

Recycled aggregates: Guidance for producers and purchasers

Introduction

This guidance document explains the fundamental procedures that must be in place to ensure that recycled aggregates meet customer's specifications and have ceased to be waste.

Recycled aggregates are widely used within UK construction applications. The quality of these aggregates varies depending upon the quality management systems employed by different producers. Producers operating to technically robust systems can demonstrate that their products meet their customers' specifications as well as the 'end of waste' criteria set by Environment Regulators.

Unfortunately, not all producers have adequate systems in place and as such their products are likely to remain waste and not comply with customer specifications.

This document highlights the key elements required within a technically robust quality management system and includes a useful checklist.

Issues addressed

- Where do the rules for producing construction aggregates come from?
- What are examples of the sort of things set within aggregates standards?
- How are testing frequencies set within the standards?
- Which are the harmonised aggregates product standards?
- How does a producer demonstrate that an aggregate product is suitable for a specific application?
- What is required to demonstrate 'end of waste' so that a recycled aggregate may be sold as a non-waste product in the same way as a natural aggregate?
- How does the Quality Protocol for Aggregates from inert waste assist producers and purchasers of recycled aggregates?
- What is CE marking and how is it applied to aggregates?



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Where do the rules for producing construction aggregates come from?

The rule books are the aggregates product standards. They ensure that all aggregate production controls and testing procedures are the same so that the aggregate characteristics declared by different producers are directly comparable.

Aggregates product standards are produced by CEN (European Committee for Standardisation), are harmonised under Construction Products Regulations, and are mandatory on all EU member states.

The product standards establish minimum quality management procedures required for producing aggregates for use in construction. This is referred to as Factory Production Control.

The product standards also detail relevant aggregate testing methods, testing frequencies and how testing results are used to determine classes and categories applied to aggregate products.

In the UK these aggregate product standards and related guidance are published by [BSI](#).

What are examples of the sort of things set within aggregates standards?

The following are examples of procedures within the scope of aggregates product standards:

1. The **sieves sizes** for testing aggregates used in the UK, in mm, are; 80, 63, 40, 31.5, 20, 16, 14, 10, 8, 6.3, 4, 2.8, 2, 1, 0.5, 0.25, 0.125, & 0.063.
2. **aggregate size**: the designation of aggregate in terms of lower (*d*) and upper (*D*) sieve sizes expressed as *d/D*. Coarse aggregates range from 4mm to 80mm, Fine aggregates from 0 to 4mm and All-in aggregates are a combination of the two. e.g. coarse 20/40, fine 0/4, all-in 0/31.5.
3. **grading**: particle size distribution expressed as the percentages by mass passing a specified set of sieves
4. **category**: level or class of a property of an aggregate expressed as a range of values (class) or a limiting value (level for individual value or declared category) e.g. a grading (G) category for a coarse aggregate (c) with a maximum of 80% passing the upper sieve size (D) and maximum of 20% passing the lower sieve size (d) will have a grading category of Gc80/20.
5. **Fines**: the particle size fraction of an aggregate that passes the 0.063 mm sieve e.g. a fines category of f4 is an aggregate with a maximum of 4% passing the 0.063mm sieve.
6. **Resistance to fragmentation**: When required, the resistance to fragmentation of coarse and all-in aggregates shall be determined in terms of the Los Angeles coefficient (LA) as specified in EN 1097-2. Categories for LA range LA15 to LA60 e.g. a coarse aggregate with a Los Angeles Coefficient result of $\leq 50\%$ will have a category of LA50. (the lower the number, the greater the resistance)
7. **Classification of Constituents**: For recycled aggregates, the proportions of constituent materials in coarse and all-in recycled aggregates shall be determined in accordance with EN 933-11. This is an important test for recycled aggregates enabling the producer to categorise the aggregate's constituents according to defined descriptions and categories:

Constituent	Description
Rc	Concrete, concrete products, mortar, concrete masonry units
Ru	Unbound aggregate, natural stone, hydraulically bound aggregate
Rb	Clay masonry units (i.e. bricks and tiles), calcium silicate masonry units, aerated non-floating concrete
Ra	Bituminous materials
Rg	Glass
FL	Floating material in volume
X	Cohesive (e.g. clay and soil), metals, wood, plastic, rubber, gypsum plaster

e.g. A recycled aggregate having 55% concrete, 25% brick, 19% asphalt and $\leq 1\%$ clay would have the categories Rc50, Rb30-, Ra20- and X1-.

8. **Factory Production Control:** The factory production control section describes the comprehensive requirements for the quality management system to be implemented by the producer to control the sourcing and processing of the aggregate, combined with routine sampling and testing, to provide ongoing assurance that the aggregates product continues to conform to those properties determined through initial testing procedures. For recycled aggregates 'sourcing' includes waste acceptance procedures to ensure only suitable waste is processed into aggregates.

How are testing frequencies set within the standards?

Testing frequencies and procedures are initially designed for ensuring consistent production and quality over time. This removes the need for testing all products before dispatch from site.

Tests for more variable characteristics are set at one per week of production, a production week may be measured as five days of production in a period no longer than three months.

Tests for less variable characteristics are set as one per month of production, a production month may be measured as twenty days of production in a period no longer than six months.

Tests for the least variable characteristics are set at one per year of production but to ensure a full testing programme a year of production may be taken as the same as a calendar year.

Examples of testing frequencies for recycled aggregates are:

Test	BS EN test reference	Minimum test frequency BS EN 13242	Minimum test frequency BS EN 12620
Particle size Distribution	EN 933-1	1 per week	1 per week
Fines content	EN 933-1	1 per week	1 per week
Classification of constituents	EN 933-11	1 per month	1 per month
Particle density	EN 1097-6	1 per month	1 per month
Water soluble sulfates	EN 1744-1	1 per month	1 per month
Resistance to fragmentation (LA)	EN 1097-2	2 per year	1 per year
Magnesium sulfate soundness	EN 1367-2	1 per 2 years	1 per 2 years



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Details of testing should be provided in the quality management scheme

Which are the harmonised aggregates product standards?

The full set of CEN harmonised aggregate product standards published by [BSI](#) are:

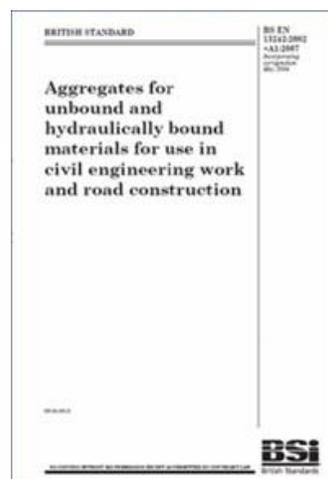
- **BS EN 12620, Aggregates for concrete;**
- **BS EN 13043, Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas;**
- **BS EN 13139, Aggregates for mortar;**
- **BS EN 13242, Aggregates for unbound and hydraulic bound materials for use in civil engineering work and road construction;**
- **BS EN 13383-1, Armourstone**
- **BS EN 13450, Aggregates for railway ballast.**

At the moment the Factory Production Control and testing frequency sections are in annexes to these standards however these sections are to be moved into one common standard, EN 16236, when all the standards are republished, probably in 2017.

Most recycled aggregates are purchased for use in unbound applications in civil engineering and as such come under BS EN 13242.

There is a growing demand for recycled aggregates for use in the production of concrete and those aggregates will come under BS EN 12620.

The BSI guidance documents on the use of these two aggregates standards are PD6682-6 and PD6682-1 respectively. They explain how the European Standards are applied to UK aggregate production, they have yet to be updated with certain details relating to BS EN 16236 and CE Marking but are still very useful.



Example of an aggregates product standard and corresponding BSI guidance document

How does a producer demonstrate that an aggregate product is suitable for a specific application?

Aggregates produced to aggregates product standards may be suitable for a range of applications within construction. The characteristics that make an aggregate suitable for a specific construction application are set by the designer's engineering specification.

The specification stipulates the relevant aggregate product standard and will use the standard's classes and categories to set the minimum characteristics required from an aggregate to make it suitable for each application.

By working in conformity with an aggregates product standard an aggregate producer is able to demonstrate to a specifier or purchaser that their aggregate is compliant with the specification requirements for an application.

Examples:

1. 10/20 pipe bedding

Highways England, Specification for Highway Works ([SHW Series 500](#)), Drainage and Service Ducts, includes the specification requirements for aggregates to be suitable for use in a pipe bedding application:

- Aggregates must comply with BS EN 13242
- Classification of Constituents test: Class X $\leq 1\%$
- Resistance to fragmentation: LA50
- Water soluble sulfate: $< 0.38\%$

There are options for aggregate size depending upon the diameter of the pipe including coarse aggregates of 2/14, 4/20, 10/20 and 4/40 for a pipe diameter exceeding 400mm.

For all coarse aggregates there are additional category requirements:

- Grading: Gc80/20
- Fines for crushed rock and recycled aggregates: f4

From this information when a purchaser specifies a 10/20 pipe bedding aggregate to SHW Series 500 the recycled aggregate producer must be able to demonstrate that their 10/20 aggregate is produced in conformity to BS EN 13242 and meets the specified characteristics in order to comply with the specification.





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If the only test result available is for a grading the aggregate will not be shown to meet the specification and could still be waste

2. 0/80 6F5 capping

Highways England, [SHW Series 600](#), Earthworks, includes the specification requirements for aggregates to be suitable for a 6F5 capping application, (this can be the unbound pavement layer between a subgrade and a subbase). This aggregate product is classified as an 'unbound mixture' and as such the specification also references 'BS EN 13285 Unbound mixtures: Specification' which involves some additional designations.

General requirements are:

- Recycled aggregates must conform with BS EN 13242
- Classification of Constituents test: Class X $\leq 1\%$, Ra $\leq 50\%$,
- Resistance to Fragmentation: LA50
- Aggregate size: 0/80
- Grading: GE (from BS EN 13285) i.e. GA75 from BS EN 13242
- Oversize: OC75 (from BS EN 13285) i.e. GA75 from BS EN 13242
- Fines: UF12 (from BS EN 13285) i.e. f12 from BS EN 13242

(Note: there are further requirements relating to water soluble sulfates, total sulfur and sulfides which vary depending on material and location of use. Details, revised in February 2016, are in SHW Series 600)

To clarify how these grading requirements are applied to a sieve analysis the specification provides additional detail:

Sieve size mm	% passing
125	100
80	75-99
40	50-90
20	30-75
10	15-60
2	0-35
0.063	0-12

From this information when a purchaser specifies a 6F5 capping aggregate to SHW Series 600 the recycled aggregate producer must be able to demonstrate that their 0/80 aggregate is produced in conformity to BS EN 13242 and meets the specified characteristics in order to comply with the specification.

3. 0/31.5 Type 1 subbase

Highways England, [SHW Series 800](#), Road Pavements, includes the specification requirements for aggregates to be suitable for a Type 1 subbase application. This aggregate product is classified as an 'unbound mixture' and as such the specification also references 'BS EN 13285 Unbound mixtures: Specification' which involves some additional designations. The specification also includes an additional test to those listed in BS EN 13242.

General requirements are:

- Recycled aggregates must have a quality control procedure in accordance with Quality Protocol for aggregates from inert waste, i.e. conform to BS EN 13242.
- Classification of Constituents test: Class X $\leq 1\%$, Ra $\leq 50\%$, Rg $\leq 25\%$,
- Resistance to Fragmentation: LA50
- Crushed particle category: C 90/3
- Resistance to freezing and thawing (Magnesium sulfate soundness): MS35
- Frost Heave to BS 812-124: mean heave $\leq 15\text{mm}$
- Aggregate size: 0/31.5
- Grading: Gp (from BS EN 13285)
- Oversize: OC75 (from BS EN 13285) i.e. GA75 from BS EN 13242
- Fines: UF9 (from BS EN 13285) i.e. f9 from BS EN 13242

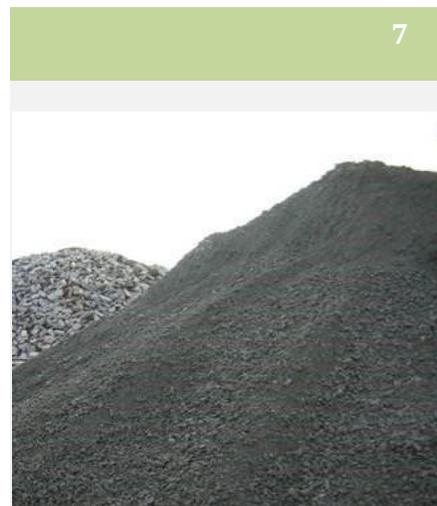
(Note: there are further requirements relating to water soluble sulfates, total sulfur and sulfides which vary depending on material and location of use. Details, revised in February 2016, are in SHW Series 800)

The grading requirements for some classes of unbound mixtures, including Type 1, stipulate an overall grading range within which will be a narrower 'Supplier declared value range' which enables a producer to have a 'declared value' for certain sieve sizes against which variability should be managed within a defined \pm tolerance range.

To clarify how these grading requirements are applied to a sieve analysis, and other requirements, the specification provides additional details in clause 803.

Sieve size mm	% by mass passing		
	Overall grading range	Supplier declared value grading range	Tolerance on supplier declared value
63	100		
31.5	75-99		
16	43-81	54-72	± 15
8	23-66	33-52	± 15
4	12-53	21-38	± 15
2	6-42	14-27	± 13
1	3-32	9-20	± 10
0.063	0-9		

From this information when a purchaser specifies a Type 1 subbase aggregate to SHW Series 800 the recycled aggregate producer must be able to demonstrate that their 0/31.5 aggregate is produced in conformity to BS EN 13242 and meets the specified characteristics in order to comply with the specification.



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Wide variations in the results of the Classification of Constituents tests for Rc and Rb can impact on Frost Heave results



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Recycled aggregates that do not meet 'end of waste' criteria remain waste and should be transported as waste by registered carriers and receiving sites require an appropriate exemption or permit for receiving waste

What is required to demonstrate 'end of waste' so that a recycled aggregate may be sold as a non-waste product in the same way as a natural aggregate?

To demonstrate that products are no longer waste the producer must have in place procedures that meet the following ['end of waste'](#) requirements:

1. the waste has been converted into a distinct and marketable product
2. the processed substance can be used in exactly the same way as a non-waste
3. the processed substance can be stored and used with no worse environmental effects when compared to the material it is intended to replace

These criteria may be applied to recycled aggregates as follows:

1. Suitable wastes processed into recycled aggregates in conformity to an aggregates product standard become a distinct and marketable product.
2. Recycled aggregates produced in conformity to an aggregates product standard to show compliance with construction application specifications can be used in exactly the same way as natural aggregates.
3. Recycled aggregates produced from suitable wastes and in conformity to an aggregates product standard can be stored and used with no worse environmental effects when compared to natural aggregates.

In order for recycled aggregate producers to market their products as non-waste they must have in place and operate to procedures and documentation that demonstrate:

- the aggregates are produced in conformity to an aggregates product standard
- the aggregate products are compliant with application specifications
- the aggregates are processed from suitable wastes

Where such procedures and documentation are not in place, or operational, the recycled aggregates will remain waste.

How does the Quality Protocol for Aggregates from inert waste assist producers and purchasers of recycled aggregates?

[The Quality Protocol for Aggregates from inert waste](#) (Aggregates QP) provides 'end of waste' criteria for the production of aggregates from inert waste. This includes detailed guidance on the structure required for a recycled aggregates producer's quality management system, including waste acceptance procedures, to be in conformity to aggregates product standards.

It provides a table (Aggregates QP Appendix B: Table B1) that links construction applications, product standards, and related specifications. Below is an illustrative extract:

Product type and Application	Aggregate Product Standard	Specification
Unbound recycled aggregate: Pipe bedding Drainage	BS EN 13242: Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction	Highways England Specification for Highway Works (SHW): Series 500
Unbound recycled aggregate: Granular fill General fill Capping	BS EN 13242: Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction	Highways England Specification for Highway Works: Series 600 BS EN 13285: Unbound mixtures: Specifications
Unbound recycled aggregate: sub base	BS EN 13242: Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction	Highways England Specification for Highway Works: Series 800 BS EN 13285: Unbound mixtures: Specifications
Recycled aggregate for concrete	BS EN 12620: Aggregates for concrete	Highways England Specification for Highway Works: Series 1000 BS 8500-2: Concrete

It also contains a qualified table of wastes and waste codes (Aggregates QP Appendix C: Table C1) that the Environment Regulators in England, Wales and Northern Ireland consider suitable for processing into recycled aggregates, without further environmental testing, within an 'end of waste' recovery process.

Wastes with codes not included in Table C1 are not within the scope of the aggregates QP, exclusions include: mixed skip waste 17 09 04 (except uncontaminated suitable trench arisings) and mixtures of materials from mechanical processing of waste 19 12 12. (section continued below)



Quality management systems should be proportionate to the type, range and tonnage of aggregates produced but **all must have key elements** to conform to aggregate product standards and end of waste criteria.

Non-conformity to any of these key elements will most probably indicate that the recycled aggregate will not meet the purchaser's specification for an application and will remain waste.

Checklist for key elements within a quality management system for recycled aggregates

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<p>1. Quality Management Manual A document detailing the management systems in place at the point of recycled aggregate production. This document will set out the procedures in place to meet the Factory Production Control requirements for conformity to the aggregates product standards.</p>	
<p>Manual details will include:</p>	
<p>2. The management and operatives' roles and responsibilities in implementing and monitoring the quality management manual procedures. (see Aggregates Quality Protocol: section B2.1)</p>	
<p>3. Waste Acceptance Procedures including acceptable waste codes, inspection systems and how rejected incoming waste is managed. (see Aggregates Quality Protocol: section B2.2)</p>	
<p>4. A list or table of aggregate products that are produced at the facility including product descriptions and relevant application specifications to which they comply. (see Aggregates Quality Protocol: sections B2.3 & B2.5)</p>	
<p>5. A list or table of tests undertaken to determine that the aggregate products have the characteristics to meet all the specification requirements. (see Aggregates Quality Protocol: section B2.7)</p>	
<p>6. Sampling and testing frequencies in line with minimum requirements relating to the aggregate product standards. (see Aggregates Quality Protocol: section B2.8)</p>	
<p>Test Results: (see Aggregates Quality Protocol: section B2.6)</p>	
<p>7. Recycled aggregate producers must have results for all tests listed within the Quality Management Manual for their aggregate products.</p>	
<p>8. The frequency of testing must meet the minimum testing frequencies listed within the Quality Management Manual.</p>	

What is CE marking and how is it applied to aggregates?

CE marking indicates that a construction product is in conformity with its Declaration of Performance and that it has been assessed according to a harmonised European standard.

For aggregates, CE marking applies to aggregates placed on the market as products supplied in conformity to harmonised aggregates standards under Construction Products Regulations.

CE marking and Declarations of Performance do not place additional testing or quality management requirements on an aggregate producer working in conformity to a harmonised aggregates standard but rather provide a verification of conformity.

Information on CE Marking, Declaration of Performance (DoP) and systems for Assessment and Verification of Constancy of Performance (AVCP) are within the harmonised standards, however, terminology varies as standards are being redrafted from the original Construction Products Directive versions in order to meet the requirements of Construction Products Regulations (CPR).

Hardly surprisingly, there is some confusion on how CE marking is applied to unbound recycled aggregates when they are produced in conformity to the harmonised aggregate product standard BS EN 13242 as part of an 'end of waste' procedure. The critical issue relates to the specification against which the aggregate is sold, i.e. placed on the market.

Aggregates that are placed on the market to unharmonised standards or specifications do not come within the scope of CE marking under CPR.

Therefore, CE marking does not have to be applied to BS EN 13285 unbound mixtures such as SHW Series 600: capping 6F3, 6F4, and 6F5.

Similarly, CE marking does not have to be applied to BS EN 13285 unbound mixtures to SHW Series 800: Types 1,2,3 & 4 subbases.

This situation will change if EN 13285 Unbound mixtures: Specifications, becomes a harmonised European Standard under CPR.



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John Barritt Consulting Ltd. provides information and guidance services on recycled aggregates and related issues to aggregate producers, construction companies and environmental regulators.

From 2002 to 2014 John Barritt provided technical leadership and support on aggregates, construction materials, waste regulations and statistics to support the strategy, design and execution of the Built Environment programme and other appropriate programmes across WRAP.

He chaired the 2003/4 working group that produced the end of waste Quality Protocol for the production of aggregates from inert waste (aggregates QP) and then chaired the 2009/10 Technical Advisory Group for the five-year review of the aggregates QP.

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