Learning Text

Part 3

Aggregates

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Introduction

This learning text considers the subject of aggregates; the text discusses the formation, specification and properties of the aggregates used in mortar. A glossary of terminology and bibliography are included. The final section of this learning text is self-assessment questions and answers.

Fine aggregate (sand) is the main constituent of masonry mortars and renders. Some screeds incorporate a coarse aggregate (normally 10 mm maximum size) but generally their major constituent is also fine aggregate. Confusion sometimes exists over the difference between the terms fine aggregate and sand, there is in fact no difference the two words may be interchanged. However, the European standard uses the term fine aggregate. The historic terminology is just that used by local tradition and custom.

Fine aggregate quality is affected by a number of factors:

- The mean particle size
- The grading
- The presence of impurities
- Shape
- Texture

As the main constituent of masonry mortars, renders and screeds, the fine aggregate has a significant effect upon the properties of the product in both its fresh and hardened state. The selection of suitable aggregates, which are capable of producing a product with the optimum properties, is most important. The design of mortar mixes is based on the concept that the voids in the fine aggregate, which are generally in the range 25-40%, will be filled with binder. Where the voids are not completely filled there is an increasing risk that the mortar will not be durable. A later learning text in this series (Part 6) will discuss the importance of desirable properties of masonry mortar; which are influenced by the grading and consequent voids within the mortar mix.

Rock Formation

The earth is composed of rocks that have been formed over hundreds of millions of years. The centre of the earth is composed of a core of solid material, which is believed to be made up of nickel and iron. A number of layers (some composed of liquid material called magma, make up the structure of the earth the outermost layer being called the crust. The earth's crust varies a great deal in thickness ranging from about 65 km under mountains, to as little as 5 km under some oceans; it is the earth's crust, which is the source of rocks used by mankind.

Geologists divide rocks into three categories:

- Igneous rocks. These are derived from molten material, which originates from the layers below the earth's crust. Television programmes sometimes show the destructive effects of molten material (magma), which is ejected by volcanoes. The word igneous is derived from the Latin word ignis meaning fire. Some molten material solidifies before it reaches the earth's surface and that is the reason why a range of igneous rocks exist, their properties are dependent on the rate of cooling, as well as the chemical composition of the liquid magma. Igneous rocks include granite, diorite, and basalt.

- Sedimentary rocks. The majority of sedimentary rocks originate as accumulations of material, formed as a result of the transportation of solid particles eroded from pre-existing rocks to the place where they are deposited as sediments. Other sedimentary rocks are formed from the accumulation of animal or vegetable remains. A third group of sedimentary rocks are formed from the precipitation of materials carried in solution. The name sedimentary is given to this group of rocks because they are formed from sediments. Sedimentary rocks include limestone, sandstone and gritstone.

- Metamorphic rocks. Metamorphism is the term used to describe the transformation of rocks into new structures and mineral compositions, as a result of the energy put into them by heat and/or pressure. The altered rocks are known as metamorphic rocks.

The word metamorphism means a change in form, for example adult frogs are produced by metamorphosis from tadpoles and butterflies are produced by a change of state from caterpillars.

When fine grained limestone is metamorphosed then the whole mass is recrystallised into marble, varying chemical compositions of the limestone result in coloured bands within the marble, for example the green streaked serpentine marble found in Connemara in Southern Ireland.

Metamorphic rocks also include slates and gneisses.

Aggregate Processing

Sand and gravel

Sands and gravels, which are the products of natural disintegration, are obtained by either a wet or dry extraction process. Historically sands and gravels are referred to as being extracted from a pit.

In the wet process the main types of equipment used are suction dredgers, floating cranes, floating grab dredgers and draglines. Suction dredgers work by having a pump below the water level, the material being sucked up by means of a vacuum system.

In the dry process the first step is the removal of the topsoil or overburden; then a front-end loader or excavator digs out the material that is conveyed to the processing plant.

The material extracted by either the wet or dry process is transported to the processing plant, where it is vigorously washed in a scrubber to remove the clay and silt particles and then screened into its constituent sizes. The fine material passes to a series of classifiers where a process of differential settlement allows various grades of fine aggregate (sand) to be produced.

The processed material then passes to a dewatering system to allow the excess water used for processing to be removed, this system tends to be a combination of mechanical and natural methods (drainage by gravity).

An alternative to the washing and classification system is to simply dry screen the extracted material. A dry screened product will have a higher proportion of fine material which may be beneficial in the production of mortar.

Sands and gravels are normally rounded or irregular in shape. However, increasingly some gravels are crushed to produce smaller particles and crushed gravel sands with a shape similar to crushed rock materials (angular).

Crushed rock

Crushed rocks are obtained from a quarry by drilling and blasting the bedrock. The material is then transported to the processing plant where, after removal of the fine material, it is subjected to crushing and screening a number of times before final screening into its constituent sizes. The crushing imparts to the rock particles an angular shape. It is unusual for these materials to be washed. Due to the processing requirements, crushed stone is more expensive to produce than sands and gravels.

Marine dredged

The extraction of marine aggregates is a similar process to the wet process of sand and gravel extraction, except that the suction pump or dredger is located on a sea going vessel with a hold capacity of up to 5,000 tonnes. Marine aggregates are extracted from the seabed at a number of locations around the coast of the United Kingdom. The material is off loaded at wharves and then processed, particular care being taken with washing/draining to reduce the chlorides that are present from the seawater. The use of marine aggregates has increased over recent years, as less reserves of land-based materials are available and planning permission becomes more difficult to obtain, particularly in areas such as London where there is good river access.

Grading of Aggregates

Sands, gravels and crushed stone come in a variety of shapes and sizes; the classification of these materials into approximate size fractions is called the grading. Traditional terminology was to classify aggregates as belonging to one of three categories, all in aggregate, coarse aggregate and sand (fine aggregate). These are defined below but it should be noted that the first two are not used in mortar production.

- All in Aggregate: This is material composed of a mixture of coarse material and sand.

- Coarse aggregate: The European Standard classifies aggregates over 4 mm as coarse aggregate. (Traditionally, British Standards used a slightly different classification: based on material mainly retained on a 5.0 mm sieve) The coarse aggregate classification can be further divided into graded aggregates and single size aggregates.

  A graded aggregate consists of particles of different sizes from the maximum down to the minimum.

- Fine aggregate: The European Standard uses the term fine aggregate in place of the term sand for material less than or equal to 4 mm in size. (Traditionally, British Standards defined this material as material passing 5.0 mm test sieve but retained on a 75 μm test sieve.

(The symbol μm = micron which is one millionth of a metre or one thousand of a millimetre). The unit micron is not used in the European aggregate Standard, it is replaced by the unit "millimetre".

The European Standard BS EN 13139 lists the preferred sizes of aggregates for mortar, these are: 0/1 mm, 0/2 mm, 0/4 mm, 2/4 mm and 2/8 mm. (Where the first figure in each set represents d and the second D). A table within the standard prescribes for most of the preferred aggregate sizes; limits for percentages passing sieves with an aperture of:

2D referred to as oversize
1.4D referred to as oversize
D referred to as oversize
d. referred to as undersize (not specified for the 2/4 and the 2/8 sizes)
0.5d referred to as undersize (not specified for the 2/4 and the 2/8 sizes)

Aggregate producers have data on typical gradings and the tolerances that normally occur.

Sieve sizes in European standardisation have been divided into three sets. Basic, Set 1 and Set 2, individual countries will adopt the Basic set plus either Set 1 or set 2. The United Kingdom have adopted the Basic set and set 2 and therefore the sieve sizes in the United Kingdom are

Basic set plus set 2 mm
0
1
2
4
6.3 (6)
8
10
12.5 (12)
14
16
20
31.5 (32)
40
63

Table 1: Basic set plus set 2

Sieve Sizes mm
0.063
0.125
0.250
0.500
1.00
2.00
2.8
6.3
8.0
10.0
14.0
16.0

Table 2: Sieve sizes applicable for aggregates for use in mortar and screed

PD 6682-3 lists the sieves that are applicable to aggregates for use in mortars and screeds and these are shown in Table 2:

Particle shape can be important for fine aggregates with excessive amounts of flaky or elongated particles sometimes proving problematic for the site operative. For example the resultant mortar may feel harsh and difficult to work on the trowel and joints may prove more difficult to finish. Similarly crushed material is more angular than natural rounded material and again can be more difficult to work.

Lightweight Aggregate

The European Standard for lightweight aggregate (BS EN 13055-1) specifies the properties and technical requirements for lightweight aggregates for mortar and concrete. The term lightweight aggregate covers a wide range of materials, some of which are naturally occurring, others are by products of industrial processes or natural materials, which have been subjected to a process, which alters their properties.

The testing of light-weight aggregates is similar to the procedure undertaken for natural aggregates, testing is undertaken for chloride content, sulfate content, loss on ignition and organic material. Sieve analysis is also undertaken to determine the particle size distribution and a table within the standard prescribes minimum test frequencies with all relevant properties assessed as discussed in this section.

Impurities

The European Standard BS EN 13139 (Aggregates for Mortar) incorporates an informative annex - Annex D that is entitled “Guidance on the effects of some chemical constituents of aggregates on the mortar in which they are incorporated”. Small quantities of some impurities can have a significant effect on the properties of the mortar, render or screed and therefore their presence must be avoided if possible.

Silt, clay and fines

Fines (as opposed to fine aggregate) are defined in the European standard as material passing a 0,063 mm (63 µm) sieve.

This is a change from traditional British standards which defined fines as inherent material passing a 75 µm sieve. The European Standard prescribes different limits for fines content; the quantity that is permitted to pass the 0,063 mm sieve depends on the aggregate size and the proposed end use of the mortar. End use applications are divided into four categories:

- Category 1: Floor screeds, sprayed repair mortar and grouts (all aggregates)
- Category 2: Rendering and plastering mortars (all aggregates)
- Category 3: Masonry mortars (all aggregates except crushed rock)
- Category 4: Masonry mortars (crushed rock)

The limits permitted to pass the 0,063 mm sieve are:

- Category 1 - 3%
- Category 2 - 5%
- Category 3 - 8%
- Category 4 - 30% (except the 0/8 and the 2/8 aggregate sizes where the limit is 11%)

The standard states that where the fines limit exceeds 3%, but a history of satisfactory use exists, no further testing may be necessary.

A greater proportion of fines are permitted for crushed rock, as the fine material resulting from the mechanical crushing of rock is not as likely to contain harmful materials such as clay.

There is a fifth category (category five), which is applicable only to the 0/1 mm aggregate size. The producer is required to declare the percentage passing the 0.063 mm sieve.

In some instances, e.g. marine dredged material, where there are no inherent fines it may be beneficial to add filler aggregate (passing 0.063 mm) to improve the workability/consistence.

Organic matter

Decaying vegetation may result in aggregates being contaminated with organic matter. This material may have a retarding effect on the setting of cementitious material and may result in lower strengths of the hardened material at all ages. The presence of most harmful organic compounds can be detected by a simple test based on the use of sodium hydroxide. BS EN 1744-1 describes the test in Clause 15.1.

Chlorides

Chlorides present in aggregates may dissolve in the mixing water and promote corrosion of any embedded metal present. They may also cause efflorescence, which is a white deposit that may form on the surface of brickwork. The rate at which mortar, render or screeds gain strength may also be affected. Annex D of BS EN 13139 recommends that the water- soluble chloride content of the aggregate does not exceed 0.15% for plain mortar and 0.06% for mortar with embedded metals (e.g. wall ties or lathing support).

When required, the chloride content is determined in accordance with the method given in clause 7 of BS EN 1744-1.

Sulfates

The presence of sulfates can lead to the expansion of the mortar and the formation of unsightly deposits on the mortar surface. The presence of sulfates may be determined by the method given in clause 12 of BS EN 1744-1.

Iron pyrite

A form of ferrous sulfide may be present in some aggregates. This can react and oxidise to form iron hydroxide, which is brown in colour. Iron pyrites can cause staining and lead to pop outs at the surface, this is obviously a more visually apparent problem with screeds and rendering and plastering mortars.

Lignite and coal

Lignite and coal particles may cause brown stains and/or popouts to appear at the surface of the hardened material. Lignite particles can be a very serious problem if they are present in some screeds, having a lower density than the mortar matrix they float to the surface and may pop out.

Shell content

The shell content is normally unimportant for fine aggregate, although regional preferences on the part of site operatives may play a part in deciding on the suitability of the material. Where screed mixes are to be produced using an aggregate size larger than 4 mm the shell content may need to be determined. BS EN 12620 (Aggregates for concrete including those for use in pavements) recommends a maximum limit of 10% for coarse aggregate.

Mica

Mica occurs as a by-product of china clay production. It has higher water demand for a given level of consistence and therefore may have an adverse affect on strength. However, mica has a sparkling appearance and may therefore be regarded as a beneficial constituent of mortar by some construction professionals. The occurrence of micaceous sands is mainly confined to the South West of England where, it is widely used for mortar production.

Testing

Testing is the means by which the properties of a material are routinely evaluated and compared with the appropriate specification requirements. The type of material that the aggregate is going to be used in may well lead to different specification requirements. Test results also provide a historic record of how the properties of a material vary with time.

The introduction of European standards has resulted in the revision of a number of traditional test methods and the introduction of some unfamiliar ones. The tests applicable to aggregates for mortar are:

BS EN 932: Tests for general properties of aggregates

- BS EN 932- Part 1: Methods for sampling

The objective of sampling is to obtain a bulk sample that is representative of the average properties of the batch, it is important to remember that information obtained from test samples is only as representative of the material as the samples on which the tests are undertaken.

Bulk samples can be reduced to portions suitable for testing by two principal methods, by using a riffle box or by coning and quartering.

- Riffle box: There are several sizes of riffle box to suit different sizes of aggregate, one of which is illustrated in Figure 1. The box consists of an even number of chutes discharging in alternate directions. The material is passed through the riffle box, which divides it into two portions, one of which is discarded. The other portion is passed through again and the process repeated until the sample has been reduced to the required size. It should be noted that a riffle box can only be used on dry material.

- Coning and quartering: This method of sample reduction involves shovelling the bulk sample to form a cone, the cone is turned over three times and then flattened. The sample is then divided into four quarters and two of the diagonally opposite quarters discarded. The process of coning and quartering is repeated until the sample is reduced to the appropriate size for testing.

Figure 1: A riffle box

- BS EN 932- Part 5: Common equipment and calibration

This part of the standard gives details of the common equipment required for aggregate testing and the required precision of the various items of equipment.

BS EN 933: Tests for geometrical properties of aggregates

- BS EN 933- Part 1: Determination of particle size distribution - Sieving method

Sieving is a method of dividing up a material into size fractions by passing it through sieves with decreasing apertures.

The quantity of material on each sieve is measured and it is then possible to calculate a particle size distribution (grading) for the sample. The results of a sieve analysis are frequently plotted on a log scale to produce a particle size distribution chart (or computer printout). The range of gradings that are acceptable for a particular application are normally referred to as a grading envelope. Figure 2 shows a selection of sieves. It should be noted that the term particle size distribution is sometimes used instead of the term grading.

Figure 2: Grading sieves

Two tests prescribed in the test method series BS 933, those for sand equivalence and methylene blue absorption, have not been fully accepted within the United Kingdom. PD 6682-3 states " these tests are not considered sufficiently precise for determining harmful fines content in fine aggregates for mortar in the United Kingdom". Never the less these two tests are outlined in the following sections.

- BS EN 933- Part 8 : Assessment of fines - Sand equivalent test

This is a rapid test to determine the proportion of clay or plastic fines in the 0/2 mm fraction of a fine aggregate. A small quantity of flocculating solution and a measured volume of oven dried fine aggregate are poured into a measuring cylinder. Agitation loosens the clay like coatings from the coarser particles, irrigation with additional flocculating agent forces the clay-like material into suspension above the fine aggregate. The sample is allowed to settle for a twenty- minute period and the heights of the columns of clay and sand are measured. The sand equivalent is reported as the ratio of the height of the sediment expressed as a percentage of the total height. This test is very similar to the field settling test used for concrete aggregates, the difference between the two tests is in the composition of the flocculating agent.

- BS EN 933 - Part 9: Assessment of fines – Methylene blue test

This test is used to assess the quantity of potentially harmful fines in sands; the test is undertaken by adding Methylene blue dye to a sample in suspension and measuring the quantity of dye absorbed. The principle of the test is that clay minerals adsorb basic dyes from aqueous solutions, therefore the greater the quantity of dye absorbed the greater the quantity of potentially harmful fines present.

BS EN 1097-6 Tests for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption.

This part of the standard describes two methods for determining particle density and water absorption. For coarse aggregates a method that requires the use of a wire basket is specified and for fine aggregate a method that uses a pyknometer is used. (A pyknometer is a glass jar, which has a tightly fitting stopper.) The water absorption of a sample is the increase in mass of an oven dry sample when it is immersed in water, the greater the volume of voids in the sample the easier it is for water to penetrate it and the higher the water absorption.

The particle density of a sample is determined by calculating its mass and dividing this by the volume the sample occupies.

BS EN 1744-1 Tests for chemical properties of aggregates – Part 1: Chemical analysis.

- Water soluble chloride: three methods are given for the determination of water soluble chloride. The reference method is the classic titration with silver nitrate solution (Volhard method).

- Acid soluble sulfate: the method of determining the acid soluble sulfate involves dissolving a crushed sample in hydrochloric acid and precipitating the sulfate as barium sulfate. The precipitate is then filtered and ignited in a muffle furnace, the remaining mass is then weighed.

- Organic compounds: a 3% solution of sodium hydroxide is poured into a glass bottle to a height of 80 mm, a sample of the material being tested which all passes a 4 mm sieve is poured in until the height of the solution is 120 mm. The stopper is placed in the bottle and it is vigorously shaken and then allowed to stand for twenty-four hours, the colour of the solution is then compared to a standard colour solution. A rule of thumb is that if the test solution is clear no harmful organic materials are present, if it is the colour of a beer shandy small quantities are present, where the solution is the colour of a bitter (beer) the material is heavily contaminated. Where coloration of the test sample occurs more precise tests have to be undertaken.

- Loss on ignition: A sample, which has been dried at approximately 100˚C, is weighed into a tared crucible and placed into an electric muffle furnace at a temperature of 975^{o} C for a minimum period of an hour. The sample is then removed and allowed to cool and then reweighed, the loss in mass is expressed as a percentage of the original mass and reported as the loss on ignition.

A table within Annex E of BS EN 13139 prescribes minimum test frequencies for the various properties and the appropriate test method.

The following two tests are for concrete and screed applications only but are included in this mortar learning text for completeness.

Figure 3: Sieves used for the determination of flakiness index

- BS EN 933 - Part 3: Determination of particle shape - Flakiness index

Flakiness index is not applicable to particle sizes less than 4 mm. To determine the flakiness index of a sample, it is first reduced into a number of size fractions, for example passing 10 mm retained on 8 mm or passing 6.3 mm retained on 5 mm.

The individual size fractions are then sieved on special sieves, (Shown in Figure 3) the aperture of these is the larger of the two size fractions (D) divided by two (e.g. for the 8-10 mm size the aperture of the flakiness sieves would be 5. 0 mm). Flakiness is therefore a measure of particles, which are approximately half the nominal size in thickness).

The flakiness index is calculated by calculating the percentage in mass of the total sample, which pass the appropriate sieve flakiness sieves.

- BS EN 933-7 Part 7: Determination of shell content-Percentage of shells in coarse aggregate

This test involves sorting by hand the number of particles of shell in a given sample and expressing the mass as a percentage of the total sample.

Handling and Storage

Where aggregates are not stored in overhead bins, they should be stored on clean hard bases that permit free drainage. Care must be taken that cross contamination between different sized materials does not take place. It is good practice not to store fine aggregate (sand) which is to be used in mortar production adjacent to coarse aggregate.

Attention should be given to potential contamination from overhanging trees, especially when the material is stored for extended periods of time.

During cold weather it is advisable to cover stockpiles of fine aggregate to prevent freezing of the material, especially if it is intended to use the material in the early hours of the morning when any ice particles will not have melted.

European Standards

Historically, the specification for aggregates for use in mortars, screeds and renders was covered by a number of British Standards. These have been superseded by the European standard BS EN 13139. British Standards Institution has also published PD 6682-3 Which, is entitled: Aggregates Part 3: Aggregates for mortar- Guidance on the use of BS EN 13139. This published document (PD) provides amplification on the Standard requirements and a comparison of the grading requirements and other properties against the superseded British Standard.

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Glossary of Terms

The definitions in this learning text are based on those given in BS EN 13139 and BS EN 13055-1, where they are taken from a different source this is indicated.

Aggregate	-	Granular material used in construction. Aggregate may be natural, manufactured or recycled.
Aggregate size	-	Description of aggregate in terms of lower (d) and upper (D) sieve sizes (see text).
Coarse aggregate	-	Designation given to the larger aggregate sizes with D greater or equal to 4 mm and d greater than or equal to 2 mm.
Fine Aggregate	-	Designation given to the smaller aggregate sizes with D less than or equal to 4 mm.
Filler aggregate	-	Aggregate, most of which passes a 0,063 mm sieve, which can be added to construction materials to provide certain properties.
Fines	-	Particle size fraction of an aggregate which passes the 0.063 mm sieve.
Grading	-	Particle sized distribution expressed as the percentage by mass passing a specified set of sieves.
Lightweight aggregates	-	An aggregate of mineral origin having a particle density not exceeding 2,00 Mg/m^3 (2000 kg/m^3) or a loose bulk density not exceeding 1,20 Mg/m^3 (1200 kg/m^3).
Manufactured aggregate	-	Aggregate of mineral origin resulting from an industrial process involving thermal or other modification.
Natural aggregate	-	Aggregate from mineral sources which has been subjected to nothing more than mechanical processing.
Oversize	-	That part of the aggregate retained on the larger of the limiting sieves used in the aggregate size description.
Popout	-	The expansion of a porous aggregate particle due to freezing that separates from the concrete, mortar or screed taking a portion of the surface mortar with it leaving a conical shaped hole. (Physical action) Note: Popouts may also be caused by alkali silica reaction (Chemical action).
Undersize	-	That part of the aggregate passing the smaller of the limiting sieves used in the aggregate size description.

Bibliography

BS EN 932 –1:1997	Tests for general properties of aggregates – Part 1: Methods for sampling.
BS EN 932 –5: 2000	Tests for general properties of aggregates – Part 5: Common equipment and calibration.
BS EN 933 –1: 1997	Tests for geometrical properties of aggregates - Part 1: Determination of particle size distribution - Sieving method.
BS EN 933 –3: 1997	Tests for geometrical properties of aggregates - Part 3: Determination of particle shape - Flakiness index.
BS EN 933 –7: 1998	Tests for geometrical properties of aggregates - Part 7: Determination of shell content - Percentage of shells in coarse aggregates.
BS EN 933 –8: 1999	Tests for geometrical properties of aggregates - Part 8: Assessment of fines. Sand equivalent test.
BS EN 933 –9: 1999	Tests for geometrical properties of aggregates - Part 9: Assessment of fines. Methylene-blue test.
BS EN 1097-6:2000	Tests for mechanical and physical properties of aggregates- Part 6: Determination of particle density and water absorption.
BS EN 1744-1:1998	Tests for chemical properties of aggregates- Part 1: Chemical analysis
BS EN 12620: 2002	Aggregates for concrete including those for use in pavements.
BS EN 13055-1: 2002	Lightweight aggregates – Part 1: Lightweight aggregates for concrete, mortar and grout.
BS EN 13139: 2002	Aggregates for Mortar.
PD 6682-3: 2003	Aggregates for mortar - Guidance on the use of BS EN 13139.
BS 8204- 1: 2003	Screeds, bases and in-situ floorings: Part: 1: Concrete bases and cement sand levelling screeds to receive floorings. Code of practice

Self-Assessment Questions

1	Below what sieve size is material classified as fines?
2	Which European standard is concerned with the specification of natural aggregates for use in mortars?
3	Which two impurities within an aggregate may cause staining and popouts?
4	What are the three categories of rock?
5	What is the recommended limit for fines in rendering and plastering mortars?
6	How is the size of an aggregate designated in the European Standard?
7	What are the two principal effects of organic impurities in fine aggregate?
8	What does the Methylene blue test measure?
9	What are the two methods for reducing bulk samples?
10	What is the typical range of voidage in a fine aggregate that has to be filled with cementitious binder to make a satisfactory mortar?

Answers to Self-Assessment Questions

1	0.063 mm (63μm).
2	BS EN 13139 –Aggregates for Mortar.
3	Lignite, iron pyrite.
4	Igneous, sedimentary, metamorphic.
5	5%.
6	A pair of sieves designates the size of an aggregate (where the size is given in millimetres) with d as the lower limit designation and D as the upper limit designation.
7	An increase in setting time and a decrease in compressive strength.
8	The presence of clay minerals in fine aggregate.
9	A riffle box, coning and quartering.
10	25-40%.