Ref. : WB(W) 209/32/105
Group : 5, 12

27 March 2002

Works Bureau Technical Circular 12/2002

Specifications Facilitating the Use of Recycled Aggregates

Scope

This circular promulgates the particular specifications to facilitate the use of recycled aggregates in concrete production, and construction of road sub-base in PWP projects.

Effective Date

2. This circular takes immediate effect.

Effect on Existing Circulars

3. This circular supersedes WBTC 23/2001 and 31/2000.

Introduction

4. The hard inert construction and demolition (C&D) materials, such as broken rock and concrete, can be recycled into aggregates for reuse in construction works. In order to reduce the pressure on the demand for public filling and landfill capacity, it is essential that

the reusable portion of C&D materials be recycled and put into good use. This Circular promulgates the particular specifications to facilitate the use of recycled aggregates in Grade 20 prescribed mix and Grade 25-35 designed mix concrete, and in road sub-base construction. The relevant particular specifications were developed by Standing Committee on Concrete Technology and Highways Department, based on internationally recognized standards and results of laboratory tests carried out locally. The particular specifications are given in Appendices A, B & C.

5. Recycled aggregates are also suitable for use in earthworks, drainage and marine works. The relevant specifications are promulgated in Corrigendum No. 1/2001 to the General Specification for Civil Engineering Works (1992 Edition). The use of recycled aggregates as sub-base materials for footpaths is being examined and if found feasible, a separate particular specification will be issued in due course.

Policy

6. The project department should consider using recycled aggregates in lieu of virgin materials wherever possible in the planning and design of a project, in accordance with the particular specifications in this Circular. Where necessary, provisions should be included in the contract to cater for unforeseen problems, such as an unexpected shortage of supply of recycled aggregates.

7. Any feedback on the use of recycled aggregates and on the specifications should be forwarded to Works Bureau (Attn: PAS(WP&S)) for consideration.

(W S Chan)
Deputy Secretary (Works Policy)

Particular Specification for Prescribed Mix Concrete with 100% Recycled Coarse Aggregate

Scope	This Particular Specification is only applicable to concrete of 20 MPa grade strength
Application	Concrete with 100% recycled coarse aggregate shall only be used in benches, stools, planter walls, concrete mass walls and other minor concrete structures where specifically permitted in the contract.
General Requirements	Concrete shall comply with Section 16 of GS and the additional requirements given below. In case of discrepancies, the requirements in this Particular Specification shall take precedence.
Recycled Coarse Aggregates	Recycled Coarse Aggregate shall be produced by crushing old concrete and shall meet the requirements in Table 1.
Fine Aggregates	Fine aggregate shall be within the limits of grading M in BS 882. Fine aggregate derived from recycled concrete shall not be used.
Grading	The grading of the coarse aggregates shall comply with the limits of Table 3 of BS 882:1992 for single-sized 20 mm and 10 mm aggregates
Mix Proportions	Concrete shall be mixed in the following proportions:

Ordinary Portland Cement	:	100 Kg
Fine Aggregate	:	180 Kg
20 mm Coarse Aggregate	:	180 Kg
10 mm Coarse Aggregate	:	90 Kg

Workability	*Recycled coarse aggregates have to be thoroughly wetted before being used.* The concrete shall have a slump of 75 mm when it is ready to be compacted to its final position.
Test Cubes	4 concrete cubes shall be made on each concreting day, 2 for crushing tests at 7 days and another 2 at 28 days
Minimum Strength	The minimum concrete cube strength shall be 14 MPa and 20 MPa at 7 and 28 days respectively.
Trials	Laboratory trials shall be conducted to confirm that the strength requirement can be met before the prescribed mix is used in the works. The 28 day strength of each of the 3 cubes in the trial shall not be less than 26 MPa.

Table 1

Mandatory Requirements	**Limits**	**Testing Method**
Minimum dry particle density (kg/m3)	2000	BS 812: Part 2
Max. water absorption	10 %	BS 812; Part 2
Max. content of wood and other material less dense than water	0.5 %	Manual sorting in accordance with BRE Digest 433
Max. content of other foreign materials (e.g. metals, plastics, clay lumps, asphalt and tar, glass etc)	1 %	
Max. fines	4 % -Note 1	BS 812: Section 103.1
Max. content of sand (<4mm) (% m/m)	5 %	BS 812: Section 103.1

Mandatory Requirements	**Limits**	**Testing Method**
Max content of sulphate (%m/m)	1%	BS 812: Part 118
Flakiness index	40 % - Note 2	BS 812: Section 105.1
10% fines test	100 kN- Note 3	BS 812: Part 111
Grading	Table 3 of BS 882:1992	
Maximum Chloride content	Table 7 of BS 882 – 0.05% by mass of chloride ion of combined aggregate – Note 4	

Note 1 Filler (<0.063mm) should be less than 2% in the RILEM Specification. BS 882 says that fines passing 75μm sieve shall not exceed 4 %. The latter requirement is easier to satisfy.

Note 2 Clause 16.08 (3) of the General Specification for Civil Engineering Works (GS) states that flakiness shall not exceed 35% whereas BS 882 states that it shall not exceed 40% for crushed rock or crushed gravel.

Note 3 Clause 16.08(3) of GS states that the 10% fines value shall be at least 100kN. BS 882 states that the 10% fines value to be 50kN for concrete not subjected to wearing. BRE Digest 433 states that 70kN is achievable in recycled aggregate derived from brickwork, and 100kN for those derived from crushed concrete. In recent tests carried out on recycled aggregates derived from old concrete,100kN can be satisfied.

Note 4 BRE Digest 433 recommends to determine acid soluble chloride rather than water soluble chloride.

Particular Specification for Designed Mix Concrete with 20% Recycled Coarse Aggregate

Scope	This Particular Specification is only applicable to *designed mix* concrete of 25-35 MPa grade strength.
Application	Concrete with 20 % recycled coarse aggregates is for general application *except in water retaining structures* or otherwise precluded in the contract.
Cementitious Material	Only ordinary Portland Cement to BS 12 shall be used.
Coarse Aggregates	Coarse aggregates shall consist of 80% natural rock aggregates as defined in Cl. 16.08(3) of GS and 20% recycled coarse aggregates. Recycled Coarse Aggregates shall be produced by crushing old concrete and shall meet the requirements in Table 1. Tests on recycled aggregates from a particular source shall be carried out at weekly intervals to check compliance with Table 1.
Fine Aggregates	Fine aggregates shall be as defined in Cl.16.08(2) of GS. Fine aggregates recycled from old concrete shall not be used.
Grading	The grading of the coarse aggregates shall comply with the limits of Table 3 of BS 882:1992 for single-sized 20 mm and 10 mm aggregates.

Workability	*Recycled coarse aggregates have to be thoroughly wetted before being used*.
	The concrete shall have a *minimum* slump of 75 mm when it is ready to be compacted to its final position.
Laboratory mix trials and plant trials	Before any concrete is produced for use in the works, laboratory trials and plant trials must be performed in accordance with Cl. 16.25 and Cl.16.24 respectively.
Compliance Criteria	Compliance criteria shall be as in Cl. 16.27 and Cl. 16.26 respectively *if 150 mm cubes are used.*
	If 100 mm cubes are used, the modified compliance criteria will apply.
Concrete batching	Recycled aggregates have to be stored in separate stockpiles or silos to prevent inadvertent mixing with natural aggregates.
	A separate compartment must be provided for recycled aggregates in the batching plant.

Table 1

Mandatory Requirements	**Limits**	**Testing Method**
Minimum dry particle density (kg/m3)	2000	BS 812: Part 2
Max. water absorption	10 %	BS 812; Part 2
Max. content of wood and other material less dense than water	0.5 %	Manual sorting in accordance with BRE Digest 433
Max. content of other foreign materials (e.g. metals, plastics, clay lumps, asphalt and tar, glass etc)	1 %	
Max. fines	4 % -Note 1	BS 812: Section 103.1
Max. content of sand (<4mm) (% m/m)	5 %	BS 812: Section 103.1
Max content of sulphate (%m/m)	1%	BS 812: Part 118
Flakiness index	40 % - Note 2	BS 812: Section 105.1
10% fines test	100 kN- Note 3	BS 812: Part 111
Grading	Table 3 of BS 882:1992	
Maximum Chloride content	Table 7 of BS 882 – 0.05% by mass of chloride ion of combined aggregate – Note 4	

Note 1 Filler (<0.063mm) should be less than 2% in the RILEM Specification. BS 882 says that fines passing 75μm sieve shall not exceed 4 %. The latter requirement is easier to satisfy.

Note 2 Clause 16.08 (3) of the General Specification for Civil Engineering Works (GS) states that flakiness shall not exceed 35% whereas BS 882 states that it shall not exceed 40% for crushed rock or crushed gravel.

Note 3 Clause 16.08(3) of GS states that the 10% fines value shall be at least 100 kN. BS 882 states that the 10% fines value to be 50kN for concrete not subjected to wearing. BRE Digest 433 states that 70kN is achievable in recycled aggregate derived from brickwork, and 100 kN for those derived from crushed concrete. In recent tests carried out on recycled aggregates derived from old concrete,100 kN can be satisfied.

Note 4 BRE Digest 433 recommends to determine acid soluble chloride rather than water soluble chloride.

Particular Specification for Recycled Sub-base Materials

SECTION 9

CARRIAGEWAYS : RECYCLED SUB-BASE MATERIAL

GLOSSARY OF TERMS

MATERIALS

Recycled sub-base material

9.02A (1) Recycled sub-base material shall be crushed rock, crushed concrete or clean crushed inert demolition material and may contain up to 12.5% by mass of natural sand, which passes the 5mm BS test sieve. The material shall lie within the grading limits of Table 9.1A, and not be gap graded.

(2) The material shall have a ten percent fines value of 50 KN or more when tested in accordance with Clause 9.43A(3)

(3) The material passing the 425μm BS test sieve shall be non-plastic when tested in accordance with Clause 9.43A(4).

(4) The aggregate shall be considered suitable if it has a soundness value greater than 65.

(5) The material shall have a water-soluble sulphate content of less than 1.9g of sulphate (expressed as SO_3) per litre, if used within 500mm of cement-bound material, concrete pavements, concrete structures or concrete products.

(6) The material shall have a minimum laboratory CBR value of 30% or such other higher value as specified by the Engineer.

(7) The material shall not contain quantities of contaminants in excess of the percentages given in Table 9.1B unless otherwise approved by the Engineer.

Table 9.1A : Recycled sub-base – Permissible range of particle size distribution

Properties	BS test sieve	Percentage by mass passing
Particle size distribution	75 mm	100
	37.5 mm	85 - 100
	20 mm	60 - 85
	10 mm	40 - 70
	5 mm	25 - 45
	600 μm	8 - 22
	75 μm	0 - 10

Table 9.1B : Allowable contamination of recycled sub-base material

Sub-base type	Type of contamination			
	Maximum sulphate content By mass	Maximum metals content By mass	Maximum foreign material content e.g. glass, soft material etc. By mass	Maximum organic material content(by mass)
Recycled sub-base	1%	1%	1%	0.5%

SUBMISSIONS

Particulars of recycled sub-base material 9.11A (1) The following particulars of recycled sub-base material shall be submitted to the Engineer:

(a) details of the recycling plant, and test results for:
- ten percent fines value
- soundness value
- CBR value
- content of contaminant in percentage by mass
- Water-soluble sulphate content
- Organic material content, and

(b) grading details in tabular and graphical form

LAYING AND COMPACTION OF RECYCLED SUB-BASE MATERIAL

Laying and compaction of recycled sub-base material 9.29A (1) Recycled sub-base material shall be laid and compacted in a manner which will not result in segregation of the material and at a moisture content which allows the compaction stated in Clause 9.29A(7) to be achieved. The moisture content shall not be less than 2%.

(2) The recycled sub-base shall consist of an upper layer of virgin sub-base material overlying an underlying layer of recycled sub-base material. The ratio of the thickness of the recycled sub-base layer to that of the virgin sub-base layer shall be approximately 6 to 4. During laying and compaction, the thickness of each of these two layers shall take into account the layer thickness requirements given in sub-clause (3) below.

(3) Recycled sub-base material shall be laid in layers in such a manner that the compacted thickness of each layer will not exceed 225 mm. If the specified final compacted thickness of the sub-base exceeds 225 mm, the material shall be laid in two or more layers; the minimum thickness of each layer shall be 100 mm and, if the layers are of unequal thickness, the lowest layer shall be the thickest.

(4) Each layer of recycled sub-base material shall be evenly spread immediately after placing in position and shall be compacted immediately after spreading.

(5) The minimum compaction plant to be used for compaction of recycled sub-base material shall be of the type as stated in Clause 9.33(1).

(6) The permission of the Engineer shall be obtained before the next layer is placed on each layer of compacted recycled sub-base material.

(7) Recycled sub-base material shall be compacted to obtain a relative compaction of at least 95% maximum dry density throughout.

(8) The surface of each layer of recycled sub-base shall be maintained in a compacted condition until the next layer of sub-base material or roadbase material is laid; the surface shall not be disturbed by Constructional Plant or other vehicles, and shall be free from ridges, cracks, loose material, pot-holes, ruts or other defects.

TESTING : RECYCLED SUB-BASE MATERIAL

Testing: Recycled sub-base material

9.43A (1) Each sample of recycled sub-base material shall be tested to determine the particle size distribution, ten percent fines value, maximum dry density, optimum moisture content, plasticity index of the portion passing a 425μm BS test sieve, CBR value, soundness value, water-soluble sulphate content and percentage of contaminants as defined in Table 9.1B.

(2) The method of testing for particle size distribution shall be in accordance with BS 812:Part 103.1.

(3) The method of testing for ten percent fines value shall be in accordance with BS 812:Part 111, except that the sample shall be soaked in water at room temperature for 24 hours and shall not be oven-dried before testing.

(4) The method of testing for plasticity index shall be in accordance with GEO Report No. 36, test 2.4.3 and 2.5.3, except that sample preparation shall be by wet sieving the material over a 425 μm BS test sieve.

(5) The method for testing for maximum dry density and optimum moisture content shall be in accordance with BS5835:Part 1:1980.

(6) Soundness value shall be determined in accordance with BS 812:Part 121.

(7) Water-soluble sulphate content shall be determined in accordance with BS 1377: Part 3.

(8) The maximum organic material content shall be determined in accordance with BS1377: Part3.

(9) The maximum metals and foreign material content shall be determined in accordance with the following procedure:

Using the sampling procedure detailed in BS812: Part101, a sample shall be obtained of the aggregate containing at least 500 particles. The particles shall then be sorted manually into the following separate fractions:

(i) Concrete and dense or normal weight aggregates.

(ii) Brick, mortar, lightweight block and lightweight aggregate.

(iii) Asphalt, bitumen, tar and mixtures of these materials with aggregate.

(iv) Wood.

(v) Glass.

(vi) Metal.

(vii) Other foreign material such as clay lumps and plastics

Because of the adherence of dust it may be necessary to ash or break some particles to make a positive identification. The resulting fractions shall be weighed and expressed as a percentage of the total weight of material.

Notes:

(a) Lightweight block materials – These should be noted as a separate category if more than 1% by volume (approx. 5 pieces in 500).
(b) Ultra-lightweight materials (e.g. insulation) - These should be noted if more than 1% by volume (5 pieces in 500).

(10) CBR value shall be determined in accordance with BS1377:Part 4 with surcharge discs. The material shall be tested at the density and moisture content likely to develop in equilibrium pavement conditions, which shall be taken as being the density relating to a uniform air voids content of 5% and the optimum moisture content determined in compliance with BS 5835:Part 1:1980.

This particular specification shall be read in conjunction with Section 9 of the General Specification for Civil Engineering Works, 1992 Edition (GS). The clause No. denoted herein supersedes the same clause No. in the GS without the suffix. The clause and table nos. referred to are the clause and table nos. in the GS