Waste Materials in Construction.
J.J.J.R. Goumans, H.A. van der Sloot and Th.G. Aalbers (Editors)

RECYCLING OF CONSTRUCTION WASTE

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SUMMARY

Although Britain is relatively rich in natural aggregate reserves, planning approvals to develop new quarries are running at about half the rate of aggregate extraction. This paper reports on a property study of crushed concrete and demolition debris with a view to using these materials in construction instead of natural aggregate. One of the objects of the research, on which this paper reports, was to accumulate data which would be a basis for the production of a British Standard for recycled materials in construction.

1. INTRODUCTION

Due to an increased awareness of the environment, planning approvals to develop new quarries in the United Kingdom are running at about half the rate of aggregate extraction. The use of secondary materials may not completely remove the problem of the resulting shortage of aggregate but it could alleviate it.

The increasing price of land in London and the South-East of Britain has caused the price of dumping to increase. Therefore demolition contractors have found that it is now more expensive to dump demolition waste then to recycle it. This encouraged the Institute of Demolition Engineers to sponsor research into the properties of aggregates produced from construction waste.

2. MATERIALS

The recycled aggregates included crushed concrete which was obtained from the breaking up and crushing of concrete slabs during a repair contract on the M25 orbital motorway. Demolition debris was the other recycled aggregate which was obtained from the demolition and crushing of various structures. It contained a random mix of materials including brick, concrete, glass, etc. This material was not cleaned and was included in the research as representing the worst condition in which a recycled aggregate might be used. The properties of these aggregates were compared with those of limestone when the materials were being considered for use in road construction. The aggregates were well graded and their particle gradings are included in O'Mahony (6). A further study was conducted which involved comparing recycled aggregate for use in concrete manufacture with the use of natural aggregate.

3. TESTS

For the unbound aggregate property study, the tests included CBR, shear strength, compaction and frost susceptibility tests. The CBR tests were conducted in accordance with BS 1377 (1) and were performed on samples at a range of densities and moisture contents, but particular attention was paid to the optimum moisture content and peak dry density condition.

The shear strength tests were performed in a 300mm x 300mm x 179mm shear box located at the Transport & Road Research Laboratory. The first series of shear strength tests was conducted at the same vertical stress of 50 kN/m^2 but the density of the material was varied whereas in the second series the density was maintained constant and the vertical stress was varied. The third series of shear strength tests involved testing the materials at the same conditions which Earland and Pike (2) describe in their test for the stability of gravel sub-bases.

The compaction tests were conducted to observe whether particles in the fraction 37.5mm-75mm affected the density of aggregates when placed in unbound layers in road construction. Although particles of this size are allowed, the maximum particle size normally present in natural aggregates is 37.5mm but in the demolition debris samples particles larger than this were evident. The frost susceptibility tests were conducted in accordance with Roe and Webster (3), as materials to be placed within 450mm of a road surface should not be frost susceptible. The materials were tested at three moisture contents including the optimum moisture content.

The tests conducted on the recycled aggregate concrete were compressive strength, modulus of elasticity, shrinkage and creep tests. Concrete at a range of water/cement ratios was examined.

4. RESULTS AND DISCUSSION

4.1 Tests on Unbound Aggregates

The CBR of crushed concrete at optimum moisture content and peak dry density was in the range of 400-500% and this compared well with the results for limestone. The CBR of demolition debris was considerably lower at 130% but this result was greater than that required by the Specification for Highway Works (4) for sub-base materials. Both recycled aggregates therefore could be used as sub-base aggregates with regard to bearing capacity.

Compaction tests conducted using a vibrating hammer on material contained in a 300mm diameter mould showed that the particles in the 37.5mm to 75mm range, which were present in the demolition debris samples, did not affect the maximum density which could be achieved. This suggests that the jaws on the crusher in a recycling plant need not be set as closely as those in crushers used in natural aggregate production.

It can be seen in Fig 1 that the recycled materials had friction angles similar to those of limestone although these angles were achieved at lower dry densities. The specific gravity of crushed concrete and demolition debris is lower than that of limestone and this accounts for most of the difference in density but it was found in compaction tests that the limestone particles pack more closely together than those of the recycled aggregates. The recycled aggregates would be useful as lightweight backfill to structures considering their high friction angles and low specific gravities.

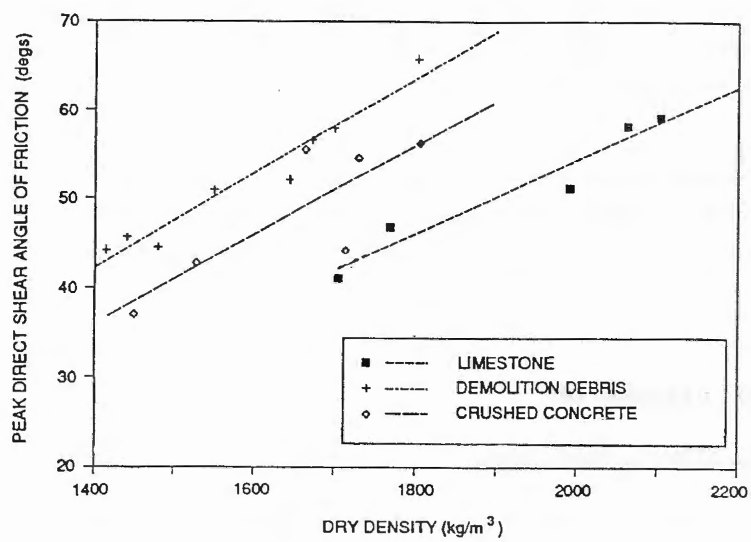

Figure 1. Influence of dry density on the angle of friction.

When the density of the limestone and recycled materials was maintained the same and the vertical stress was altered the friction angles of the materials were found not to be dependent on vertical stress, within the range 50kN/m^2 to 200kN/m^2.

The shear box test (2) for examining the stability of sub-base aggregates, which it is hoped will soon be included in a British Standard, involves testing the material at optimum moisture content and peak dry density at a vertical stress of 10 kN/m^2 and at a shearing rate of 1mm/min. The recycled aggregates, when tested in these conditions, were found to be in the medium strength category, as defined in (2), where a preliminary trafficking trial would need to be conducted on the material before it could be used as an aggregate in a sub-base layer. Limestone was found to be in the high strength category and therefore could be used without a preliminary trafficking trial in normal conditions.

Crushed concrete and demolition debris were found to be frost susceptible whereas limestone exhibited very little frost heave. This was the only test where the recycled aggregates did not perform well. Crushed concrete heaved 18mm at optimum moisture content and peak dry density and the heave exhibited by demolition debris was 12.3mm. The maximum frost heave allowed is 12mm. However, it is likely that the recycled aggregates would exhibit a self-cementing action with time similar to that which was found by Sweere (5). If this was the case then a lower frost heave might be measured if the materials were tested some time after placement. Further research is needed into the frost susceptibility of recycled aggregates.

4.2 Tests on recycled aggregate concrete

The mix proportions for the concrete mixes are listed in Table 1. The compressive strength of the recycled aggregate concrete was comparable with the strength of the conventional concrete after 28 days. The recycled aggregate concretes achieved the same or higher moduli of elasticity.

Shrinkage did not appear to be dependent on the type of aggregate used or the quantity of fine aggregate present but at high water/cement ratios, higher creep was exhibited in the recycled aggregate concrete than in the natural aggregate concrete.

Mix No.	CEMENT	FINE AGGREG	COARSE AGGREG	TOTAL WATER	FREE W/C RATIO	SLUMP (mm)
	Mass (kg) of constituents per m^3					
SET A						
C1	493	1004	670	212	0.36	10
R1	532	1004	670	255	0.35	50
C2	493	1004	670	233	0.4	115
R2	532	1004	670	229	0.3	10
C3	493	1004	670	246	0.45	190
R3	532	1004	670	279	0.4	190
SET B						
C4	580	744	839	236	0.35	35
R4	626	744	839	293	0.35	170
C5	580	744	839	265	0.4	190
R5	626	744	839	261	0.3	40
C6	580	744	839	293	0.45	235
R6	626	744	839	325	0.4	215

Note: C = control, **R** = recycled

Table 1 Concrete mix quantities and slump

5. CONCLUSIONS

It is clear from the above results that recycled aggregates could be considered for fairly demanding situations such as in sub-base layers, as granular fill to structures and as aggregate in concrete. However, further research is needed into the frost susceptibility of these materials and into the effect of varying degrees of contamination in recycled aggregates. Monitoring of contamination would be necessary if recycled aggregate was reused in industry to ensure that deleterious substances were not present.

The production of a British Standard on recycled aggregates and allowable levels of contamination would be useful for demolition contractors hoping to recycle construction waste on a large scale. To accomplish this recycling of construction waste must be taken more seriously by engineers and clients.

ACKNOWLEDGEMENTS

The research on which this paper reports was sponsored in part by the Institute of Demolition Engineers. Funding was also provided by the Geotechnical Consulting Group as part of a contract for the Transport and Road Research Laboratory.

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