

Technical Specifications for Sand as per BIS

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Fine aggregate popularly known as SAND is an essential building construction material. River sand is generally used by everyone for various construction purposes; production of concrete, cement-sand mortar and concrete blocks. As river sand is becoming scarce, various Government, Non Governmental Organisations and Research Institutes are striving to identify alternative materials to supplement river sand. There is a strong need for research on river sand substitutes for concrete production and cement sand mortar production. The research should aim to identify suitable river sand substitutes for practical applications in the construction industry and also focus on formulating practical solutions for using river sand substitutes. The development of standards / specifications and incorporating in the BIS codes will reduce the pressure on using river sand. The standards and codal specifications will assist to select and use the alternatives by the various stake holders. Quality certification of the alternate aggregates and quality certification of the concrete manufacturing process plays a vital role in ensuring the durability of the concrete.

Researchers are in continuous search for the alternatives to sand. Fine aggregate is one of the important constituents of concrete. River sand is becoming a scarce material. Sand mining from rivers has become objectionably excessive. It has reached a stage where it is killing all our rivers day by day. So sand mining has to be discouraged so as to save the rivers. As natural sand deposits become depleted near some areas of metropolitan growth, the use of alternatives to sands as a replacement fine aggregate in concrete is receiving increased attention. The National Green Tribunal also imposed ban and restrictions on the sand mining.

Some of the alternatives to river sand are;

- Manufactured Sand
- Fly Ash/ Bottom Ash/Pond Ash
- Copper Slag
- Filtered Sand
- Sea Sand
- Slag Sand
- Crushed Waste Glass
- Recycled Aggregate/C&D Waste Aggregate etc..

Technical Specifications for Sand as per Bis

The latest Indian Standard IS: 383-2016; "Coarse and Fine Aggregates for Concrete- Specification (Third Revision)" covers the requirements for aggregates, crushed or uncrushed, derived from natural sources, such as river terraces and riverbeds, glacial deposits, rocks, boulders and gravels, and manu-

factured aggregates produced from other than natural sources, for use in the production of concrete for normal structural purposes including mass concrete works.

This standard was first published in 1952 and subsequently revised in 1963 and 1970. This revision has been taken up to incorporate the modifications found necessary in the light of experience gained in its use and also to bring it in line with the latest development on the subject. Significant modifications in this revision include,

- a) Scope of the standard has been widened to cover aggregates from other than natural sources
- b) Definitions of various terms have been rationalized
- c) limits for mica as deleterious material for muscovite and muscovite plus biotite varieties have been included.
- d) The requirements for crushing value, impact value and abrasion value have been classified under a common head of mechanical properties.
- e) Requirement for flakiness and elongation has been specified for which a combined index has been introduced along with the procedure for determination of the same
- f) Provisions on alkali aggregate reactivity have been included to bring coherence of the same with IS 456 : 2000 'Code of practice for plain and reinforced concrete (fourth revision)' and requirements for compliance for the same have been included; and
- g) Mixed sand has been included along with crushed sand.

Before choosing fine aggregate; natural or manufactured or any other alternative one should check the technical specifications as per the BIS codes. Sand is mainly used for the preparation of mortar and concrete. It is also required to manufacture the building blocks. The standard terminology used for sand is fine aggregate. We all know that sand is a naturally occurring granular material composed of finely divided rock and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand is silica (silicon dioxide, or SiO₂), usually in the form of quartz. Fine aggregates are less than 4.75 mm in size and F.A. content usually 35% to 45% by mass or volume of total aggregate.

Classification of fine Aggregates as per IS: 383-2016

Terminology

For the purpose of this standard, the definitions given in IS 6461 (Part 1) and the following shall apply.

Fine Aggregate - Aggregate most of which passes 4.75 mm

IS Sieve and contains only so much coarser material as permitted in 6.3.

Natural Sand - Fine aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies. This may also be called as un-crushed sand.

Crushed Sand

Crushed stone sand- Fine aggregate produced by crushing hard stone.

Crushed gravel sand - Fine aggregate produced by crushing natural gravel.

Mixed Sand - Fine aggregate produced by blending natural sand and crushed stone sand or crushed gravel sand in suitable proportions.

Manufactured Fine Aggregate (Manufactured Sand) - Fine aggregate manufactured from other than natural sources, by processing materials, using thermal or other processes such as separation, washing, crushing and scrubbing.

NOTE - Manufactured fine aggregate may be Recycled Concrete Aggregate (RCA) (see Annex A).

Quality of Aggregates

All-in-Aggregate – Material composed of fine aggregate and coarse aggregate.

Classification

The aggregate shall be classified as given in 4.1 and 4.2. In case of missed sand the manufacturer / supplier should supply the individual sand to be mixed at site, at the time of batching.

Aggregates from Natural sources

These shall be coarse and fine aggregates as defined in

3.1.1, 3.1.2, 3.1.3 and 3.2 [see also Note under 3.2 (a), (b) and (c)]

Manufactured Aggregates and Extent of Utilization

These shall be coarse and fine aggregates as defined in 3.1.4 and 3.2 (see also Note under 3.2 (d))

The manufactured aggregates shall be permitted with their extent of utilization as percent of total mass of fine or coarse aggregates as the case may be, as indicated in Table 1 against each, for use in plain and reinforced concrete and lean concrete.

Manufactured aggregates shall not be permitted for use in prestressed concrete.

Quality of Aggregate

General

Aggregate shall be naturally occurring (crushed or un-crushed) stones, gravel and sand or combination thereof or produced from other than natural sources. They shall be hard, strong, dense, durable, clear and free from veins; and free from injurious amounts of disintegrated pieces, alkali, free lime, vegetable matter and other deleterious substances as well as adherent coating. As far as possible, scoriaceous, flaky and elongated pieces should be avoided.

Deleterious Materials

Aggregate shall not contain any harmful material, such as pyrites, coal, lignite, mica, shale or similar laminated material, clay, alkali, free lime, soft fragments, sea shells and organic impurities in such quantity as to affect the strength or durability of concrete. Aggregate to be used for reinforced concrete shall not contain any material liable to attack the steel reinforcement.

Limits of Deleterious Materials

Sl.No.	Type of Aggregate	Maximum Utilization		
		Plain Concrete Percent	Reinforced Concrete Percent	Lean Concrete (Less than M15 Grade) Percent
i)	Coarse aggregate:			
	a) Iron slag aggregate	50	25	100
	b) Steel slag aggregate	25	Nil	100
	c) Recycled concrete aggregate ¹ (RCA) (see note 1)	25	20 (only upto M25 Grade)	100
	d) Recycled aggregate ¹ (RA)	Nil	Nil	100
	e) Bottom ash from Thermal Power Plants	Nil	Nil	25
ii)	ii) Fine aggregate:			
	a) Iron slag aggregate	50	25	100
	b) Steel slag aggregate	25	Nil	100
	c) Copper slag aggregate	40	25	50
	d) Recycled concrete aggregate ¹ (RCA) (see Note 1)	25	20 (only upto M25 Grade)	100

Table 1: Extent of Utilization, 1) See A.3 for brief information on recycled aggregates (RA) and recycled concrete aggregates (RCA).

NOTES

- 1 It is desirable to source the recycled concrete aggregates from sites being redeveloped for use in the same site.
- 2 In any given structure, only one type of manufactured coarse aggregate and one type of manufactured fine aggregate shall be used.
- 3 The increase in density of concrete due to use of copper slag and steel slag aggregates need to be taken into consideration in the design of structures.
- 4 While using manufactured aggregate as part replacement for natural aggregate, it should be ensured that the final grading meets the requirements specified in Table 7, Table 8 and Table 9.

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Deleterious Substance	Method of Test, Ref to	Fine Aggregate Percentage by Mass Max			Coarse Aggregate Percentage by Mass Max		
Coal and lignite	IS 2386 (Part 2)	1.00	1.00	1.00	1.00	1.00	1.00
Clay lumps	IS 2386 (Part 2)	1.00	1.00	1.00	1.00	1.00	1.00
Materials finer than 75 µm IS sieve	IS 2386 (Part 10)	3.00	15.00 (for crushed sand) 12.00 (For mixrd sand) see Note 1)	10.00	1.00	1.00	1.00
Soft fragments	IS 2386 (Part 2)	-	-	-	3.00	-	3.00
Shale	(see Note 2)	1.00	-	1.00	-	-	-
Total of percentages of all deleterious materials (except mica) including SI no. (1) to (5) for col 4,7 and 8 and SI No. (1) and (2) for col 5,6 and 9	-	5.00	2.00	2.00	5.00	2.00	2.00

Table 2: Limits of Deleterious Materials

NOTES

- The sands used for blending in mixed sand shall individually also satisfy the requirements of Table 2. The uncrushed sand used for blending shall not have material finer than 75 mm more than 3.00 percent.
- When the clay stones are harder, platy and fissile, they are known as shales. The presence and extent of shales shall be determined by petrography at the time of selection and change of Source.
- The presence of mica in the fine aggregate has been found to affect adversely the workability, Strength, abrasion resistance and durability of concrete. Where no tests for strength and durability are conducted, the mica in the fine aggregate may be limited to 1.00 percent by mass. Where tests are conducted to ensure adequate workability, satisfactory strength, permeability and abrasion (for wearing surfaces), the mica up to 3.00 percent by mass for muscovite type shall be permitted. In case of presence of both muscovite and biotite mica, the permissible limit shall be 5.00 percent, maximum by mass. This is subject to total deleterious materials (including mica) being limited to 8.00 percent by mass for col 4 and 5.00 percent for col 5.
Till a method is included in IS 2386 (Part 2), for determination of mica content, suitable methodology may be used for the same. Normally, petrographic density separation and wind blowing methods can be used.
- The aggregate shall not contain harmful organic impurities [tested in accordance with IS 2386 (Part 2) in sufficient quantities to affect adversely the strength or durability of concrete. A fine aggregate which fails in the testing of organic impurities may be used, provided that, When tested for the effect of organic impurities on the strength of mortar, the relative strength at 7 and 28 days, reported in accordance with IS 2386 (Part 6) is not less than 95 percent.

The maximum quantity of deleterious materials shall not exceed the limits specified in Table 2. However, the engineer-in-charge at his discretion may relax some of the limits as a result of some further tests and evidence of satisfactory performance of the aggregates.

Soundness of Aggregate

For concrete liable to be exposed to the action of frost, the coarse and fine aggregates shall pass a sodium or magnesium sulphate accelerated soundness test specified in IS 2386 (Part 5), the limits being set by agreement between the purchaser and the supplier.

NOTE - As a general guide, it may be taken that the average loss of mass after 5 cycles shall not exceed the following:

- For fine aggregate: 10 percent when tested with sodium sulphate (Na₂SO₄), and 15 percent when testing with magnesium sulphate (MgSO₄)

For slag aggregates, following additional tests shall be carried out

- Iron unsoundness - When chemical analysis of aggregates shows that the ferrous oxide content is equal to or more than 3.0 percent, and, sulphur content is equal to or more than 1.0 percent, the aggregate shall be tested for iron unsoundness. The iron unsoundness of the slag aggregate when tested as per the procedure given in Annex D, shall not exceed 1 percent.
- Volumetric expansion ratio - It shall not be more than 2.0 percent. The procedure shall be as given in Annex E.
- Unsoundness due to free lime - Prior to use iron slag (for production of aggregates) from anew source or when significant changes in furnace chemistry occur in an existing source which may result in the presence of free lime, the potential for pop-out formation shall be assessed by determining the free-lime content of the slag by petrographic

Characteristic	Requirement
Total alkali content as Na ₂ O equivalent, percent, Max	0.3
Total sulphate content as So ₃ , percent Max	0.5
Acid soluble chloride content, percent, Max	0.04
Water absorption, percent, Max	5 [see Note 1]
Specific gravity	2.1 to 3.2 [see Note 2 and 3]

Table 3 Additional requirements for all Manufactured Aggregates.

NOTES

- For recycled concrete aggregate and recycled aggregate, higher water absorption up to 10 percent may be permitted subject to pre-wetting (saturation) of aggregates before batching and mixing.
- The limits are intended for use of aggregate in normal weight concrete.
- Copper slag having higher specific gravity (up to 3.8) shall be permitted for part replacement of aggregates in accordance with 4.2.1 such that the average specific gravity of the fine aggregate is not more than 3.2.

examination or quantitative x-ray diffractometry on a representative sample.

If the number of particles containing free lime exceeds 1 in 20, then weathering of the slag stockpile (in moist condition or at/near saturated surface dry condition) represented by the test sample shall be continued until further testing shows that the level has fallen below 1 in 20.

Manufactured aggregates shall meet the additional requirements as given in Table 3, Table 4, Table 5 and Table 6.

Characteristic [2]	Requirement
Calcium oxide as CaO, percent, Max	45.0
Total sulphur as S, percent, Max	2.0
Total iron as FeO, percent, Max	3.0

Table 4: Additional Requirements for Iron and Steel Slag Aggregates
 Note: Stockpiling of slag aggregate: Crushed slag aggregate should be stockpiled in moist condition at or near the saturated surface dry (SSD) condition before use, with the moisture condition being maintained by sprinkling with water.

Characteristic [2]	Requirement
Calcium oxide as CaO, percent, Max	40
Magnesium oxide as MgO, percent, Max	10
Total iron as FeO, percent, Max	50
Basicity as CaO/SiO ₂ , percent, Max	2

Table 5: Additional Requirements for Electric Furnace Oxidation Slag Coarse Aggregate

Characteristic [2]	Requirement
Calcium oxide as CaO, percent, Max	12.0
Total sulphur as S, percent, Max	2.0
Total iron as FeO, percent, Max	70
Chlorine as NaCl, percent, Max	0.03

Table 6: Additional Requirements for Copper Slag Aggregate

particular grading zone of service other than 11600 µm IS Sieve by an amount not exceeding 5 percent for a particular sieve size, (subject to a cumulative amount of 10 percent), it shall be regarded as falling within that grading zone. This tolerance shall not be applied to percentage passing the 600 µm IS Sieve or to percentage passing any other sieve size on the coarse limit of Grading Zone I or the finer limit of Grading Zone IV.

IS Sieve Designation	Percentage Passing			
	Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
10 mm	100	100	100	100
4.75 mm	90-100	90-100	90-100	90-100
2.36 mm	60-95	75-100	85-100	95-100
1.18 mm	30-70	55-90	75-100	90-100
600 µm	15-34	35-59	60-79	80-100
300 µm	5-20	8-30	12-40	15-50
150 µm	0-10	0-10	0-10	0-15

Table 7 Fine Aggregates

NOTES

- For crushed stone sands, the permissible limit on 150 µm IS Sieve is increased to 20 percent. This does not affect the 5 percent allowance permitted in 6.3 applying to other sieve sizes.
- Fine aggregate complying with the requirements of any grading zone in this table is suitable for concrete but the quality of concrete produced will depend upon a number of factors including proportions.
- As the fine aggregate grading becomes progressively finer, that is, from Grading Zones I to N, the ratio of fine aggregate coarse aggregate should be progressively reduced. The most suitable fine to coarse ratio to be used for any particular mix will, however, depend upon the actual grading, particle shape and surface texture of both fine and coarse aggregates.
- It is recommended that fine aggregate conforming to Grading Zone IV should not be used in reinforced concrete unless tests have been made to ascertain the suitability of proposed mix proportions.

Sampling and Testing

Sampling

The method of sampling shall be in accordance with IS 2430. The amount of material required for each test shall be as specified in the relevant method of test given in IS 2386 (Part 1) to IS 2386 (Part 8).

Size and Grading of Aggregates

Fine Aggregate

The grading of fine aggregate, when determined as described in IS 2386 (Part 1) shall be within the limits given in Table 9 and shall be described as fine aggregate, Grading Zones I, II, III and IV. Where the grading falls outside the limits of any

Chemical tests like alkalis (Na_2O equivalent), sulphate (SO_3), calcium oxide, sulphur (S), iron (FeO), magnesium oxide (MgO), silica (SiO_2) and chlorine (NaCl), can be carried out as per IS 4032 and water soluble chloride test can be carried out as per IS 14959 (Part 2). All other tests shall be carried out as described in IS 2386 (Part 1) to IS 2386 (Part 8) and in this standard.

Supplier’s Certificate and Cost of Tests

The supplier shall satisfy himself that the material complies with the requirements of this standard and, if requested, shall supply a certificate to this effect to the purchaser.

If the purchaser requires independent tests to be made, the sample for such tests shall be taken before or immediately after delivery according to the option of the purchaser, and the tests carried out in accordance with this standard and on the written instructions of the purchaser.

The supplier shall supply free of charge, the material required for tests.

The cost of the tests carried out under 8.2 shall be borne by,

- a) the supplier, if the results show that the material does not comply with this standard
- b) the purchaser, if the results show that the material complies with this standard.

Annex A

Brief Information on Aggregates from other than Natural Sources

A-I Iron and Steel Slag Aggregates

A-I.1 Iron Slag Aggregate

A-1.1.1 Iron slag is obtained as a byproduct, while producing iron in blast furnaces or basic oxygen furnaces in integrated iron and steel plants. The lime in the flux chemically combines with the aluminates and silicates of the iron ore and coke ash to form a non-metallic product called iron/blast furnace slag. The molten slag at a temperature of approximately 1500°C is taken out of the furnace and cooled to form different types of slag products.

A-1.1.2 Air Cooled Iron Slag Aggregate

Molten slag is allowed to flow from the furnace into open pits located beside the furnaces where the material is quenched with water to facilitate cooling and crystallization. The slag after cooling can be further crushed and screened to produce different sizes of aggregates. During its usage, care should be taken to ensure that the slag passes the test for ‘iron unsoundness’ and is pre-wetted prior to its use. Figure 1 shows typical air-cooled iron slag aggregate.

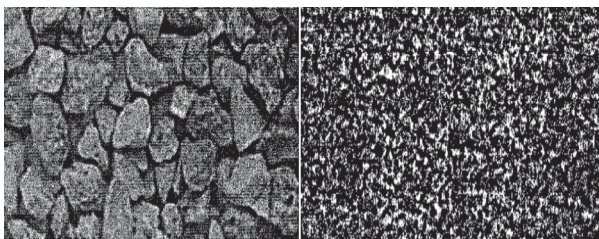


Figure 1: Air Cooled Iron Slag Aggregate

Figure 2: Granulated Iron Slag Aggregate

A-I.1.3 Granulated Iron Slag Aggregate

In this case, molten slag is allowed to flow through the launders into a granulation plant, where molten slag is quenched rapidly with large volume of water. This results in vitrified (glassy) material with a sand-like appearance, with particles typically 1 mm to 5 mm size. It is light weight aggregate, which needs further processing to improve the bulk density to more than 1.35 kg/l for its use as normal weight aggregate. Figure 2 shows typical granulated iron slag aggregate.

A-1.2 Steel Slag Aggregate

Steel slag is a byproduct produced in steel making operations in integrated iron and steel plants. The calcined lime used as flux combines with the silicates, aluminum oxides, magnesium oxides, manganese oxides and ferrites to form steel furnace slag, commonly called steel slag. Slag is poured in a cooling yard from the furnace at a temperature of 1400°C - 1700°C and cooled by air and sprinkling of water. Steelmaking slag contains about 10 to 20 metallic iron percent by mass and is recovered by magnetic separation; The metal free slag is crushed and screened to different sizes for use as aggregates. For use as aggregates, the steel slag is subjected to weathering process (natural or accelerated) to reduce the free lime content in the slag. Figure 3 shows typical steel slag aggregate.

NOTE - Air Cooled Blast furnace Slag (ACBFS) has unique chemical and physical properties that influence its behavior as an aggregate in concrete. Several of the key chemical properties are provided but the physical property of greatest concern is the high level of porosity compared to that present in naturally derived aggregates, which contributes to high absorption capacities. This is important during construction, as the moisture condition of the aggregate will impact workability and early-age, shrinkage-related cracking, if the aggregate is not kept sufficiently moist prior to batching. It may also have long-term ramifications on in service durability, depending on the level of saturation those aggregates are subjected to either at the bottom of the slabs or in the vicinity of joints, and cracks.

A-2 Copper Slag as Aggregates

Copper slag is produced as a byproduct from copper smelter, while producing copper from copper concentrate (copper pyrite) through pyrometallurgical process. In the process of smelting, the iron present in the copper concentrate combines

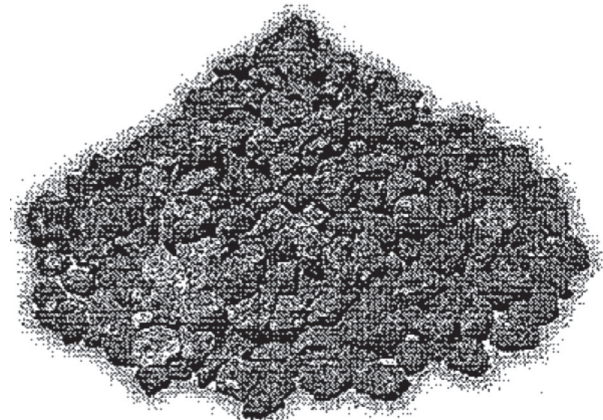


Figure 3: Steel Slag Aggregate

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chemically at 1 200°C with silica present in flux materials such as river sand/silica sand/ quartz fines to form iron silicate, which is termed as copper slag. The copper slag thus generated is quenched with water to produce granulated copper slag.

Copper slag is a blackish granular material, similar to medium to coarse sand having size ranging from 150 µm to 4.75 mm. This aggregate has potential for use as fine aggregate in accordance with provisions of this standard (see Fig. 4).

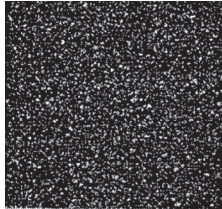


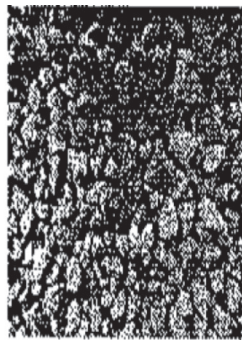
Figure 4: Typical Copper Slag Aggregate



Figure 5: Demolition Waste Before Processing



6A RCA



6B RA

Figure 6: Recycled Concrete Aggregate After Processing and Recycled Aggregate after Processing

Item	Elution volume, Max mg/kg	Content, Max, mg/l
Cadmium	0.01	150
Lead	0.01	150
Hexavalent Chromium	0.05	250
Arsenic	0.01	150
Mercury	0.0005	15
Selenium	0.01	150
Fluorine	0.8	4000
Boron	1	4000

Table 8: Environmental Safety and Quality Standards Using Iron and Steel and Copper Slag Aggregates

Sieve Size	Percentage Passing
31.5 mm	100
26.5 mm	97.5
13.2 mm	70
4.75 mm	47.3
2.36 mm	35
500 µm	20
75 µm	6

Table 9 Grading Distribution

A-3 Construction and Demolition (C&D) Waste

Use of construction and demolition (C&D) waste for manufacture of aggregates is a step towards effective management and utilization of this waste. This however requires necessary care while producing aggregates to ensure their efficacy in their use as part of concrete. These aggregates may be of two types namely Recycled Aggregate (RA) and Recycled Concrete Aggregate (RCA). RA is made from C&D waste which may comprise concrete, brick, tiles, stone, etc., and RCA is derived from concrete after requisite processing.

Recycled concrete aggregate (RCA) contain not only the original aggregate, but also hydrated cement paste adhering to its surface. This paste reduces the specific gravity and increases the porosity compared to similar virgin aggregates. Higher porosity of RCA leads to a higher absorption. Recycled aggregate (RA) will typically have higher absorption and lower specific gravity than natural aggregate. The concrete rubble has to be properly processed, including scrubbing to remove the adhered hydrated cement as much as possible.

The broad steps involved in the manufacture of aggregates from C&D waste may be:

- Receipt and inspection of C&D waste at the plant.
- Weighing of waste.
- Mechanical and manual segregation and resizing - this may involve segregation of various types of wastes such as bricks, stones, concrete, steel, tiles, etc.
- Dry and wet processing.

Figure 5, Figure 6A and Figure 6B show typical C&D waste, recycled concrete aggregate and recycled aggregate obtained there from.

RA can be used as coarse aggregate and RCA can be used as coarse and fine aggregates in accordance with this standard.

A-4 Environmental Safety and Quality Standards using Iron and Steel and Copper Slag Aggregates

The engineer-in-charge may get the iron and steel and copper slag aggregates checked for hazardous substances, at appropriate frequency. Specialist literature may be referred for the test method, the technique commonly in use are Inductively Coupled Plasma (LCP) spectroscopy and Atomic Absorption Spectrophotometer (AAS). As a guide the values given in Table 8 may be followed as the permissible values.

Annex B

Information to be Furnished by the Supplier

B-1 Details of Information

When requested by the purchaser or his representative, the supplier shall provide the following particulars:

- Source of supply, that is, precise location of source from where the materials were obtained;
- Trade group of principal rock type present, in case of aggregates from natural sources (see Annex C);
- Physical characteristics, in case of aggregates from natural sources (see Annex C);
- In case of manufactured aggregates, the brief manufacturing process, source of parent material and special characteristics having bearing on concrete properties, such as

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presence of adhered coating in case of recycled concrete aggregate, to the extent possible.

- e) Presence of reactive minerals;
- f) Service history, if any and in particular, in case of manufactured aggregates, the name of projects where used and the performance including in recently completed projects; and
- g) In case of manufactured aggregates, special precautions, if any, to be observed during concrete production.

ANNEX C

Determination of Iron Unsoundness for Slag Aggregates

C-1 Some slags containing more than 3 percent ferrous oxide (FeO) will disintegrate on immersion in water when the sulphur (S) content of the slag is 1 percent or more. Aggregates derived from such slags show iron unsoundness.

C-2 Procedure

Take randomly two test samples of not less than 50 pieces each of aggregate passing 40 mm room and retained on 20 mm IS sieve. Immerse the pieces of first sample in distilled or deionized water at room temperature for a period of 14 days. Remove the pieces from the water at the end of the 14 day period and examine them.

C-3 Criteria for Conformity

If no piece develops the following unsoundness during the storage period, the slag aggregate shall be deemed to be free from iron unsoundness:

- a) Cracking (development of a visible crack)
- b) Disintegration (physical breakdown of aggregate particle)
- c) Shaling (development of fretting or cleavage of the aggregate particle)
- d) Craze cracking at the surface of the aggregate

The second test sample shall be tested, if any of the pieces (in the above sample) shows cracking, disintegration, shaling or craze cracking at the surface of the aggregate. If not more than one in one hundred pieces (1 percent) of the two test samples tested shows cracking, disintegration, shaling or craze cracking at the surface of the aggregate, the slag shall be regarded as free from iron unsoundness.

Annex D

Determination of Volumetric Expansion Ratio of Slag Aggregates

D-1 This test specifies the procedure to calculate the volumetric expansion ratio for the evaluation of the potential expansion of aggregates like steel slag due to hydration reactions. This method can also be used to evaluate the effectiveness of weathering processes for reducing the expansive potential of such aggregate materials.

D-2 Apparatus and Tools

- a) Moulds with base plate, stay rod and wing nut, perforated plate - These shall conform to 4.1, 4.3 and 4.4 of IS 9669.
- b) Metal Rammer - As specified in 5.1 of IS 9198.
- c) Curing apparatus - The curing apparatus shall be a thermostat water tank, capable of holding not less than two 15

cm moulds, and able to keep the water temperature at $80 \pm 3^\circ\text{C}$ for 6h.

- d) Sieves - These shall be 3J.5 mm, 26.5 mm, 13.2 mm 4.75 mm, 2.36 mm, 500 μm and 75 μm IS sieves.
- e) Expansion measuring apparatus - The expansion measuring apparatus.

D-3 Sample

D-3.1 Preparation of Sample

The samples of slag shall be collected so as to represent the whole lot. The samples shall be prepared to meet the grading requirement given in Table.9.

D-3.2. Adjustment of Sample

The adjustment of sample shall be as follows:

- a) Add water to approximately 30 kg of sample so that the difference between the moisture content and the optimum moisture content is within 1 percent. Mix it well to make moisture content uniform, and keep it for not less than 24h.
- b) Reduce the above sample and obtain the sample necessary for making three specimens.

D-4 Test Procedure

D-4.1 Specimen Preparation

The specimens shall be prepared as follows:

- a) Attach collar and perforated base plate to the mould, put spacer disc, in it, and spread a filter paper on it.
- b) The measurement of moisture content shall be conducted on two samples, each sample weighing not less than 500 g. When the measured value of moisture content differs from the value of optimum moisture ratio by not less than 1 percent, new specimens shall be prepared for curing.
- c) Pour the samples prepared as in C-3.2, in the mould with a scoop keeping a falling height of approximately 50 mm and ram the sample into three layers one upon another so that the depth of each layer after ramming is nearly equal to one another.
- d) Ram the layer uniformly by free dropping of the rammer 92 times from a height of 450 mm above each rammed surface. The ramming shall be performed on a rigid and flat foundation such as a concrete floor.
- e) Rammed surfaces shall be scratched slightly with a sharp ended steel bar for securing adhesion between layers.
- f) After finishing the ramming, remove the collar, shave out the excess sample stuck on, upper part of the mould with a straight knife carefully. At this time, holes on the surface due to the removing of coarse grade materials shall be filled with fine grade materials, and the top surface shall be reformed
- g) Turn the mould upside down gently pushing the reformed top surface with a lid so that the specimen in the mould does not decay or drop down, then remove the perforated base plate and take out the spacer-disc.
- h) Spread a filter paper on the perforated base

Acknowledgement: The content of the paper is sourced from IS: 383-2016, coarse and fine aggregates for concrete -Specification, Bureau of Indian Standards, New Delhi for the purpose of knowledge dissemination only ♦