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ARAB ENGINEERING BUREAU

2 AGGREGATES

2.1 GENERAL

2.1.1 Scope

- 1 This part covers the requirements of aggregates for use in structural concrete.
- 2 Related Sections and Parts are as follows:

This Section
Part 3,.....Cementitious Materials
Part 4,.....Water
Part 6,.....Property Requirements
Part 7,.....Concrete Plants
Part 8,.....Transportation and Planning of Concrete
Part 15,.....Hot weather Concreting
Part 17,.....Structural Precast Concrete
Part 18,.....Prestressed Concrete

2.1.2 References

- ASTM C33/C33MStandard Specification for Concrete Aggregates
ASTM C40/C40MStandard Test Method for Organic Impurities in Fine Aggregates for Concrete
ASTM C87/C87MStandard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
ASTM C88/C88MStandard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
ASTM C123/C123M ...Standard Test Method for Lightweight Particles in Aggregate
ASTM C127Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
ASTM C128Standard Test Method for Relative Density (Specific Gravity) and Absorption of Fine Aggregate
ASTM C131/C131M...Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C136/C136M...Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C142/C142M...Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C535.....Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
ASTM C702/C702M ...Standard Practice for Reducing Samples of Aggregate to Testing Size
ASTM D75/D75MStandard Practice for Sampling Aggregates
- BRE Digest 330.....Alkali-silica reaction in concrete
.....Part 1: Background to the guidance notes
.....Part 2: Detailed Guidance for New Construction
.....Part 3: Worked Examples
.....Part 4: Simplified guidance for new construction using normal reactivity aggregates.

- BS 8500-2Concrete. Complementary British Standard to BS EN 206 - Specification for constituent materials and concrete
- BS PD 6682-1Aggregates. Aggregates for concrete. Guidance on the use of BS EN 12620
- BS PD 6682-4Aggregates - Lightweight aggregates for concrete, mortar and grout. Guidance on the use of BS EN 13055-1
- EN 206Concrete - Specification, performance, production and conformity
- EN 12620Aggregates for concrete
- EN 1744-1Tests for chemical properties of aggregates - Part 1: Chemical analysis
- EN 1744-5Tests for chemical properties of aggregates - Part 5: Determination of acid soluble chloride salts
- EN 1367-2Tests for thermal and weathering properties of aggregates - Part 2: Magnesium sulfate test
- EN 1367-4Tests for thermal and weathering properties of aggregates - Part 4: Determination of drying shrinkage
- EN 933Tests for geometrical properties of aggregates
- EN 933-3Tests for geometrical properties of aggregates - Part 3: Determination of particle shape - Flakiness index
- EN 933-7Tests for geometrical properties of aggregates - Part 7: Determination of shell content - Percentage of shells in coarse aggregates
- EN 933-9Tests for geometrical properties of aggregates - Part 9: Assessment of fines - Methylene blue test
- EN 933-11Tests for geometrical properties of aggregates - Part 11: Classification test for the constituents of coarse recycled aggregate
- EN 1097-2Tests for mechanical and physical properties of aggregates - Part 2: Methods for the determination of resistance to fragmentation
- EN 1097-6Tests for mechanical and physical properties of aggregates - Part 6: Determination of particle density and water absorption
- EN 13055Lightweight aggregates
- EN 13139Aggregates for mortar
- EN 998-1Specification for mortar for masonry - Part 1: Rendering and plastering mortar
- EN 998-2Specification for mortar for masonry - Part 2: Masonry mortar
- ISO 9001Quality management systems — Requirements
- ISO/IEC 17025General requirements for the competence of testing and calibration laboratories
- RILEM AAR1RILEM Recommended Test Method AAR-1: Detection of potential alkali-reactivity of aggregates – Petrographic method
- RILEM AAR3RILEM Recommended Test Method: AAR-3—Detection of Potential Alkali-Reactivity—38°C Test Method for Aggregate Combinations Using Concrete Prisms

2.1.3 Definitions

- 1 Aggregate: granular material used in construction and may be natural, manufactured or recycled.
- 2 Natural aggregate: aggregate from mineral sources which has been subjected to nothing more than mechanical processing.
- 3 Manufactured aggregate: aggregate of mineral origin resulting from an industrial process involving thermal or other modification.
- 4 Recycled aggregate: aggregate resulting from the processing of inorganic material previously used in construction.
- 5 Lightweight aggregate: aggregate of mineral origin having a particle density not exceeding 2,000 kg/m³ or a loose bulk density not exceeding 1,200 kg/m³.

2.1.4 Source Approval

- 1 The Contractor shall use only those imported materials sourced from an Accredited Quarry Producer or Accredited Supplier and which approved by concern authorities; or the Engineer.
- 2 The accredited aggregate suppliers shall provide the source name(s) for every shipment of aggregates delivered to the concrete supplier.
- 3 The source of material supply may be changed by the Contractor during the project, provided that the replacement materials shall be sourced from an Accredited Quarry Producer and the replacement materials are not significantly different in terms of physical and chemical properties, thus ensuring that the resultant concrete continues to comply fully with the specified requirements.
- 4 When considering whether an aggregates supplier and aggregates producer are suitable to be Accredited, preference will be given to organisations with a proper quality management system, such as ISO 9001 or another quality management system approved by the Engineer.
- 5 When requested by the engineer, the aggregate supplier shall provide a geotechnical analysis on the rock samples before blasting and grinding to ensure the proper quality of materials.
- 6 The aggregates shall be properly stocked and labelled without intermingling at any storage area.
- 7 When requested by the engineer, the aggregates supplier shall provide data for the past 6 months that shows the consistency of materials and conformity with this specification.
- 8 The supplier shall verify the compliance of aggregates as per QCS by an independent qualified testing agency accredited to ISO/IEC 17025.

2.1.5 Sampling

- 1 The Contractor shall provide samples of both fine and coarse aggregate to the Engineer, in accordance with the requirements of relevant standards for sampling, sample reducing and testing of Aggregates, for testing at least two weeks before beginning deliveries to the Site.
- 2 All samples shall be taken in the presence of the Engineer or an approved testing agency assigned by the Engineer.
- 3 Aggregate sampling and testing shall be conducted by qualified staff.

2.2 QUALITY AND TESTING

- 1 Aggregates shall consist of tough, hard, durable and uncoated particles containing no harmful material in quantities sufficient to adversely affect the concrete or reinforcing steel, and shall contain no materials likely to cause staining or otherwise disfigure the concrete surface.
- 2 Aggregates shall be obtained from a source approved by the Engineer.
- 3 Aggregate shall meet the requirements given in Table 2.1. Additional tests detailed in EN 12620 with BS PD 6682, EN 13139, EN 998-1, EN 998-2, or relevant ACI and ASTM standards and codes of practice may be required by the Engineer to satisfy certain requirements.
- 4 Contractor shall provide all data as specified in QCS.
- 5 Sampling of the aggregates shall be carried out in accordance with the requirements of EN 12620, EN 933, or ASTM D75/D75M and ASTM C702/C702M.
- 6 Fine aggregates shall be natural sand or manufactured crushed rock sand. Crushed rock sand shall be the direct product of a manufacturing process, not the by-product of coarse aggregate production.
- 7 Beach sand shall not be permitted for use in concrete mixes.
- 8 The use of clean Dune Sand, blended with coarser sand, may be permitted providing it can be shown that the sand is free from contaminants. The use of local Dune sand shall be preapproved by the Ministry of Municipality MM and Ministry of Environment and Climate Change MOECC.
- 9 Samples of aggregates shall be taken in accordance with the requirements of Table 1.1-Part1.
- 10 Frequency of routine testing shall meet the requirements as listed in Section 2. Frequency of testing may be increased by the engineer's request if testing results show inconsistency, and frequency may be reduced if approved by the engineer if materials are highly consistent.
- 11 Mineralogical tests are to be carried out as instructed by the Engineer.
- 12 No aggregate deliveries shall be made to the Site until the Engineer has approved the samples as complying with this specification.

2.3 STORAGE AT CONTRACTOR PLANT

- 1 Aggregate shall be stored as follows:
 - (a) each nominal size of coarse aggregate and fine aggregate shall be kept separated and clearly labelled at all times.
 - (b) The height of stockpiles shall be controlled to prevent harmful segregation and breakage of the aggregate.
 - (c) stockpiles shall be on hard and clean surfaces with not more than 5 % slope
 - (d) contamination of the aggregates by the ground or other foreign matter shall be effectively prevented at all times
 - (e) each heap of aggregate shall be capable of draining freely
 - (f) stockpiles shall be protected from direct sunlight
 - (g) unloading of aggregate shall be controlled to prevent harmful segregation and breakage.
- 2 The Contractor shall maintain the stockpiles of coarse aggregate in separate gradings.
- 3 At the construction site, the preparation, location and size of any stockpile shall be approved by the Engineer.

Table 2.1

Limits for Physical, Chemical and Mechanical Properties of Aggregates for Normal Concrete

No.	Requirement	Test Methods ¹		Permissible Limits	
		BS / EN	ASTM	Fines	Coarse
1.	Grading	933-1		Standard	Standard
2.	Natural: materials finer than 0.063 mm.	933-1		3% max	2% max
	Crushed rock: materials finer than 0.063mm.			7% max	2% max
3.	Fines quality: Methylene blue adsorption value ² (0/2mm)	933-9		0.7 (g/kg) max	
4.	Clay lumps and friable particles		C142/C1 42M	2% max	2% max
5.	Lightweight pieces		C123/C1 23M	0.5% max	0.5% max
6.	Organic impurities for fine aggregates		C40/C40 M	Colour standard not darker than plate No. 3 ³	NA
7.	Water absorption (saturated surface dry)				
	Structural concrete	1097-6		2.3% max	2.0% max
	Non-structural concrete			3 % max	3% max
8.	Particle density for normal weight concrete	1097-6		2.0 min	2.0 min
9.	Shell Content:	933-7		3% max	3% max
10.	Flakiness index	BS 812-105.1			35% max
11.	Acid-soluble chlorides:	1744-5			
	a) Reinforced and mass concrete			0.06%	0.03% ⁴
	b) Prestressed concrete and steam cured structural concrete ⁵			0.01%	0.01%
12.	Acid-soluble sulphate	1744-1		0.4% ⁶	0.3% ⁷
13.	Soundness by magnesium sulphate (5 cycles)	1367-2		15% max	15% max
14.	Resistance to fragmentation: Los Angeles abrasion	1097-2			30% max
15.	Drying shrinkage	1367-4			0.075% max
16.	Potential reactivity:	See Note 7 below			

Notes:

1. Use of EN or relevant GSO standards.
2. Not required when the fines content in the fine aggregate, or in the all-in aggregate, is 3% or less.
3. Organic impurities: use of a fine aggregate failing in the test is not prohibited, provided that:
 - a. The discoloration is due principally to the presence of small quantities of coal, lignite, or similar

- discrete particles.
- b. When tested for the effect of organic impurities on strength of mortar, the relative strength at 7 days, calculated in accordance with ASTM C87/C87M, is not less than 95 %.
 - 4. The maximum acid soluble chloride of local coarse aggregate may be accepted up to a maximum level of 0.05%, provided that the chloride content of the concrete ingredients shall be as per EN 206: table 15 , provided that for reinforced concrete shall not exceed 0.2% . Tests shall be as per BS 8500-2.
 - 5. If the chloride content is higher than 0.01% the following steps may be taken:
 - a- The aggregates may be washed by suitable water (Sec 5 Part 4) before mixing to lower the chloride content to the specified value (0.01%).
 - b- If the washing process does not reduce the chloride content to the required value, then the acid soluble chloride content in the concrete ingredients (the sum of the contributions from the constituent materials) shall be tested as mentioned in BS 8500-2. The allowable Acid Soluble chloride content limit shall not exceed the values given in Section 5, Part 6, Para 6.5.3.
 - 6. The maximum acid soluble sulfate of local fine aggregate may be accepted up to a maximum value of 0.5%, provided the combined fine and coarse aggregates shall meet the requirements of EN 12620: 2013 for acid soluble sulfate category AS_{0.8}.
 - 7. The alkali-aggregate reactivity shall be assessed at source in accordance with EN 206 and BS 8500-2. Certification shall be obtained from the aggregate source indicating absence of deleterious expansion of concrete due to alkali aggregate reactivity.

2.4 FINE AGGREGATE FOR CONCRETE AND MORTAR

- 1 Fine aggregate consist of natural clean sand, stone screenings or a combination and can be produced from natural disintegration of rock or gravel and/or by the crushing of rock or gravel or processing of manufactured aggregate or artificial, conforming to the requirements of physical and chemical properties complying with Table 2.1 and subject to the Engineer's acceptance.
- 2 Crushed fine aggregates may be blended with local washed sand provided that the final aggregate complies with the requirements in Table 2.1.
- 3 The gradation of fine aggregate for concrete and mortar shall be in accordance with the gradation designations in EN 12620 with BS PD 6682, EN 13139, EN 998-1 , EN 998-2, or relevant ACI and ASTM standards and codes of practice and subject to the Engineer's acceptance.
- 4 Each batch of aggregate delivered to the Site shall be kept separate from previous batches, and shall be stored to allow for inspection and tests to be carried out.
- 5 Local natural sand shall be mechanically washed to remove salts and other impurities in order to meet the specified requirements.
- 6 The storage area for the clean washed sand shall be shaded from the direct rays of the sun and shall be screened for protection from dust. The area in the neighbourhood of stockpile/mixing plant shall be watered as necessary, to reduce the rising of dust.
- 7 The usage of Dune sand shall be accepted as governed by the regulations of Qatar Ministry of Environment and shall be:
 - (a) Not used for any reinforced concrete
 - (b) Used only for blocks, block mortar, plasters, soil cement, shotcrete and insulation concrete.

2.5 COARSE AGGREGATE FOR CONCRETE

- 1 The coarse aggregate is granular material and may be natural, manufactured, recycled or a combination. It shall be free from deleterious matter and conforming to the requirements of physical and chemical properties in Table 2.1 as a minimum requirements and subject to the Engineer's acceptance within EN 12620, BS PD 6682 or ASTM C33/C33M

- 2 For imported aggregate, Engineer may ask for more requirements and stringent limits than specified in Table 2.1.
- 3 For other types of concrete mixes and subject to Engineer's acceptance, coarse aggregate shall comply with the relevant EN or relevant ACI and ASTM standards and codes. The nominal maximum size of coarse aggregate shall be not larger than: (a) 1/5 the narrowest dimension between sides of forms, nor (b) 1/3 the depth of slab, nor (c) 3/4 the minimum clear spacing between individual reinforcing bars or wires, bundles of bars, individual tendons, bundled tendons, or ducts.
- 4 These limitations shall not apply if, in the judgment of the licensed design professional, workability and methods of consolidation are such that concrete can be placed without honeycombs or voids.
- 5 As requested by the Engineer, the Contractor shall mechanically wash the aggregates to remove salts and other impurities in order to meet the requirements specified.

2.6 COMBINED AGGREGATE FOR CONCRETE

- 1 The material passing the 0.063mm sieve shall not exceed 3.0 % of the combined aggregate (by weight). The combined aggregate gradation used in the work shall be as specified, except when otherwise approved or directed by the Engineer.
- 2 Changes in the approved gradation shall not be made during the progress of the works unless approved or directed by the Engineer.

2.7 WASHING AND PROCESSING

- 1 Where aggregates have been washed shortly before delivery to the Site, or if stockpiles have been sprayed to cool them, samples of the aggregate shall be taken frequently to determine the correct amount of water to add to the mix.

2.8 LIGHTWEIGHT AGGREGATES

- 1 Lightweight aggregates are those having particle densities not exceeding 2,000 kg/m³ or loose bulk densities not exceeding 1200 kg/m³.
- 2 Lightweight aggregates include natural aggregate, aggregate manufactured from natural materials and/or a by product of industrial processes, and some recycled aggregate.
- 3 Lightweight aggregates shall be in accordance with EN 13055 and BS PD 6682-4, or equivalent ASTM standards.

2.9 RECYCLED AGGREGATES

- 1 Fine and coarse recycled aggregate of excavation Waste (EW), coarse recycled aggregates (RA), and coarse recycled concrete aggregates (RCA) shall meet with the requirements of Table 2.1, with the exception that water absorption shall not exceed;
 - (a) 3% for structural concrete
 - (b) 5% for non-structural concrete.
- 2 For structural concrete EW and/or RCA may be used in designated concrete of maximum C30. Its proportion shall be not more than a mass fraction of 20% of coarse aggregate (BS 8500-2 sec 6.2.2), except where approved by the Engineer to use a higher proportion.
- 3 For non-structural concrete, such as crash barriers and soakaways, EW and/or RCA may be used in designated concrete of maximum C40. Its proportion shall be not more than a mass fraction of 50% of aggregate (BS 8500-2 sec 6.2.2), except where approved by the Engineer.

- 4 For non-structural concrete RA may be used in designated concrete of maximum C25. Its proportion shall be not more than a mass fraction of 20% of aggregate (BS 8500-2 sec 6.2.2), except where approved by the Engineer to use a higher proportion.
- 5 When the composition of coarse RCA and coarse RA is tested in accordance with EN 933-11, the test result obtained for each type of particle shall not exceed the maximum value specified in Table 2.2.
- 6 EW aggregate shall meet the same requirements for RCA, as given in Table 2.2.
- 7 The engineer and/or project designer also could add and/or modify any regulation, requirement, procedure, technic, and specification that considers the minimum requirements that are mentioned in the QCS and the applicable national standards, if there are any.
- 8 It is the responsibility of the engineer, contractor, and consultant to ensure that any modification is suitable for the site's environmental conditions, safe from an engineering standpoint, and complies with the relevant quality and performance requirements.

Table 2.2
Requirements for coarse RCA and coarse RA, (mass fraction, %)

Type of Aggregate	Requirement ¹					
	Maximum masonry content	Maximum fines	Maximum lightweight material ²	Maximum Asphalt	Maximum foreign material e.g. glass, plastic, metals	Maximum acid soluble sulphate (SO_3)
RCA ^{1, 3}	5.0	5.0	0.5	5.0	1.0	1.0
RA	100	3	1.0	10.0	1.0	- ⁴

1. Where the material to be used is obtained by crushing hardened concrete of known composition that has not been in use, e.g. surplus precast units or returned fresh concrete, and not contaminated during storage and processing, the only requirements are those for grading and maximum fines.
2. Material with a density less than $1,000 \text{ kg/m}^3$
3. The provisions for coarse RCA may be applied to mixtures of natural coarse aggregates blended with the listed constituents.
4. The appropriate limit and test method needs to be determined on a case-by-case basis (see Note 6 to 4.3 of BS 8500-2).

- 9 The floating material (FL) content, as per EN 933-11, shall not exceed $5.0 \text{ cm}^3/\text{kg}$.
- 10 RCA should be treated as highly reactive aggregate. The alkali contribution from RCA shall be determined as given in BS 8500-2.
- 11 For manufacturing of masonry concrete blocks, the usage of recycled aggregates is permitted up to 100% as given in Sec. 13 in accordance with ACI 555.

END OF PART