were mainly in the range 1900-2200 kg/m³ and compared favourably with densities obtained from natural aggregate sources.

References

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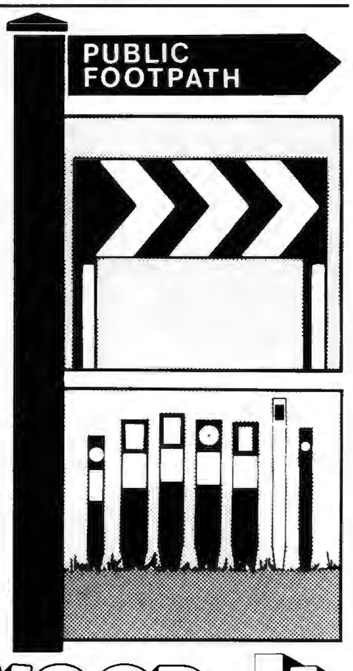

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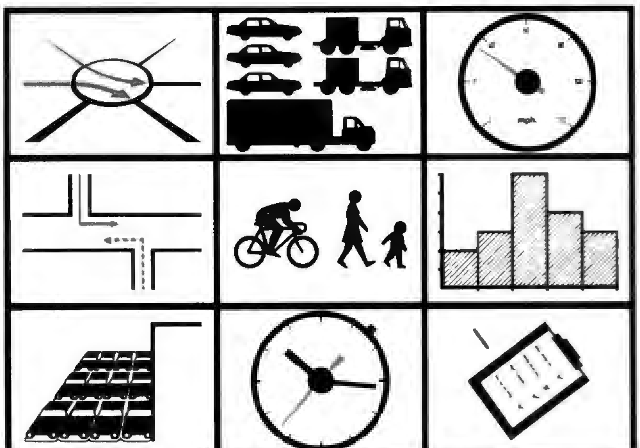

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