Use of Recycled Aggregates in Concrete

Introduction

To reduce the pressure on the demand of public filling and landfill capacity, one of the means of resource conservation and waste minimization is to recycle hard and inert construction and demolition (C&D) materials, such as broken rock and concrete, into aggregates and put them into good use. This PNAP sets out the technical guidelines for using recycled aggregates in prescribed mix concrete of specified grade strength of 20P and designed mix concrete of specified grade strengths of 25D to 35D.

Technical Guidelines

2. The technical guidelines for prescribed mix concrete (20P) with 100% recycled aggregate is given in Appendix A, and that for designed mix concrete (25D to 35D) with 20% recycled aggregate is given in Appendix B to this PNAP.

3. The above technical guidelines have made reference to the technical specifications developed by the Standing Committee on Concrete Technology (SCCT) and Highways Department which were based on internationally recognized standards and results of laboratory tests done locally. They have been promulgated amongst works departments under Works Bureau Technical Circular No. 12/2002.

4. Concrete producers in Hong Kong are also well aware of the Technical Circular through their Concrete Producers Association's meetings with SCCT during the whole process of specifications development.

Applications

5. Prescribed mix concrete of specified grade strength of 20P with 100% recycled aggregate should only be used for minor structural or non-structural works in accordance with Building (Construction) Regulation 60(1). They may include, for examples, on-grade slabs, blinding layer, U-channels/stepped channels, bedding and haunching for pipe works, concrete footings for posts and fences, and mass concrete fill which does not sustain appreciable loading.

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6. Designed mix concrete of specified grade strengths of 25D to 35D with a maximum of 20% recycled aggregates may be used for the following applications that do not have major structural concern:

(a) concrete or reinforced concrete landscape features such as planters and planter walls, fence walls, mass concrete walls and footings for supporting landscape features;

(b) manholes and sand traps except manholes for foul water, grease traps and petrol interceptors where leakage of contaminated liquid to surrounding soil is undesirable; and

(c) carriageway pavement or overlay, reinforced concrete infill walls and mass concrete under footings or rafts.

7. Concrete with recycled aggregates must **not** be used in liquid-retaining structures, pre-stressed concrete structures, transfer structures or hanger structures.

Exemption

8. The use of recycled aggregates in concrete and the technical guidelines given in Appendices A and B would deviate from the relevant provisions of Building (Construction) Regulation 51 on the structural use of concrete. However, applications for modifications or exemptions under section 42 of the Buildings Ordinance would normally be given provided that:

(a) the proposed applications fall in with those given under paragraphs 5 and/or 6 above; and

(b) corresponding technical guidelines given in Appendices A and/or B are strictly complied with.

9. Where an Authorized Person or Registered Structural Engineer intends to use concrete with recycled aggregates in building works, he/she should state it clearly on the plan that contains general structural specifications and in the Part I structural calculations. Reference should be made to PNAP 121 in this respect. The Authorized Person or Registered Structural Engineer should also make a statement on the plan that

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the proposed use of concrete with recycled aggregates shall strictly comply with the technical guidelines given in Appendices A and/or B to this PNAP. The scope of the works involving the use of recycled aggregates should also be indicated on the relevant structural layout and detail plans.

10. Other requirements governing the use of concrete in structures shall also be applied in concrete with recycled aggregates.

Implementation

11. The use of recycled aggregates in concrete is at its initial stage of implementation. Civil Engineering Department is commissioning a pilot recycling plant at Tuen Mun Area 38 with a view to supplying recycled aggregates to a number of public works projects earmarked for such purpose. The plant has been in operation since July 2002.

(H W CHEUNG)
Building Authority

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Index under: Recycled aggregates
C and D Waste Reduction

Technical Guidelines for Prescribed Mix Concrete with 100% Recycled Coarse Aggregates

Scope	This technical guidelines is only applicable to prescribed mix concrete of specified grade strength of 20P.
Applications	Concrete with 100% recycled coarse aggregates shall only be used for minor structural or non- structural works in accordance with Building (Construction) Regulation 60(1).
General Requirements	Concrete shall comply with the relevant provisions of Building (Construction) Regulations on prescribed mix concrete.
Recycled Coarse Aggregates	Recycled Coarse Aggregates shall be produced by crushing old concrete and shall meet the requirements in Table 1.
Fine Aggregates	Fine aggregates 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 Aggregates : 180 kg 20 mm Coarse Aggregates : 180 kg 10 mm Coarse Aggregates : 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	The sampling rate, making, curing and testing of concrete shall comply with Building (Construction) Regulations requirements.
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/m^3)	2000	BS 812: Part 2
Maximum water absorption	10%	BS 812: Part 2
Maximum content of wood and other material less dense than water	0.5%	Manual sorting in accordance with BRE Digest 433
Maximum content of other foreign materials (e.g. metals, plastics, clay lumps, asphalt and tar, glass etc)	1%	
Maximum fines	4%	BS 812: Section 103.1
Maximum content of sand (<4mm) (% m/m)	5%	BS 812: Section 103.1
Maximum content of sulphate (% m/m)	1%	BS 812: Part 118
Flakiness index	40%	BS 812: Section 105.1
10% fines test	100 kN	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	

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Appendix B
(PNAP 275)
(APP-129)

Technical Guidelines for Designed Mix Concrete with 20% Recycled Coarse Aggregates

Scope	This technical guidelines is only applicable to designed mix concrete of specified grade strength of 25D to 35D.
Applications	Concrete with 20% recycled coarse aggregates may be used for applications specified in this PNAP. This type of concrete must not be used in liquid-retaining structures or pre-stressed concrete.
General Requirements	Concrete shall comply with the relevant provisions of Building (Construction) Regulations on designed mix concrete.
Cementitious Material	Only ordinary Portland cement to BS 12 shall be used.
Coarse Aggregates	Coarse aggregates shall consist of 80% natural mineral aggregates as defined in the Building (Construction) Regulation 51. 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 aggregate shall comply with the Building (Construction) Regulation 51. Fine aggregate 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 Appendix C.
Compliance Criteria (laboratory trials & plant trials)	Compliance criteria shall be those given in Appendix C.
Concrete Batching	Recycled coarse 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 coarse aggregates in the batching plant.
Acceptance Criteria for Compressive Strength	Concrete shall be tested in accordance with Building (Construction) Regulation 58 for compliance with the specified grade strength set out in Building (Construction) Regulation 59.

Table 1

Mandatory Requirements	Limits	Testing Method
Minimum dry particle density (kg/m^3)	2000	BS 812: Part 2
Maximum water absorption	10%	BS 812: Part 2
Maximum content of wood and other material less dense than water	0.5%	Manual sorting in accordance with BRE Digest 433
Maximum content of other foreign materials (e.g. metals, plastics, clay lumps, asphalt and tar, glass etc)	1%	
Maximum fines	4%	BS 812: Section 103.1
Maximum content of sand (<4mm) (% m/m)	5%	BS 812: Section 103.1
Maximum content of sulphate (% m/m)	1%	BS 812: Part 118
Flakiness index	40%	BS 812: Section 105.1
10% fines test	100 kN	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	

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Appendix C
(PNAP 275)
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Laboratory Mix Trials and Plant Trials for Designed Mix Concrete with 20% Recycled Coarse Aggregates

Laboratory Mix Trials

1. Laboratory Mix Trials shall be made in the laboratory using the mix designs and constituents proposed to be used.
2. Laboratory Mix Trials shall be carried out in accordance with Section 11 of CS1. Three separate batches shall be made, each of sufficient size to provide samples for two slump tests and to make six 150mm test cubes.
3. Two slump tests in accordance with CS1 shall be performed on separate specimens from each batch of Laboratory Trial Mix concrete.
4. Six 150mm test cubes shall be made from each batch of Laboratory Trial Mix concrete, stored, cured and tested for compressive strength at 28 days in accordance with CS1.

Plant Trials

1. Plant Trials shall be made using the plant or plants proposed and the mix designs and constituents proposed to be used.
2. One batch of concrete of a proposed designed mix shall be made on each of three days in each plant proposed to be used. The batch shall be at least 60% of the mixer's nominal capacity. If the concrete is batched in a central plant and mixed in a truck mixer, three different truck mixers shall be used.
3. Three samples of concrete shall be provided from each batch at approximately 1/6, 1/2 and 5/6 of the discharge from the mixer. Each sample shall be of sufficient size to perform a slump test and make two 150mm test cubes. The method of sampling shall be as stated as in CS1.
4. Each sample taken in accordance with item (3) above shall be tested to determine its slump value in accordance with CS1.
5. Two 150mm test cubes shall be made from each sample taken in accordance item (3) above and stored, cured and tested to determine the compressive strength at 28 days in accordance with CS1.

Compliance Criteria: Laboratory Mix Trials

1. When test data relating to the proposed plant or plants show that the plant standard deviation exceeds 5MPa, or in the absence of acceptable data, the results of tests on Laboratory Mix Trial concrete shall comply with the following requirements:

   (a) The average of the six slump values shall be within 20mm or 25%, whichever is the greater, of the design slump value.
   (b) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 12MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 6MPa.

2. When test data relating to the proposed plant or plants show that the plant standard deviation does not exceed 5MPa and the data are considered acceptable, the results of tests on Laboratory Mix Trial concrete shall comply with the following requirements:

   (a) The average of the six slump values shall be within 20mm or 25%, whichever is the greater, of the design slump value.
   (b) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 8MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 2MPa.

Compliance Criteria: Plant Trials

The results of tests on concrete taken from Plant Trials shall comply with the following requirements:

(a) The average of the nine slump values shall be within 20mm or 25%, whichever is the greater, of the designed slump value.
(b) The range of the three slump values for each batch of concrete shall not exceed 20% of the average of the three slump values for that batch.
(c) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 10MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 4MPa.
(d) The range of the compressive strength of the six test cubes from each batch of concrete shall not exceed 20% of the average compressive strength of the six test cubes from that batch.