भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
BUREAU OF INDIAN STANDARDS
(Ministry of Consumer Affairs, Food & Public Distribution, Govt. of India)

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व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 02:2/टी-1 **25 जुलाई 2025**
तकनीकी समिति : सीमेंट और कंक्रीट अनुभागीय समिति , सीईडी 02
प्राप्तकर्ता :

1. **सिविल अभियांत्रिकी विभाग परिषद, सीईडीसी के सभी सदस्य**
2. **सीमेंट और कंक्रीट अनुभागीय समिति , सीईडी 02**
3. **सीईडी 02 की उपसमितियों और अन्य कार्यदल के सभी सदस्य**
4. **रुचि रखने वाले अन्य निकाय।**

महोदय/महोदया,
निम्नलिखित मानक का मसौदा संलग्न है:

प्रलेख संख्या	शीर्षक
सीईडी 02(27866)WC	**मिलावा — विशिष्टि भाग 1 कंक्रीट के लिए मोटे व महीन मिलावा का भारतीय मानक मसौदा** *(आईएस 383 का चौथा पुनरीक्षण)* (ICS 91.100.30)

कृपया इस मसौदे का अवलोकन करें और अपनी सम्मतियाँ यह बताते हुए भेजे कि यह मसौदा प्रकाशित हो तो इन पर अमल करने में आपको व्यवसाय अथवा कारोबार में क्या कठिनाइयां आ सकती हैं। संदर्भित दस्तावेज़ IS 2386 (भाग 1 से 5) और IS 2430 विकास के विभिन्न चरणों में हैं। IS 383 पर टिप्पणी के लिए, इन दस्तावेज़ों के मसौदा संशोधन की एक प्रति आपको प्रदान की जा सकती है। कृपया इसके लिए ced2@bis.gov.in पर संपर्क करें।

सम्मतियाँ भेजने की अंतिम तिथि: 23 सितम्बर 2025

सम्मति यदि कोई हो तो कृपया अधोहस्ताक्षरी को ई-मेल द्वारा ced2@bis.gov.in पर या उपरलिखित पते पर, संलग्न फोर्मेट में भेजें। सम्मतियाँ बीआईएस ई-गवर्नेंस पोर्टल, www.manakonline.in के माध्यम से ऑनलाइन भी भेजी जा सकती हैं।

यदि कोई सम्मति प्राप्त नहीं होती है अथवा सम्मति में केवल भाषा संबंधी त्रुटि हुई तो उपरोक्त प्रालेख को यथावत अंतिम रूप दे दिया जाएगा। यदि सम्मति तकनीकी प्रकृति की हुई तो विषय समिति के अध्यक्ष के परामर्श से अथवा उनकी इच्छा पर आगे की कार्यवाही के लिए विषय समिति को भेजे जाने के बाद प्रालेख को अंतिम रूप दे दिया जाएगा।

यह प्रालेख भारतीय मानक ब्यूरो की वेबसाइट www.bis.gov.in पर भी उपलब्ध हैं।

धन्यवाद।

भवदीय
ह-/
द्वैपायन भद्र
वैज्ञानिक ई एवं प्रमुख
सिविल अभियांत्रिकी विभाग

संलग्न: उपरलिखित

भारतीय मानक ब्यूरो
(उपभोक्ता मामले, खाद्य एवं सार्वजनिक वितरण मंत्रालय, भारत सरकार)
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WIDE CIRCULATION DRAFT

Our Reference: CED 02:2/T-1 **25 July 2025**

TECHNICAL COMMITTEE:CEMENT AND CONCRETE SECTIONAL COMMITTEE, CED 02

ADDRESSED TO:

1. All Members of Civil Engineering Division Council, CEDC
2. All Members of Cement and Concrete Sectional Committee, CED 02 and its Subcommittees
3. All Members of Subcommittees, Panels and Working Groups under CED 02
4. All others interested.

Dear Sir/Madam,

Please find enclosed the following draft:

Doc No.	Title
CED 02(27866)WC	**Draft Indian Standard Aggregates — Specification** **Part 1 Coarse and fine aggregates for concrete** (*fourth revision of IS 383*) (ICS 91.100.30)

Kindly examine the attached draft and forward your views stating any difficulties which you are likely to experience in your business or profession, if this is finally adopted as National Standard. The referenced documents IS 2386 (Parts 1 to 5) and IS 2430 are at various stages of development. For sake of commenting on IS 383, a copy of the draft revision of these documents may be provided to you. Kindly contact ced2@bis.gov.in for the same.

Last Date for comments: 23 September 2025

Comments if any, may please be made in the enclosed format and emailed at ced2@bis.gov.in or sent at the above address. Additionally, comments may be sent online through the BIS e-governance portal, www.manakonline.in.

In case no comments are received or comments received are of editorial nature, kindly permit us to presume your approval for the above document as finalized. However, in case comments, technical in nature are received, then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document is also hosted on BIS website www.bis.gov.in.

Thanking you,

Yours faithfully,
Sd/-
Dwaipayan Bhadra
Scientist 'E' & Head
Civil Engineering Department

Encl: As above

FORMAT FOR SENDING COMMENTS ON THE DOCUMENT

[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. Comments through e-mail to **ced2@bis.gov.in** shall be appreciated.]

Doc. No.: CED 02(27866)WC

BIS Letter Ref: CED 02:2/T-1

Title: Draft Indian Standard Aggregates — Specification Part 1 Coarse and fine aggregates for concrete *(fourth revision of IS 383) (ICS 91.100.30)*

Last date of comments: 23 September 2025

Name of the Commentator/ Organization: ____________________________________

Sl No.	Clause/ Para/ Table/ Figure No. commented	Type of Comment (General/ Technical/ Editorial)	Comments/ Modified Wordings	Justification of Proposed Change

NOTE- Kindly insert more rows as necessary for each clause/table, etc

BUREAU OF INDIAN STANDARDS

DRAFT STANDARD FOR COMMENTS ONLY

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Aggregates — Specification

Part 1 Coarse and Fine Aggregates for Concrete
(*fourth revision of IS 383*)

Cement and Concrete	Last Date for Comments:
Sectional Committee, CED 02	**23 September 2025**

Cement and Concrete Sectional Committee, CED 02

FOREWORD

(*Formal clauses to be added later*)

Aggregates are important components for making concrete and properties of concrete are substantially affected by various characteristics of the aggregates used. Aggregates from natural sources form the major variety used for making concrete, mortar and other applications. This Indian Standard has been formulated to cover requirements for aggregates derived from natural sources and other than natural sources, for use in production of concrete.

Whilst the requirements specified in this standard generally meet the normal requirements for most of the concrete works, there might be special cases where certain requirements other than those specified in the standard might have to be specified; in such case, such special requirements, the tests required and the limits for such tests may be specified by the purchaser. Byproducts generated from other industrial sources can be used for the manufacture of aggregates. However, detailed research study shall be carried out to investigate its suitability for its use in structural as well as non- structural applications.

This standard was first published in 1952 and subsequently revised in 1963, 1970 and 2016. 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. Also, in order to specify the requirements of aggregates used for making concrete and for other applications such as masonry works and plastering, the Committee decided to present the provisions for the aggregates in two parts:

Part 1 Coarse and fine aggregates for concrete
Part 2 Fine aggregates for masonry and plaster

In this revision (Part 1), the significant modifications included are:

a) Definitions of different types of aggregates have been rationalized;
b) The terminology of composite fine aggregates and composite coarse aggregates are introduced;
c) The percentage utilization of different types of aggregates obtained from other than natural sources had been revised;
d) Grading requirements of coarse aggregates for use in mass concreting is added.
e) Values of fineness modulus of fine aggregates of different grading zones are specified.
f) The requirements of light weight, medium weight and heavy weight aggregates have been included. Requirements of specific gravity, bulk density and water absorption for different types of aggregates are provided under the physical properties.
g) The requirements for fines content and fines quality in the aggregates, shell and shale content of the aggregates are provided.
h) The abrasion resistance of the aggregates in wet state using Micro Deval abrasion test and resistance to polishing for surface course using polished stone value have been provided under physical properties.
j) Chemical requirements for bottom ash aggregates are provided. An illustrative example for concrete mix design using bottom ash as fine aggregate is given in Annex E for information purpose;
k) Provisions on durability properties of aggregates are more rationalized.

Of late, scarcity in availability of aggregates from natural sources is being faced in some parts of the country. This may require supplementing the use of aggregates from natural sources with the use of aggregates from other than natural sources. This revision therefore also covers provisions regarding quality requirements and those relating to the extent of utilization of iron slag, steel slag, copper slag, recycled concrete aggregates (RCA) and recycled mixed aggregate (RMA), along with necessary provisions relating to their utilization. RCA and RMA may in turn be sourced from construction and demolition wastes. A brief note on sources of aggregates is given at Annex D. A crusher dust (or quarry dust) produced from the fine screening of quarry crushing cannot be called crushed sand as per **3.1.2**. A crusher dust (or quarry dust) produced from the fine screening of quarrycrushing may not be generally in conformity to the requirement of crushed sand as perthe standard and is not expected to perform as efficiently as properly crushed sand, unless it is processed to meet the requirement of this standard.

This standard contains clauses such as **10.1, 10.2, 10.3, 10.4, 11.1** and **11.2** which call for agreement between the purchaser and the supplier and require the supplier to furnish technical information as given in Annex B.

This standard contributes to the United Nations Sustainable Development Goal 9: ‘Industry, Innovation and Infrastructure' towards building resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

The composition of the Committee responsible for the formulation of this standard is given in Annex F.

For the purpose of deciding whether a particular requirement of this standard is compiled with, the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding off numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that specified value in this standard.

BUREAU OF INDIAN STANDARDS

Draft Indian Standard

Aggregates — Specification

Part 1 Coarse and Fine Aggregates for Concrete

(*fourth revision of IS 383*)

Cement and Concrete	Last Date for Comments:
Sectional Committee, CED 02	**23 September 2025**

1 SCOPE

This standard 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 aggregates produced from other than natural sources, for use in the production of concrete.

2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of these standards.

3 TERMINOLOGY

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

3.1 Fine Aggregate

Aggregate most of which passes 4.75 mm IS Sieve and contains only so much coarser material as permitted in **5.4.3**.

3.1.1 *Natural Sand*

Natural sand, also called as uncrushed sand, is a fine aggregate resulting from the natural disintegration of rock and which has been deposited by streams or glacial agencies.

3.1.2 *Crushed Stone Sand*

Fine aggregate produced by crushing hard stone and/or natural gravel.

3.1.3 *Mixed Sand*

Fine aggregate produced from natural sources by blending uncrushed sand and crushed stone sand in suitable proportions.

3.1.4 *Fine Aggregate from other than natural sources*

Fine aggregate from other than natural sources, by processing through thermal processes such as sintering or other processes such as separation, washing, crushing, scrubbing, alkali activation etc. This will also include recycled concrete aggregates (RCA) and recycled mixed aggregates (RMA).

3.1.5 *Composite Fine Aggregate*

Composite fine aggregate is a blend of fine aggregates from both natural (natural sand or crushed stone sand) as well as other than natural sources.

3.2 Coarse Aggregate

Aggregate most of which is retained on 4.75 mm IS Sieve and containing only so much finer material as permitted in **5.4.2**. The coarse aggregate shall be,

a) *Uncrushed coarse aggregate* — Uncrushed gravel or stone which results from natural disintegration of rock;
b) *Crushed coarse aggregate* — Crushed gravel or stone when it results from crushing of gravel or hard stone; and
c) *Mixed coarse aggregate* — Partially crushed gravel or stone when it is a product of the blending of (a) and (b);
d) *Coarse aggregates from other than natural sources* — Manufactured from other than natural sources, by processing materials, using thermal processes like sintering or other processes such as separation, washing, crushing, scrubbing, alkali activation, etc. These coarse aggregate also includes Recycled Concrete Aggregate (RCA) and Recycled Mixed Aggregate (RMA).

3.2.1 *Composite Coarse Aggregate*

Composite coarse aggregate is a blend of coarse aggregates from natural as well as from other than natural sources

3.3 All-in-Aggregate

Material composed of fine aggregate and coarse aggregate.

3.4 Heavy weight aggregate

These are natural or other than natural aggregates with specific gravity more than 3.2 and can range up to 8.0. Heavy weight aggregate is most commonly used for radiation shielding, counterweights and other applications where a high mass-to-volume ratio is desired. Goethite, Limonite, Barite, Illmenite, Magnetite, Hematite, Ferrophosphorus and Steel are some examples of heavy weight aggregates.

3.5 Light weight aggregate

Light weight aggregates are aggregates prepared by expanding, pelletizing, or sintering products such as fly ash, blast furnace slag, clay, or shale; and cinder aggregates. Lightweight aggregates shall be composed predominantly of lightweight cellular and granular inorganic material.

These are natural or aggregates from other than natural sources with specific gravity in the range 1.40 to 1.80. The light weight is due to the cellular or high internal porous structure, which gives this type of aggregate a low specific gravity. An important aspect of lightweight aggregate is the porosity. They have high absorption values, which requires a modified approach to concrete proportioning.

For structural concrete applications of light weight aggregate, IS 9142 (Part 2) and for nonstructural applications, IS 9142 (Part 1) may referred.

NOTE — Aggregates with specific gravity in the range 1.84 to 2.10 can be used in applications similarto light weight concrete where lower density values are not required.

4 SOURCES OF AGGREGATE

The sources of aggregate can either be natural sources or other than natural sources like industrial by products, thermal power plants, construction and demolition waste and other sources. Aggregates derived from natural sources are natural sand /uncrushed sand, crushed stone sand, mixed sand, uncrushed coarse aggregate, crushed coarse aggregate andmixed coarse aggregate. Aggregates from other than natural sources, can be obtained by processing through thermal processes such as sintering or other processes such as separation, washing, crushing, scrubbing, alkali activation, etc. Such sources are as follows:

a) *Industrial byproducts of iron and steel industry*, such as, blast furnace slag which includes air cooled blast furnace slag (ACBFS) and granulated blast furnace slag, or, steel slag which can be produced through basic oxygen furnace (BOF) route or non-basic oxygen furnace route which includes electric arc furnace (EAF) slag and convertible arc (conarc) slag.
b) *Copper slag* which is obtained as by product from copper smelter.
c) *Thermal power plants* — Bottom ash obtained from the thermal power plants can be used as fine aggregate when blended with fine aggregates from natural sources to obtain a composite fine aggregate.
d) *Construction & demolition (C&D) waste* — These are of two types: Recycled Mixed Aggregate (RMA) and Recycled Concrete Aggregate (RCA). RMA can be used as coarse aggregate and RCA can be used both as coarse and fine aggregates in accordance with this standard.

For detailed information on the types of sources listed above, refer Annex D.

4.1 Extent of Utilization of aggregates from different sources

4.1.1 These shall be coarse and fine aggregates as defined in **3.1** and **3.2.** Permissible extent of utilization of fine aggregates obtained from natural sources shall be 100 percent. The aggregates from other than natural sources shall be permitted with their extent of utilization as percent of total mass of coarse or fine aggregate as the case may be, as indicated in Table 1 and Table 2 against each, for use in plain and reinforced concrete and lean concrete.

Table 1 Extent of Utilization of Coarse Aggregates from other than Natural Sources
(*Clauses* 4.1.1 *and* 12.1)

Sl No.	**Type of aggregate**	**Maximum utilization as a percentageof total mass of coarse aggregate**		
		Plain Concrete, Percent	Reinforced Concrete Percent	Lean Concrete (Less than M15 Grade), Percent
(1)	(2)	(3)	(4)	(5)
i)	Processed Aircooled Blast Furnace slag (ACBFS) aggregate	50	25	100
ii)	Processed Electric arc Furnace slag(EAFs) aggregate	100	100	100
iii)	Processed Conarc slag aggregate	100	100	100
iv)	Recycled concrete aggregate (RCA)(*see* Note 1)	40	40 (upto M30 grade)	100
v)	Recycled mixed aggregate[1] (RMA)	nil	nil	100

Table 2 Extent of Utilization Fine Aggregate from Other Sources
(*Clauses* 4.1.1 *and* 12.1)

Sl No.	Type of aggregate	Maximum utilization as a percentage of total mass of fine aggregate		
		Plain Concrete, Percent	Reinforced Concrete Percent	Lean Concrete (Less than M15 Grade), Percent
(1)	(2)	(3)	(4)	(5)
i)	Processed Aircooled Blast Furnace slag(ACBFS) aggregate	100	100	100
ii)	Processed Granulated Blast Furnace slag(GBFS) aggregate	100	100 (up toM60 grade)	100
iii)	Processed Electric arc furnace slag(EAFs) aggregate	100	100	100
iv)	Processed Conarc slag aggregate	100	100	100
v)	Processed Copper slag aggregate	40	35	50
vi)	Recycled concrete aggregate (RCA) (*See* Note 1)	25	20 (only upto M25 grade)	100
vii)	Bottom ash fromThermal Power Plants	50	50* / 25**	50

* For concrete made with OPC

** For concrete made with PPC or OPC with fly ash, PSC or OPC with GGBS, and composite cement.

NOTES for Table 1 and Table 2

1 *See* Annex D for brief information on recycled mixed aggregates (RMA) and recycled concrete aggregates (RCA). 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 coarse aggregates from other than natural sources and one type of fine aggregate from other than natural sources 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 aggregates from other than natural sources as part replacement for natural aggregate,it should be ensured that the final grading meets the requirements specified in Table 5, Table 6 and Table 8.

5 Concrete mix design using bottom ash as a fine aggregate shall be done as per Annex E.

4.1.2 Aggregates from other than natural sources shall not be permitted for use in prestressed concrete.

5 PHYSICAL REQUIREMENTS

5.1 General

Aggregates 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 shall be avoided.

5.2 Specific Gravity, Bulk Density and Water Absorption

5.2.1 *Specific Gravity*

The specific gravity shall be determined in accordance with IS 2386 (Part 1) and shall comply with the requirements given in Table 3.

Table 3 Specific Gravity of Aggregates
(*Clauses* 5.2.1, E-5.1.8 *and* E-5.2.8)

Sl No.	**Type of Aggregate**	**Requirements**
(1)	(2)	(3)
i)	Light weight aggregate	1.40 to 1.84
ii)	Normal weight aggregate	2.10 to 3.20 (*see* Note)
iii)	Heavy weight aggregate	3.20 to 8.00

NOTES

1 Aggregates with higher specific gravity (up to 3.80) shall be permitted for the part replacement of the aggregates in accordance with **4.1.1**, such that the average specific gravity of the aggregate (coarse as well as fine) is not more than 3.20.

2 Aggregates with specific gravity values between 1.84 and 2.10 may be used for applications similar to light-weight concrete where lower density values are not required.

5.2.2 *Bulk Density*

The bulk density shall be determined in accordance with IS 2386 (Part 1).

5.2.3 *Water Absorption*

The water absorption shall be determined in accordance with IS 2386 (Part 1) and shall comply to the requirements given in Table 4.

Table 4 Water Absorption of the Aggregates
(*Clause* 5.2.3)

Sl No.	Type of Aggregate	Requirements
(1)	(2)	(3)
i)	Natural aggregate, percent, *Max*	2.0
ii)	Aggregates from other than natural sources, percent, *Max* [except as mentioned in (iv)]	2.0
iii)	Light weight aggregate, percent, *Max*	18.0
iv)	Recycled concrete aggregate, recycled mixed aggregate and bottom ash, percent, *Max*	5.0 (*see Note*)

NOTE — For recycled concrete aggregate and recycled mixed aggregate, higher water absorption up to 10 percent may be permitted subject to pre-wetting (saturation) of aggregates before batchingand mixing.

5.3 Aggregate Sizes

All aggregates shall be described in terms of aggregate sizes and shall conform to the grading requirements specified in **5.4.**

5.4 Grading

5.4.1 *General*

Grading of aggregates shall be determined as per the method for sieve analysis described in IS 2386 (Part I).

5.4.2 *Coarse Aggregates*

In order to achieve economy and dense concrete, it is preferable to use graded coarse aggregate in accordance to **5.4.2.2** in the design concrete mix. However, coarse aggregate can be supplied in single size aggregate in accordance to **5.4.2.1** that should be mixed in appropriate proportions to obtain graded coarse aggregate for the production of concrete.

5.4.2.1 *Single-Sized Coarse Aggregate* — Coarse aggregates shall be supplied in the nominal sizes given in Table 5, as per the method described in IS 2386 (Part 1).

Table 5 Coarse Aggregates for Single-Sized Aggregate
(*Clauses* 4.1.1, 5.4.2.1 *and* 5.4.2.2)

Sl No.	IS Sieve Designation	Percentage Passing for Single-Sized Aggregate of Nominal Size					
		63 mm	40 mm	20 mm	16 mm	12.5 mm	10 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	80 mm	100	-	-	-	-	-
ii)	63 mm	85 to 100	100	-	-	-	-
iii)	40 mm	0 to 30	85 to 100	100	-	-	-
iv)	20 mm	0 to 5	0 to 20	85 to 100	100	-	-
v)	16 mm	-	-	-	85 to 100	100	-
vi)	12.5 mm	-	-	-	-	85 to 100	100
vii)	10 mm	0 to 5	0 to 5	0 to 20	0 to 30	0 to 45	85 to 100
viii)	4.75 mm	-	-	0 to 5	0 to 5	0 to 10	0 to 20
ix)	2.36 mm	-	-	-	-	-	0 to 5

5.4.2.2 *Graded Coarse Aggregate* — Graded coarse aggregates may be supplied in the nominal sizes given in Table 6. However, in case coarse aggregate is supplied in single size in accordance to Table 5, graded coarse aggregate can be obtained by blending single sized coarse aggregate in the appropriate proportions to obtain graded coarse aggregate in accordance with Table 6.

Table 6 Coarse Aggregates for Graded Aggregate
(*Clauses* 4.1.1, 5.4.2.1, 5.4.2.2, 5.4.2.3 *and* 5.4.2.4)

Sl No.	IS Sieve Designation	Percentage Passing for Graded Aggregate of Nominal Size				
		63 mm	40 mm	20 mm	16 mm	12.5 mm
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)	80 mm	100	100	-	-	-
ii)	63 mm	90-100	-	-	-	-
iii)	40 mm	30-70	90 to 100	100	-	-
iv)	20 mm	5-10	30 to 70	90 to 100	100	100
v)	16 mm	-	-	-	90 to 100	-
vi)	12.5 mm	-	-	-	-	90 to 100

vii)	10 mm	0-5	10 to 35	25 to 55	30 to 70	40 to 85
viii)	4.75 mm	-	0 to 5	0 to 10	0 to 10	0 to 10
ix)	2.36 mm	-	-	-	-	-

5.4.2.3 *Coarse aggregate for mass concrete*

Coarse aggregate for mass concrete works such as dams shall be in the sizes specified in Table 7. These aggregates are blended in the appropriate proportions to obtain graded coarse aggregate in accordance with Table 8 for producing an economical and dense concrete.

Table 7 Sizes of Coarse Aggregates for Mass Concrete
(*Clauses* 5.4.2.3 *and* E-3.6)

Sl No.	**Class and Size**	**IS Sieve Designation**	**Percentage Passing**
(1)	(2)	(3)	(4)
i)	Very large, 150 to 80 mm	160 mm 80 mm	90 to 100 0 to 10
ii)	Large, 80 to 40 mm	80 mm 40 mm	90 to 100 0 to 10
iii)	Medium, 40 to 20 mm	40 mm 20 mm	90 to 100 0 to 10
iv)	Small, 20 to 4.75 mm	20 mm 4.75 mm 2.36 mm	90 to 100 0 to 10 0 to 0.2

Table 8 Grading Requirement for Coarse Aggregates for Mass Concrete
(*Clauses* 4.1.1 *and* 5.4.2.3)

Sl No.	**IS Sieve Designation**	**Percentage Passing for Graded Aggregate**	
		150 mm	80 mm
(1)	(2)	(3)	(4)
i)	150 mm	100	100
ii)	80 mm	55-65	100
iii)	40 mm	29-40	53-62
iv)	20 mm	14-22	26-34
v)	10 mm	6-0	10-15
vi)	4.75 mm	0-5	0-5

NOTE- In mass concreting, rounded aggregate is also used, and the fine aggregate is on the lower side as compared to crushed aggregate. Therefore, it is recommended that, for rounded aggregate, the percentage passing shall be towards the higher limit of the range specified for various sieve sizes and for crushed aggregate, the percentage passing, shall be towards the lower limit of the range specified for various sieve sizes. This recommendation is valid for grading requirements for 150 mm MSA and 80mm MSA as mentioned above, and for 40mm MSA as per Table 6.

5.4.2.4 *Overall limits and tolerance for coarse aggregate*

The allowable deviation in the gradation of the actual value obtained with respect to declared value in concrete mix design shall be in the range of declared value ± 10 percent. This is subject to both the declared, as well as the actual value being within the specified limits given in Table 6. The sieve sizes on which this deviation is allowed are as follows:

Graded Coarse Aggregate (1)	*Sieve size over which tolerance limit is admissible* (2)
40 mm	20 mm
20 mm	10 mm
16 mm	10 mm
12.5 mm	10 mm

5.4.3 *Fine Aggregates*

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 particular grading zone of sieves other than 600 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 coarser limit of Grading Zone I or the finer limit of Grading Zone IV.

Table 9 Grading of Fine Aggregates
(*Clause* 5.4.3)

Sl No.	**IS Sieve Designation**	**Percentage Passing**			
		Grading Zone I	Grading Zone II	Grading Zone III	Grading Zone IV
(1)	(2)	(3)	(4)	(5)	(6)
i)	10 mm	100	100	100	100
ii)	4.75 mm	90-100	90-100	90-100	95-100
iii)	2.36 mm	60-95	75-100	85-100	95-100
iv)	1.18 mm	30-70	55-90	75-100	90-100
v)	600 µm	15-34	35-59	60-79	80-100
vi)	300 µm	5-20	8-30	12-40	15-50
vii)	150 µm	0-10	0-10	0-10	0-15
Fineness Modulus		2.71-4.00	2.11-3.37	1.71-2.78	1.35-2.25

NOTES

1 Fineness modulus of the aggregate shall be determined in accordance to IS 2386 (Part1).

2 For crushed stone sands mixed sand, fine aggregates from other than natural sourcesand composite fine aggregate, the permissible limit on 150 µm IS Sieve is increased to20 percent. This does not affect the 5 percent allowance permitted in 6.3 applying to other sieve sizes.

3 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.

4 As the fine aggregate grading becomes progressively finer, that is, from Grading Zones I to IV, the ratio of fine aggregate to 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.

5 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 ofproposed mix proportions.

6 Bottom ash when used as a fine aggregate in the composite fine aggregate shall have Fineness modulus not less 1.0. Additionally, the composite fine aggregate obtained by blending of bottom ash and fine aggregate from the natural sources shall have minimum Fineness Modulus of 1.35.

5.4.4 *All-in Aggregates*

If combined aggregates are available, they need not be separated into fine and coarse. The grading of the all-in-aggregate, when analyzed, as described in IS 2386 (Part 1) shall be in accordance with Table 10. Necessary adjustments may be made in the grading by the addition of single-sized aggregates

Table 10 Grading of All-in-Aggregate
(*Clause* 5.4.4)

Sl No.	**IS Sieve Designation**	**Percentage Passing for All-in-Aggregate of Nominal Size**	
		40 mm	20 mm
(1)	(2)	(3)	(4)
i)	80 mm	100	-
ii)	40 mm	95 to 100	100
iii)	20 mm	45 to 75	95 to 100
iv)	4.75 mm	25 to 45	30 to 50
v)	600 µm	8 to 30	10 to 35
vi)	150 µm	0 to 6	0 to 6

5.5 Fines content and Fines quality

5.5.1 Fines content in the aggregates is defined as material finer than 75 µm. The fines content of the aggregates shall be determined as per IS 2386 (Part 1) and shall conform to the requirements given in Table 11(iii).

5.5.2 When the fines content in the fine aggregate is not greater than limits prescribed in the Table 15, no further testing is required. However, If the fines content is greater than limits prescribed in the Table 15, the fines of fine aggregate shall be considered non-harmful (like, swelling of clay) when both the following conditions applies:

a) The sand equivalent value (SE), when tested in accordance with IS 2386 (Part 1) shall not be less than 50.
b) Methylene blue test is an effective indictor of amount and type of clay present in the fine aggregate. The methylene blue value (MB) shall be determined in accordance with IS 2386 (Part 1). Maximum methylene blue value shall be established based upon successful performance of the fine aggregate in the application as well as desired properties of concrete under considerations. In any case, the maximum permissible methylene blue (MB) value is 5 gm/kg.

NOTE — Methylene blue test for fine aggregate sourced from natural (uncrushed) sources isapplicable only when the material finer than 75 micron IS sieve is in the range of 3 percent to 5 percent.

5.6 Combined Flakiness and Elongation index

Flakiness and elongation shall be determined in accordance with IS 2386 (Part 1) on the same sample. After carrying out the flakiness index test, the flaky material shall be removed from sample and the remaining portion shall be used for carrying out elongation index. Indices so worked out shall be added numerically to give combined flakiness and elongation index. The combined flakiness and elongation index so obtained shall not exceed 40 percent for uncrushed or crushed aggregate. However, the engineer-in-charge at his discretion may relax the limit keeping in view the requirement, the availability of aggregates and their performance based on tests on concrete.

5.7 Shell and Shale Content of Aggregates

5.7.1 Shell is defined as all fossil skeletons of invertebrate marine life (fresh and/or saltwater) including but not limited to snails, conchs, limpets, turitellas, vermicularia, and oliva, as well as bi-values, etcetera. The shell content of coarse aggregate shall be determined in accordance with IS 2386 (Part 1) and shall not bemore than 10 percent as mentioned in Table 15.

5.7.1 Shales are typically gray in color and are composed of clay minerals and quartz grains. The shale content of the fine aggregates shall not be more than 10 percent as mentioned in Table 15.

5.8 Resistance to Wear (Dry State) — Los Angeles Value

The Los Angeles abrasion test evaluates aggregate's resistance to abrasion and its ability to withstand disintegration. Los Angeles abrasion test is an indicator of the relative quality or competence of various sources of aggregate having similar mineral compositions when test under dry condition. The aggregate abrasion value, when determined in accordance with IS 2386 (Part 2) using Los Angeles machine, shall not exceed the following values:

a) For aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, Spillways, tunnel lining carrying water and stilling basins)	30 percent
b) For aggregates to be used in concrete other than for wearing surfaces	50 percent

5.9 Resistance to Wear (Wet State) — Micro Deval Coefficient

The micro deval abrasion test is an indicator of anti-abrasion performance of coarse aggregates in moisturized conditions. Many aggregates are more susceptible to abrasion when wet than dry, and the use of water in this test incorporates this reduction in resistance to degradation in contrast to some other tests like Los AngelesAbrasion Value Test, which are conducted on dry aggregate. This test is most suitablefor the structure such as spillway, glacis and cases where aggregates get exposed to water. The resistance to wear [micro-Deval coefficient (MD)] shall be determined in accordance with IS 2386 (Part 2), shall not exceed 15 percent for the wearing surfaces of concrete pavement and 25 percent in case of structural concrete.

5.10 Resistance to Crushing – Crushing Value or 10 Percent Fine Value

The aggregate crushing value gives a relative measure of the resistance of an aggregate to crushing under a gradually applied compressive load. The aggregate crushing value/ ten percent fines value, when determined in accordance with IS 2386 (Part 2) shall be as follows:

a) For aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, tunnel lining carrying water, spillwaysand stilling basins)	30 percent, *Max*
b) For aggregates to be used in concrete other than for wearing surfaces	In case the aggregate crushing value exceeds 30 percent , then the test for 'ten percent fines' should be conducted and the minimum load for the ten percent fines should be 50 kN

5.11 Resistance to Impact – Impact Value

The aggregate impact value gives a relative measure of the resistance of an aggregate to sudden shock or impact. As an alternative to **5.10**, the aggregate impact value may be determined in accordance with the method specified in IS 2386 (Part 2). The aggregate impact value shall not exceed the following values:

a) For aggregates to be used in concrete for wearing surfaces, (such as runways, roads, pavements, Spillways, tunnel lining carrying water and stilling basins)	30 percent
b) For aggregates to be used in concrete other thanfor wearing surfaces	50 percent

NOTE — For concrete of grades M 65 and above, stronger aggregates are required and hence the maximum aggregate crushing value and aggregate impact value shall not exceed 22 percent.

5.12 Resistance to Polishing for Surface Courses (Polished Stone Value)

Polished stone value of aggregate is an indicator of the state to which aggregate gets polished under traffic. The polished stone value (PSV) of a coarse aggregate is used in road surfacing. The resistance to polishing for surface course aggregate [polished stone value (PSV*)*] shall be determined in accordance with IS 2386 (Part 2) and shall not be less than 60.

In case polished stone value (PSV) of aggregate is 60 or greater, then aggregate abrasion value (AAV) shall be measured. AAV indicates the skid resistant property of the aggregate when used in road surfacing. The resistance to surface abrasion [aggregate abrasion value (AAV*)*] shall be determined in accordance with IS 2386 (Part 2) and shall be less than 10.

6 CHEMICAL REQUIREMENTS

6.1 General

The necessity for testing and declaring all properties specified in this clause shall be limited according to the particular application at end use or origin of the aggregate. When required, the aggregates (natural as well as from other than natural sources) shall be tested as specified in **6** to determine the relevant chemical properties.

6.2 Sulphur Containing Compounds

Sulphate in aggregates can give rise to expansive disruption of the concrete. Generally, a substantial proportion of the sulfate in crystalline blast-furnace slag is encapsulated in the slag grains and therefore, plays no part in the hydration reactions of cement. For this reason, a higher proportion of sulphate is tolerable in the slag. However, under certain circumstances, significant expansions can occur due to the presence of sulphides, such as pyrite, pyrrhotite, and marcasite, in the aggregate that might oxidize and hydrate with volume increase or the release of sulphate that produces sulphate attack in concrete.

6.2.1 *Total Sulphate*

Total sulphate determined as acid-soluble sulphate (expressed as SO_3) of the aggregates for concrete shall be determined in accordance to IS 2386 (Part 4) and shall be less than 0.2 percent by mass in case of natural aggregates and 0.5 percent by mass in case of aggregates from other than natural sources. However, in case of bottom ash aggregate, total sulphate shall be less than 2.0 percent by mass.

NOTE — Sulphates present in concrete cured at elevated temperature may participate in delayed ettringite formation. Therefore, it is advisable to test the concrete for water soluble sulphates as per requirements of IS 456 to ensure that they are within the permissible limits.

6.2.2 *Total Sulphur*

The aggregates from other than natural sources shall be tested for total Sulphur (expressed as S) in accordance to IS 2386 (Part 4) and the total Sulphur content shall be less than 2.0 percent by mass as mentioned in Table 11, Table 12 and Table 13.

6.3 Chlorides

Chlorides can be present in aggregates, usually as sodium and potassium salts. The quantity present being largely dependent on the source of the aggregate. Such salts contribute to the total chloride and alkali content of the concrete. To minimize the risk of corrosion of embedded metal, generally the total quantity of chloride ion contributed by all the constituent materials in the concrete is limited. The water-soluble chloride ion content of aggregates for concrete shall be determined in accordance to IS 2386 (Part 4) and shall be less than 0.01 percent by mass in the case of natural aggregate and 0.04 percent by mass in case of aggregates from other than natural sources.

Further, it should be noted that, where it can be shown that the chloride content of such materials is not greater than 0.01 percent, this value shall be used in the calculation of chloride content of concrete.

6.4 Additional Chemical Requirements for Aggregates from Other Than Natural Sources

6.4.1 The aggregates from other than natural sources to be used in concrete production shall comply for the additional chemical parameters mentioned in the Table 11, Table 12 , Table 13 and Table 14 when tested as per IS 2386 (Part 4).

Table 11 Chemical requirements for Blast Furnace slag aggregates
(*Clauses* 5.5.1, 6.2.2 *and* 6.4.1)

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Calcium Oxide as CaO,percent, *Max*	45.0
ii)	Total iron as FeO, percent ,*Max*	3.0
iii)	Total Sulphur as S, percent, *Max*	2.0

NOTE – When the ferrous oxide (FeO) content is equal to or more than 3.0 percent and sulphur content is equal to or more than 1.0 percent, the aggregates shall be tested for iron unsoundness as per **7.3.1.**

Table 12 Chemical Requirements for Non-Basic Oxygen Furnace (N-BOF) Slag (EAF Slag and Conarc Slag Aggregates)
(*Clauses* 6.2.2 *and* 6.4.1)

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Calcium Oxide as CaO,percent, *Max*	40.0
ii)	Magnesium Oxide as MgO, percent, *Max*	10.0
iii)	Total iron as FeO, percent ,*Max*	50.0
iv)	Silica as SiO_2, percent ,*Min*	15.0
v)	Basicity as CaO/SiO_2 , *Max*	2.0
vi)	Basicity as $(CaO+ MgO)/SiO_2$, *Max*	2.5
vii)	Total Sulphur as S, percent, *Max*	2.0

Table 13 Chemical Requirements for Copper Slag Aggregates
(*Clauses* 6.2.2 *and* 6.4.1)

Sl No.	Characteristic	Requirement
(1)	(2)	(3)
i)	Calcium Oxide as CaO,percent, *Max*	12.0
ii)	Total iron as FeO, percent ,*Max*	70.0
iii)	Total Sulphur as S, percent, *Max*	2.0
iv)	Chlorine as NaCl , percent , *Max*	0.03

Table 14 Chemical Requirements for Bottom Ash Aggregates
(*Clause* 6.4.1)

Sl No.	Characteristics	Requirement, in percent
(1)	(2)	(3)
i)	Loss on Ignition, *Max*	5
ii)	SiO_2, *Min*	50
iii)	MgO, *Max*	3
iv)	$SiO_2+Al_2O_3+Fe_2O_3$, *Min*	70
v)	Total Chloride, *Max*	0.05

vi)	Total Alkalies as Na_2O equivalent, *Max*	1.5

6.4.2 In case of Recycled Concrete Aggregate (RCA), Recycled Mixed Aggregate (RMA), Blast Furnace slag aggregates, Non-Basic Oxygen Furnace (N-BOF) slag that is, EAF slag and Conarc slag aggregates, copper slag aggregates, the total alkali content expressed as Na_2O equivalent determined as per IS 2386 (Part 4) shall be less than 0.3 percent by mass.

6.5 Constituents which Alter the Rate of Setting and Hardening of Concrete (Deleterious Materials)

6.5.1 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.

6.5.2 The maximum quantity of deleterious materials shall not exceed the limits specified in Table 15. 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.

Table 15 Limits of Deleterious Materials
(*Clauses* 5.5.2, 5.7, 6.5.2 *and* 9.1.3)

Sl No.	Deleterious Substance	Method of Test, Ref to	Fine Aggregate Percentage by Mass, *Max*			Coarse Aggregate Percentage by Mass, *Max*		
			Uncrushed	Crushed stone sand/ Mixed sand	From other than natural sources	Uncrushed	Crushed	From other than natural sources
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Coal and lignite	IS 2386 (Part 1)	1.00	1.00	1.00	1.00	1.00	1.00
ii)	Clay lumps	IS 2386 (Part 1)	1.00	1.00	1.00	1.00	1.00	1.00
iii)	Materials finer than 75 µm IS Sieve	IS 2386 (Part 1)	3.00 (*see* Note 5)	15.00 (for crushed stone sand) 12.00 (for mixed sand) (*see* Note 1)	10.00/12. 00 (for bottom ash)	1.00	1.00	1.00
iv)	Soft fragments	IS 2386 (Part 1)	—	—	—	3.00	—	3.00
v)	Shale	(*see* Note 2)	1.00	—	1.00	—	—	—
vi)	Shell	IS 2386 (Part 1)	-	-	-	10	10	-

vii)	Total of percentages of all deleterious materials (except mica) including Sl No. (i) to (v) for col. 4, 7 and 8 and Sl No. (i) and (ii) for col. 5, 6 and 9	–	5.00	2.00	2.00	5.00	2.00	2.00

NOTES

1 The sands used for blending in mixed sand shall individually also satisfy the requirements of Table 15. The uncrushed sand used for blending shall not have material finer than 75 µm more than 3.00 percent.

2 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.

3 The presence of mica in the fine aggregate has been found to adversely affect 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, *max* 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). Normally, petrographic density separation and wind blowing methods can be used for determination of mica content.

4 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 2) is not less than 95 percent.

5 Fines content in natural (uncrushed) fine aggregate shall in no case be greater than 5 percent by mass.

6 In RCA, foreign materials such as brick, ceramics and glass shall be segregated by visual observation. Such materials shall not be more than 5 percent by mass.

7 Durability

7.1 General

The necessity for testing and declaring all properties specified in this clause shall be limited according to the particular application at end use or origin of the aggregate. When required, the aggregates (natural as well as from other than natural sources) shall be tested as specified in **7** to determine the relevant durability properties

7.2 Soundness of Coarse and Fine Aggregates

For concrete liable to be exposed to the action of weathering, the coarse and fine aggregates shall pass a sodium or magnesium sulphate accelerated soundness test specified in IS 2386 (Part 3), the limits being set by agreement between the purchaser and the supplier.

7.2.1 *Against Sodium Sulphate Attack*

It may be taken that the average loss of mass after 5 cycles shallnot exceed the following:

a) For fine aggregate : 10 percent
b) For coarse aggregate : 12 percent

7.2.2 *Against Magnesium Sulphate Attack*

It may be taken that the average loss of mass after 5 cycles shallnot exceed the following:

a) For fine aggregate : 15 percent
b) For coarse aggregate : 18 percent

7.3 Unsoundness of Aggregate Sourced from Iron and Steel Industry

7.3.1 *Iron Unsoundness*

Iron slag is produced during iron making which is a reduction process. In this process, there exists possibility of iron and/or partially reduced iron oxides getting oxidized leading to iron unsoundness. Therefore, when chemical analysis of iron slag 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 soundness due to iron. The iron unsoundness of the slag aggregate when tested as per the procedure given in IS 2386 (Part 3), shall not exceed 1 percent.

7.3.2 *Unsoundness due to Free Lime and Free Magnesia*

Steel slag particularly Basic oxygen furnace (BOF) slag contains hydratable oxides that is, CaO and / or MgO that can result in volumetric instability. Such volume expansion can be attributed to the chemical composition of the slag. Prior to the use of steel slag (for production of aggregates) from a new source or when significant changes in furnace chemistry occur in an existing source which may result in the presence of free lime (CaO) and/or free magnesia (MgO) that can be studied through petrographic examination or quantitative x-ray diffractometry or chemical analysis 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.

The volumetric expansion determined as per IS 2386 (Part 3) shall not exceed 1 percent.

7.4 Alkali Aggregate reactivity

7.4.1 *General*

In alkali aggregate reactivity, alkalis participating in the expansive reactions with aggregate constituents in concrete usually are derived from the cement; under certain circumstances they may be derived from other constituents of concrete or from external sources. Two types of alkali reactivity of aggregates are recognized, they are alkali carbonate reactivity (ACR) and alkali silica reactivity (ASR) as described in **7.4.3** and **7.4.4** respectively. The mineral constituents in aggregates that are responsible for alkali aggregate reactivity are identified through petrography examination as described in **7.4.2**.

In ACR, dolomite in certain calcareous dolomites or dolomitic limestones with clayey insoluble residues, and dolostones are responsible for undesirable expansion. Some dolomites essentially free of clay and some very fine-grained limestones free of clay and with minor insoluble residue, mostly quartz, are also capable of some alkali-carbonate reactions, however, such reactions are not necessarily deleterious. Deleteriously reactive alkali-carbonate aggregates often exhibit a characteristic microscopic texture consisting of dolomite rhombs within a fine-grained matrix of calcite, quartz and clay. In ASR, reactive minerals include: opal, chalcedony, cristobalite, tridymite, highly strained quartz, microcrystalline quartz, cryptocrystalline quartz, volcanic glass, and synthetic siliceous glass. These mineral constituents are found in aggregate made from rocks such as acidic volcanic rocks, some argillites, phyllites, graywacke, gneiss, schist, gneissic granite, vein quartz, quartzite, sandstone, chert, and carbonate rocks containing alkali reactive forms of silica.

7.4.2 *Petrographic Examination*

7.4.2.1 Petrographic examination identifies the presence of constituents that are potentially responsible for alkali aggregate reactivity that is, alkali-silica reactivity and alkali-carbonate reactivity.

7.4.2.2 The petrographic description of the aggregate shall be determined in accordance with IS 2386 (Part 5) with an intent to get information over parameters like undulatory extinction angle, percentage of strain quartz and identification of minerals and their relative percentage present.

NOTE

In most cases the petrographic examination will require the use of optical microscopy. However, for particular purposes and to investigate particular problems may require examination of aggregates by means of additional procedures, such as X-ray diffraction (XRD) analysis, differential thermal analysis (DTA), infrared spectroscopy, or other scanning electron microscopy (SEM) energy-dispersive x-ray analysis (EDX). Petrographic examinations provide identification of types and varieties of rocks present in potential aggregates. Additionally, the purpose of petrographic examination also includes:

a) Examining the presence of chemically unstable minerals (such as soluble sulphates) or volumetrically unstable materials, such as smectites (formerly known as the montmorillonite-saponite group of minerals or swelling clays) or iron sulphide minerals that may potentially oxidize within the concrete.
b) Identifying the portion of each coarse aggregate that is composed of weathered or otherwise altered particles and the extent of that weathering or alteration, whether it is severe, moderate, or slight, and determining the proportion of each rock type in each condition.
c) Identifying the presence of contaminants in aggregates, such as synthetic glass, cinders, clinker, or coal ash, magnesium oxide, calcium oxide, or both, gypsum, soil, hydrocarbons, chemicals, etc., that may affect the properties of concrete.

7.4.2.3 The aggregates containing more than 20 percent strained quartz and undulatory extinction angle greater than 15 ^{o}C, causing deleterious reaction and also possibly showing presence of microcrystalline quartz is termed as slowly reactive aggregates and shall be further tested accordingly.

7.4.2.3 *Alkali Carbonate Reactivity (ACR)*

7.4.3.1 Alkali carbonate reactivity involves reaction between dolomite as described in **7.4.1** with the alkalies (Na_2O and K_2O) originating from cement and other sources. The reaction is usually accompanied by dedolomitization and expansion of the affected aggregate particles, leading to abnormal expansion and cracking of concrete in service.

7.4.3.2 Aggregates that contain minerals which are potentially hazardous to ACR identified through petrography shall be tested in accordance to IS 2386 (Part 5) for length change of concrete due to alkali carbonate reactivity.

7.4.3.3 The aggregate can be classified as potentially deleterious, if the average expansion of six concrete specimens is equal to or greater than: 0.015 percent at 3 months; 0.025 percent at 6 months; or 0.030 percent at 1 year.

7.4.4 *Alkali Silica Reactivity (ASR)*

7.4.4.1 Aggregates containing particular varieties of silica as described in **7.4.1** may be susceptible to attack by alkalies (Na_2O and K_2O) originating from cement and other sources, producing an expansive reaction which can cause cracking and disruption of concrete. Damage to concrete from this reaction will normally only occur when all the following are present together:

a) A high moisture level within the concrete.
b) A cement with high alkali content, or another source of alkali.
c) Aggregate containing an alkali reactive constituent.

7.4.4.2 Aggregates susceptible to ASR shall preferably be tested by accelerated mortar bar test or mortar bar test. The aggregate shall comply with the requirements as follows, when tested in accordance with IS 2386 (Part 3).

a) *Chemical method*

1) The aggregate when tested in accordance with the chemical method, shall conform to the requirement as specified in IS 2386 (Part 3). If test results indicate deleterious or potentially deleterious character, the aggregate should be tested using mortar bar method as specified in IS 2386 (Part 3) to verify thepotential for expansion in concrete.

2) This chemical method (for determination of potential reactivity) however, is not found to be suitable for slowly reactive aggregates or for aggregate containing carbonates (limestone aggregates) or magnesium silicates, such as antigorite (serpentine). Therefore, petrographic analysis of aggregates shall be carried out and relevant test as mentioned in **7.4.4.2(b) 7.4.4.2(c)**, **7.4.4.2(d)** and **7.4.4.2(e)** should be conducted.

b) *Accelerated mortar bar method*

The accelerated mortar bar test shall be carried out at 80°C using 1N NaOH. The criteria for this test is as under:

1) Expansions of less than 0.10 percent at 16 days after casting are indicative of innocuous behavior in most cases. In some granitic gneisses and metabasalts deleterious expansion has been observed in field performance even though their expansion in this test was less than 0.10 percent at 16 days after casting. With such aggregate, it is recommended that prior field performance be investigated. In the absence of field performance data, mitigative measures shall be taken.

2) Expansions of more than 0.20 percent at 16 days after casting are indicative of potentially deleterious expansion [see 4.2.2 of IS 2386 (Part 3)].

3) Expansions between 0.10 and 0.20 percent at 16 days after casting include both aggregate that are known to be innocuous and deleterious in field performance. For these aggregate, it is particularly important to develop supplemental information as described in 4.2.2 of IS 2386 (Part 3). In such a situation, it may also be useful to take comparator reading until 28 days. It may be useful to support this test with test by mortar bar method at 38 ºC and 60 ºC, as applicable.

c) *Mortar bar method*

1) *Using 38 ºC temperature regime* — The permissible limits for mortar bar expansion at 38 °C shall be 0.05 percent at 90 days and 0.10 percent at 180 days. For slowly reactive aggregates (as explained in NOTE above) mortar bar method using temperature regime of 38 °C shall not be used for determination of potential reactivity. Such slowly reactive aggregates shall be tested using

60°C temperature regime. Therefore, petrographic analysis of aggregates shall be carried out to find out the strained quartz percentage, undulatory extinction angle and its mineral composition before conducting the test.

2) *Using 60 °C temperature regime* — The permissible limit mortar bar expansion at 60 °C shall be 0.05 percent at 90 days and 0.06 percent at 180 days for slowly reactive aggregates.

d) *Accelerated Mortar Bar Test for Combinations of Cementitious Materials with Aggregates*

1) This test method has been developed for evaluating combinations of certain cementitious materials with a single aggregate source in a mortar of standard proportions that cannot be evaluated using accelerated mortar bar test as per **7.4.4.2(b)**. This test is carried out at 80 °C using 1 N NaOH as per IS 2386 (Part 3).

2) The criteria for evaluating the combination of cementitious materials with the particular aggregate source is the same as described in **7.4.4.2(b)**.

e) *Concrete prism bar test*

1) This test method covers the determination of the susceptibility of an aggregate or combination of an aggregate with pozzolana or slag for participation in expansive alkali-silica reaction by measurement of length change of concrete prisms.
2) This test is conducted in accordance with IS 2386 (Part 3) and records the expansion of prismatic specimens of concrete at ages of 7, 28 and 56 days and also at 3, 6, 9 and 12 months. An aggregate might reasonably be classified as potentially deleteriously reactive if the average expansion of three concrete specimens is equal to or greater than 0.04 percent at one year.
3) When the expansions in this test method are greater than this limit, supplemental information should be developed to confirm that the expansion is actually due to alkali-silica reaction. Petrographic examination of the concrete prisms should be conducted to confirm that known reactive constituents are present and to identify the products of alkali-silica reactivity.

7.5 Drying Shrinkage

When concrete is made with recycled mixed aggregate or light weight aggregate with water absorption greater than 3.5 percent, it may have an impact in terms of increase in drying shrinkage of concrete. Effect of such aggregate on drying shrinkage of concrete can be assessed by testing of concrete of fixed mix proportions as per IS 2386 (Part 3) and drying shrinkage value shall not exceed by 0.075 percent.

NOTE — To minimize the effect of such aggregate on drying shrinkage of concrete, such aggregates shall be used in saturated surface dry condition for making concrete.

8 ENVIRONMENTAL SAFETY AND QUALITY STANDARDS OF AGGREGATES FROM OTHER THAN NATURAL SOURCES

When aggregate is sourced from industrial by products such as iron slag, steel slag, copper slag, it may contain hazardous substances and shall be tested for source approval at appropriate frequency depending upon the changes in the furnace chemistry for iron, steel and copper. The presence of hazardous substances such as cadmium, lead, hexavalent chromium, arsenic, mercury, selenium, fluorine, boron shall meet the requirements given in Table 16 when tested in accordance to IS 2386 (Part 4).

Table 16 Environmental Safety and Quality Standards for Iron, Steel and Copper Slag Aggregates

(*Clause* 8)

Sl No.	**Item**	**Elution volume**, *Max*, mg / L	**Content**, *Max* mg/kg
(1)	(2)	(3)	(4)
i)	Cadmium	0.01	150
ii)	Lead	0.01	150
iii)	Hexavalentchromium	0.05	250
iv)	Arsenic	0.01	150
v)	Mercury	0.000 5	15
vi)	Selenium	0.01	150
vii)	Fluorine	0.8	4 000
viii)	Boron	1	3 000

9 Evaluation of conformity

9.1 Sampling and Testing

9.1.1 For aggregates to be used in making concrete, sampling may be required at the different stages depending on the party intending to carry out the tests and the quality control tests to be carried out in accordance with the procedures described in IS 2386 Parts 1 to 5. The methods of sampling involve obtaining the gross sample from sub lots, and subsequently reduction of gross sample to laboratory sample. The methods of sampling and packing shall be in accordance with IS 2430.

9.1.2 The amount of material required for testing at laboratory will depend upon the number and type of tests to be carried out as specified in 9.2. 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 5).

9.1.3 In the case of all-in-aggregate, for purposes of tests to verify its compliance with the requirements given in Table 15, and when necessary for such other tests as required by the purchaser, the aggregate shall be first separated into two fractions, one finer than 4.75 mm IS Sieve and the other coarser than 4.75 mm IS Sieve, and the appropriate tests shall be made on samples from each component, the former being tested as fine aggregate and the latter as coarse aggregate.

9.2 Testing Plan and Number of Tests

9.2.1 For the purpose of preliminary investigation of the potential source of aggregate, with no known history of field performance, petrographic examination shall be carried out as per IS 2386 (Part 5). For known sources, record of the petrographic examination shall be documented by the end user. For the purpose of preliminary investigation of the potential source of aggregate from other than natural sources, determination of unsoundness due to free lime, free magnesia and iron as per IS 2386 (Part 3), and determination of chemical constituents & hazardous substances in accordance with the requirements of clause 6 and clause 8 shall be carried out as per IS 2386 (Part 4).

9.2.2 The durability properties of the aggregates such as soundness against sodium and /magnesium sulphate attack, unsoundness due to iron, free lime and free magnesia, alkali aggregate reactivity such as alkali carbonate reactivity and alkali silica reactivity, etc., is required for source approval and selection of aggregate for the production of concrete. The results of the durability properties are neither used in the concrete mix design nor for quality control purposes. However, these tests shall be repeated in case of change of source or change in nature of aggregate from the same source. The sampling for this purpose shall be done from the potential source of aggregate. In some cases, the sampling may be done at the crusher/crushing plant/processing unit. The durability properties of the aggregate shall be determined in accordance with IS 2386 (Part 3).

9.2.3 The physical properties of the aggregate such as specific gravity, water absorption, sieve analysis, etc., is required for concrete mix design and quality control of concrete at site of work. For quality control of concrete at site, the frequency of these tests shall be mentioned in the quality assurance plan. Depending on the party intending to carry out the tests, sampling may be required at the source of supply (such as at the crusher/crushing plant) or the shipment of materials or the site of work or at batching/RMC plant. The physical properties of the aggregate shall be determined in accordance with IS 2386 (Part 1).

9.2.4 The mechanical properties of the aggregates such as crushing value, impact value, abrasion value, etc., is required for source approval and selection of aggregate for the production of concrete. The results of mechanical properties are not directly used in concrete mix design, however, these tests may be done for quality control purposes. The frequency of these tests may be mentioned in the quality assurance plan. Depending on the party intending to carry out the tests, sampling may also be done at the potential source of aggregate in addition to the source of supply (such as at the crusher/crushing plant) or the shipment of materials or the site of work or at batching/RMC plant. The mechanical properties of the aggregate shall be determined in accordance with IS 2386 (Part 2).

9.2.5 The chemical and hazardous properties of the aggregates such sulphates, chlorides, heavy metals, etc., is required for source approval and selection of aggregate for the production of concrete. The results of the chemical and hazardous properties are neither used in the concrete mix design nor for quality control purposes. However, these tests shall be repeated in case of change of source or change in nature of aggregate from the same source. The sampling for this purpose shall be done from the potential source of aggregate. In some cases, the sampling may be done at the crusher/crushing plant/ processing unit. The chemical and hazardous properties of the aggregate shall be determined in accordance with IS 2386 (Part 4).

10 SUPPLIER'S CERTIFICATE AND COST OF TESTS

10.1 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.

10.2 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.

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

10.4 The cost of the tests carried out under **10.2** shall be borne by,

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

11 DELIVERY

11.1 Supplies of aggregate may be made in bulk in suitable quantities mutually agreed upon between the purchaser and the supplier. Where so required by the purchaser, the aggregate may be supplied in bags (jute, jute-laminated, polyethylene lined or as may be mutually agreed between the purchaser and the supplier) bearing the net quantity (may be 15 kg, 30 kg, 300 kg, 600 kg or as agreed to between the purchaser and the supplier). The tolerance on the quantity of aggregate in each bag or consignment shall be as per **11.2** unless mutually agreed upon between the purchaser and the supplier.

11.2 Tolerance Requirements for the Quantity of Aggregate Packed in Bags

11.2.1 The average of net quantity of aggregate packed in bags at the plant in a sample shall be equal to or more than 25 kg, 50 kg, 300 kg, 600 kg, etc., as applicable.The number of bags in a sample shall be as given below:

Batch Size (1)	*Sample Size* (2)
100 to 150	20
151 to 280	32
281 to 500	50

501 to 1 200	80
1 201 to 3 200	125
3 201 and over	200

The bags in a sample shall be selected at random (see IS 4905).

11.2.2 The number of bags in a sample showing a minus error greater than 2 percent of the specified net quantity shall be not more than 5 percent of the bags in the sample. Also the minus error in none of such bags in the sample shall exceed 4 percent of the specified net quantity of aggregate in the bag.

11.2.3 In case of a wagon or truck load of 5 t to 25 t, the overall tolerance on net quantity of aggregate shall be 0 percent to + 0.5 percent.

12 MARKING AND LABELLING

12.1 Each consignment/bag of aggregate shall be legibly and indelibly marked with the following information:

a) Manufacturer's name and his registered trade-mark, if any;
b) Net quantity, in kg;
c) Batch/control unit number;
d) Address of the manufacturer;
e) Month and year of consignment/packing;
f) Type of aggregate, such as 'Coarse Aggregate' or 'Fine Aggregate';
g) In case the aggregates are from natural sources, the words 'Natural Aggregate';
j) In case of aggregates from other than natural sources, the type of coarse/fine aggregate (*see* Table 1 and Table 2);
k) In case of coarse aggregate, the nominal size along with the words, 'Single Sized' or 'Graded', as the case may be; and
m) In case of fine aggregate, the grading zone.

12.2 Similar information shall be provided in the delivery advices accompanying the shipment of aggregate in bulk (*see* **12.3**).

12.3 BIS Certification Marking

The product(s) may be marked with Standard Mark as per the conformity assessment schemes governed by the provisions of *the Bureau of Indian Standards Act*, 2016 and the Rules and Regulations made there under. The details of conditions for the license may be obtained from the Bureau of Indian Standards.

ANNEX A

(*Clause* 2)

LIST OF REFERRED STANDARDS

IS No.	*Title*
IS 456: 2000	Plain and reinforced concrete — Code of practice (*fourth revision*)
IS 2386	Methods of test for aggregates for concrete:
(Part 1) : XXXX	Determination of physical properties (*first revision*) [*under development CED 02(27866)*]
(Part 2) : XXXX	Determination of mechanical properties (*first revision*) [(*under development*) *CED 02(27867)*]
(Part 3) : XXXX	Determination of durability properties (*first revision*) (*under development*)
(Part 4) : XXXX	Determination of chemical properties and hazardous substances (*first revision*) (*under development*)
(Part 5): XXXX	Guidelines for petrographic examination of aggregates for concrete (*first revision*) (*under development*)
IS 2430: XXXX	Methods for sampling of aggregates for concrete (*first revision*) (*under development*)
IS 2686: 1977	Cinder as fine aggregates for use in lime concrete
IS 4905: 1968	Methods for random sampling
IS 6461 (Part 1) :2024	Glossary of terms relating to cement concrete: Part 1 Concrete aggregates (*first revision*)
IS 9142	Artificial lightweight aggregate for concrete — Specification
Part 1:2018	For concrete masonry blocks and for applications other than for structural concrete (*first revision*)
Part 2:2018	Sintered fly ash coarse aggregate (*first revision*)
10262: 2019	Concrete mix proportioning — Guidelines (*second revision*)

Annex B
(*Foreword*)

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:

a) Source of supply, that is, precise location of source from where the materials were obtained;
b) Trade group of principal rock type present, in case of aggregates from natural sources (*see* Annex C);
c) Physical characteristics, in case of aggregates from natural sources (*see* Annex C);
d) In case of aggregates from other than natural sources, the brief manufacturing process, source of parent material and special characteristics having bearing on concrete properties, such as presence of adhered coating in case ofrecycled concrete aggregate, to the extent possible.
e) Presence of reactive minerals;
f) Service history, if any and in particular, in case of aggregates from other than natural sources, the name of projects where used and the performance including in recently completed projects; and
g) In case of aggregates from other than natural sources, special precautions, if any, to be observed during concrete production.

ANNEX C
[*Clauses* B-1(b) *and* B-1(c)]

GUIDANCE ON THE DESCRIPTION AND PHYSICAL CHARACTERISTICS OF AGGREGATES FROM NATURAL SOURCES FOR CONCRETE

C- 1 GENERAL INFORMATION

C-1.1 To enable detailed reports on aggregate, the petrographic examination as per IS 2386 (Part 8) may be carried out and information in the following general headings may be given, are suggested as a guide:

a) *Trade group* — For example, granite, limestone and sandstone (*see* **C-2.2**);

b) *Petrological name and description* — The correct petrological name should be used and should be accompanied by a brief description of such properties as hardness, colour, grain, imperfections, etc.;

c) *Description of the bulk* — The degree of cleanliness, that is, freedom from dust, should be stated and reference made to the presence of any pieces not representative of the bulk;

d) *Particle shapes* — *See* **C-3**; and

e) *Surface texture* — *See* **C-3**.

C- 2 NOMENCLATURE OF ROCK

C-2.1 The technical nomenclature of rocks is an extensive one and for practical purposes it is sufficient to group together with those rocks having certain petrological characteristics in common. Accordingly, the list of trade groups given in **C-2.2** is adopted for the convenience of producers and users of aggregates:

C-2.2 Trade Groups of Rocks Used as Concrete Aggregate

The list of rocks placed under appropriate trade groups is given below:

A) IGNEOUS ROCKS		
	1. Granite Group	
Granite Gmnophyre		Granodiorite Diorite Syenite
	2. Gabbro Group	
Gabbro Norite Anorthosite		Peridotite Pyroxenite Epidiorite
	3. Aplite Group	
Aplite Porphyry		Quartz reef
	4. Dolerite Group	

Dolerite		Lamprophyre
	5. Rhyolite Group	
Rhyolite Trachyte		Felsite Pumicite
	6. Basalt Group	
Andesite		Basalt
B) SEDIMENTARY ROCKS		
	1. Sandstone Group	
Sandstone Quartzite		Arkose GraywackeGrit
	2. Limestone Group	
Limestone		Dolomite
C) METAMORPHIC ROCKS		
	1.Granulite and Gneiss Groups	
Granite gneiss Composite gneiss		Amphibolite Granulite
	2.Schist Group	
Slate		Phyllite Schist
	3.Marble Group	
Marble		Crystalline limestone

The correct identification of a rock and its placing under the appropriate trade group shall be left to the decision of the Geological Survey of India or any competent geologist.

C-3 PARTICLE SHAPE AND SURFACE TEXTURE

C-3.1 The external characteristics of any mixture of mineral aggregate include a wide variety of physical shape, colour and surface condition. In order to avoid lengthy descriptions, it may be convenient to apply to distinctive group types of aggregates some general term which could be adopted.

C-3.2 The simple system shown in Table 17 and Table 18 has, therefore, been devised for facilitate defining the essential features of both particle shape and surface characteristics.

Table 17 Particle Shape
(*Clause* C-3.2)

Sl No.	Classification	Description	Illustrations of Characteristic Specimens	Example
(1)	(2)	(3)	(4)	(5)
i)	Rounded	Fully water worn or completely shaped by attrition	Fig. 1	River or seashore gravels; desert, seashore an dwindblown sands
ii)	Irregular or partly rounded	Naturally irregular, or partly shaped by attrition, and having rounded edges	Fig. 2	Pit sands andgravels; land or dug flints; cuboid rock
iii)	Angular	Possessing well -defined edges formed at the inter-section of roughly planar faces	Fig. 3	Crushed rocks of all types; talus; screes
iv)	Flaky	Material, usuall y angular, of which the thickness is smallrelative to the width and/or length	Fig. 4	Laminated rocks

Table 18 Surface Characteristics of Aggregates
(*Clauses* C-3.2 *and* C-3.3)

Sl No.	Group	Surface Texture	Example
(1)	(2)	(3)	(4)
i)	1	Glassy	Black flint
ii)	2	Smooth	Chert, slate, marble, some rhyolite
iii)	3	Granular	Sandstone, oolites

iv)	4	Crystalline	*Fine* ─ Basalt, trachyte, keratophyre *Medium* ─ Dolerite, granophyre, granulite, microgranite, some limestones, manydolomites *Coarse* ─ Gabbro, gneiss, granite, granodiorite, syenite
v)	5	Honey- combed and porous	Scoriae, pumice, trass

FIG. 1 PARTICLE SHAPE - ROUNDED

FIG. 2 PARTICLE SHAPE - IRREGULAR

FIG. 3 PARTICLE SHAPE - ANGULAR

FIG. 4 PARTICLE SHAPE – FLAKY

C-3.3 Surface characteristics have been classified under five groups in Table 18. The grouping is broad; it does not purport to be a precise petrographical classification but is based upon a visual examination of hand specimens. With certain materials, however, it may be necessary to use a combined description with more than one group number for an adequate description of the surface texture, for example, crushed gravel, 1 and 2; oolites 3 and 5.

ANNEX D
(Foreword and *Clause* 4)

BRIEF INFORMATION ON THE SOURCES OF AGGREGATE

D-1 NATURAL

These are mineral sources that are used to obtain aggregates by subjecting to nothing more than mechanical processing such as crushing, washing and sieving. Aggregates derived from natural sources are natural sand /uncrushed sand, crushed stone sand, mixed sand, uncrushed coarse aggregate, crushed coarse aggregate and mixed coarse aggregate.

D- 2 INDUSTRIAL BY PRODUCTS

D-2.1 Iron and Steel industry

In the integrated iron and steel plant, the slag generated during the manufacturing of pig iron is known as iron slag. Since iron slag is produced through blast furnace route, it is also known as blast furnace slag whereas slag generated during the manufacturing of steel from the pig iron is known as steel slag.

D-2.1.1 *Blast Furnace Slag*

The slag produced from the blast furnace during production of pig iron is called blast furnace slag. This is a non-metallic product consisting primarily of silicates, alumina-silicates, and calcium-alumina-silicates. In the blast furnace, the slag floating over molten pig iron is flushed out and then cooled. Depending on the cooling process, different types of slags are generated, they are as follows

D-2.1.1.1 *Air cooled blast furnace slag (ACBFS)*

Air cooled blast furnace slag (ACBFS) is produced by allowing the molten slag to cool under atmospheric conditions in a pit. Under slow cooling conditions, escaping gases leave behind a porous structure. The slag after cooling can be further crushed and screened to produce different sizes of aggregates. The physical characteristics of aggregates will depend upon the cooling process and different sizes of aggregates so manufactured.

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 comparedto 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 onthe level of saturation those aggregates are subjected to either at the bottom of the slabs or in the vicinity of joints and cracks.

D-2.1.1.2 *Granulated blast furnace slag*

Granulated Blast Furnace slag (GBFS) is produced by the sudden cooling or quenching of the molten slag by means of high-pressure water jets. Quenching prevents crystallization, thus resulting in granular and glassy particles.

D-2.1.1.3 *Expanded blast furnace slag*

Expanded Blast Furnace slag is formed through controlled cooling of molten slag in water or water with a combination of steam and compressed air. Formation of steam and other gases enhances the porosity and vesicular nature of slag. Thus, this type of slag can be used in the manufacturing of light weight aggregate.

D-2.1.2 *Steel Slag*

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. This is cooled in a cooling yard with air and sprinkling of water. Depending on the type of furnace route used for the manufacture of steel, following type of steel slags are generated.

D-2.1.2.1 *Basic oxygen furnace (BOF) slag (*Linz–Donawitz (LD) slag*)*

In basic oxygen furnace, the molten pig iron is converted into steel by blowing oxygen through the molten pig iron that lowers the carbon content of the alloy and changes into low carbon steel. The steel slag is further processed through a series of steps involving cooling, metal recovery, crushing, screening, weathering and stockpiling. Volumetric stability in the BOFS is a major concern, which occurs mainly due to the presence of free lime (CaO) and free magnesium oxide (MgO) which hydrates expansively in presence of water. Thus, it is necessary to reduce free CaO and free MgO through various weathering techniques. The BOF slag with free CaO and free MgO, such that the expansion caused in concrete is in the range of when natural aggregates are used, can be used as an aggregate.

D-2.1.2.2 *Non-Basic oxygen furnace (N-BOF) route*

a) Electric Arc Furnace slag (EAF)

EAF slag is a non-metallic by-product that consists mainly of silicates and oxides formed during the process of refining the molten steel using Electric arc furnace method. Production of EAF slag consists of collection of liquid slag from EAF in slag pots which are positioned below the furnace. The slag pots are then carried tothe slag pits and the slag is then poured and allowed to cool in air/water sprays. After the slag cools down and solidifies, it is broken down into smaller pieces and sent to the slag processing unit. The boulders are broken down using balling cranein various size fractions such as 0-6 mm, 6-20 mm, 20-40 mm etc. for various possible utilization. EAF slag can be used for the manufacture of coarse as well asfine aggregate.

b) *Convertible arc slag (Conarc slag)*

The name conarc is the fusion of two processes, that is, converter and arcing. Conarc Steelmaking process is divided into two stages: Converter Stage and EAF Stage. In the Converter Stage, the decarburization of liquid iron is carried out by blowing oxygen and subsequently the process ends with EAF Stage, where the electric energy is utilized to melt the solid charge and superheating the bath to the tapping temperature. During converter stage the content of carbon, silica, manganese and phosphorous are reduced. During this process slag is generated. Afterward during the arcing phase, the remaining solid charge material like scrap orDRI is charged into the bath so as to achieve the desired tapping temperature. Conarc slag can exhibit volumetric expansion equal or higher than the EAF slag butsignificantly less than the BOF steel slag based on its composition and presence offree lime/dolime. Conarc slag can be used in the manufacture of coarse as well asfine aggregate.

D- 2.2 Copper Slag

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 chemically at 1 200 ºC 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 can be used as fine aggregate.

D- 2.3 Bottom Ash from Thermal Power Plants

In thermal power plants, approximately 80 percent of the ash transported by the flue gases and collected using electrostatic precipitator (ESP) is obtained in the form of fly ash and the remaining is collected in the form of bottom ash. In coal based thermal power plants, bottom ash is collected at Hydrobin or dumped at ash dyke. Bottom ash contains significant amount of relatively coarser particles and can be used as fine aggregate when blended with fine aggregates from natural sources to obtain a composite fine aggregate.

NOTE— Sea water shall not be used for the quenching and transportation of bottom ash to be used for concrete production.

D- 3 CONSTRUCTION AND DEMOLITION (C&D) WASTE

Construction and demolition (C&D) waste is generated from construction, renovation, repair, and demolition of houses, large building structures, roads, bridges, piers, etc. C&D waste can be used in the manufacture of aggregates. These aggregates may be of two types namely recycled mixed aggregate (RMA) and recycled concrete aggregate (RCA). RMA can be used as coarse aggregate and RCA can be used both as coarse and fine aggregates in accordance with this standard.

D-3.1 Recycled Mixed Aggregate

RMA is made from C&D waste which may comprise of concrete, brick, tiles, stone, etc.

Recycled mixed aggregate (RMA) may typically have a higher water absorption value and a lower specific gravity than natural aggregate.

D-3.2 Recycled Concrete Aggregate

RCA is derived from concrete after requisite processing. Recycled concrete aggregate (RCA) comprises of not only the original aggregate, but also the hydrated cement paste adhering to its surface. This paste may reduce the specific gravity of the aggregate and increase the porosity as compared to similar virgin aggregates. Higher porosity of RCA may lead to a higher water absorption.

ANNEX E

(*Foreword and Clause* 4.1.1)

GUIDELINES FOR MIX DESIGN OF CONCRETE INCORPORATING BOTTOM ASH AS REPLACEMENT OF FINE AGGREGATE

E-1 DATA FOR MIX PROPORTIONING

E-1.1 The information and data required is same as given in IS 10262 (*see* **4.1**).

E-2 TARGET STRENGTH FOR MIX PROPORTIONING

E-2.1 Target Mean Strength — Concrete mix has to be proportioned for highertarget mean strength. Determine the target mean strength f_{ck}' from the specified characteristic compressive strength at 28-day f_{ck} and standard deviation.

$f_{\mathrm{ck}}' = f_{\mathrm{ck}} + 1.65\,S$ or $f_{\mathrm{ck}} + X$, whichever is higher
Where X is the factor based on the grade of concrete obtained from Table 19and S is the standard deviation obtained from Table 20.

Table 19 Value of X
(*Clause* E-2.1)

SI No.	**Grade of Concrete**	**Value of X N/mm^2**
(1)	(2)	(3)
i)	M10,M15	5.0
ii)	M20,M25	5.5
iii)	M30,M35,M40,M45,M50,M55,M60	6.5
iv)	M65 and Above	8.0

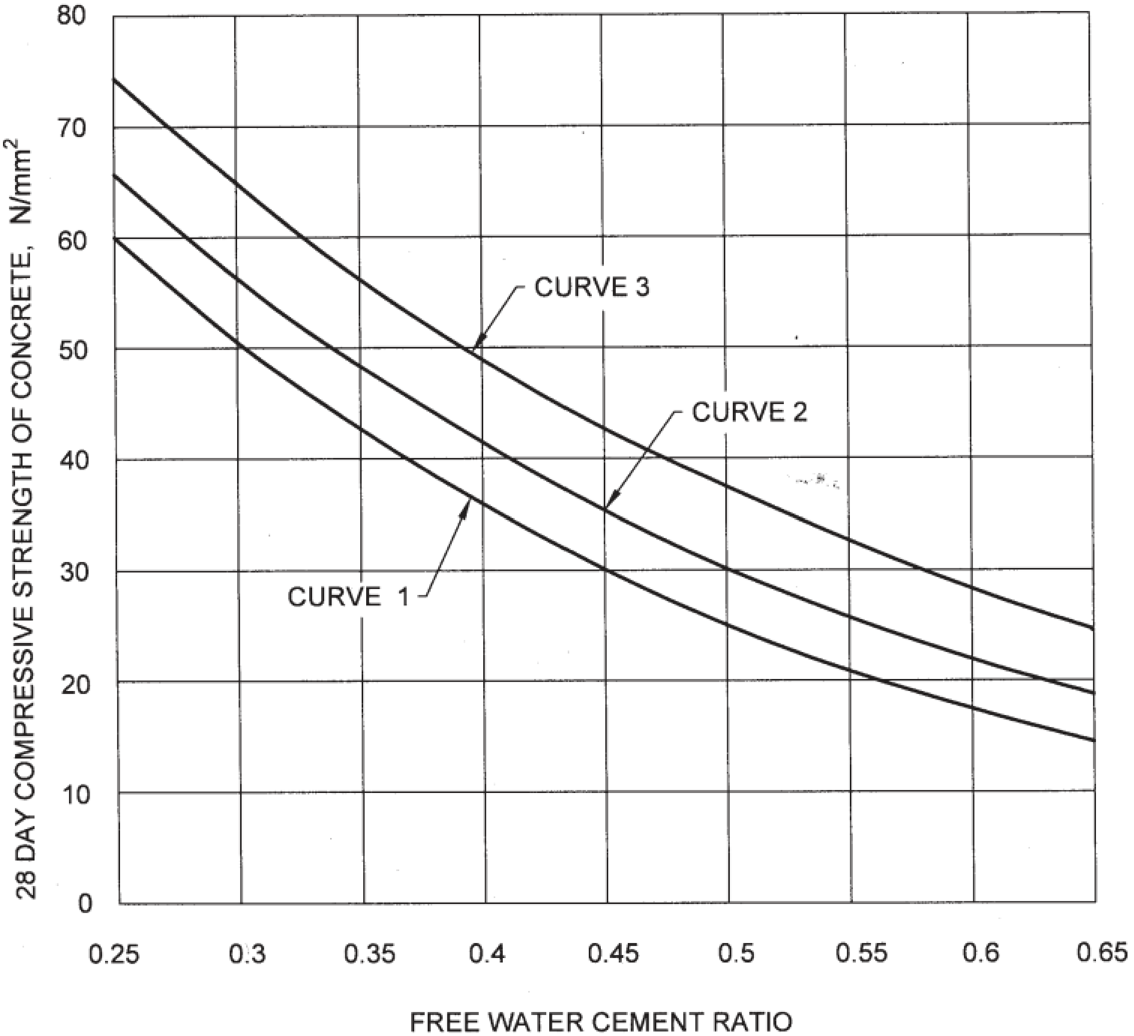
Table 20 Assumed Standard Deviation
(*Clause* E-2.1)

SI No.	**Grade of Concrete**	**Assumed Standard deviation N/mm^2**
(1)	(2)	(3)
i)	M10, M15	3.5
ii)	M20, M25	4.0
iii)	M30, M35, M40, M45, M50, M55, M60	5.0
iv)	M65, M70, M75, M80	6.0

E-3 SELECTION OF MIX PROPORTIONS

E-3.1 Selection of Water-Cement Ratio

Obtain the free water cement ratio for the desired mean target strength using any established relationship or using FIG. 5. The water cement ratio so chosen is checked against the limiting water cement ratio for the requirements of durability given in Table 5 of IS 456 and adopts the lower of the two values.



Curve 1 : for expected 28 days compressive strength of 33 and < 43 N/mm^2.
Curve 2 : for expected 28 days compressive strength of 43 and < 53 N/mm^2.
Curve 3 : for expected 28 days compressive strength of 53 N/mm^2 and above.

FIG. 5 RELATIONSHIP BETWEEN FREE WATER CEMENT RATIO AND 28 DAYS COMPRESSIVE STRENGTHS OF CONCRETE FOR CEMENTS OF VARIOUS EXPECTED 28 DAYS COMPRESSIVESTRENGTHS

E-3.2 Estimation of Air Content

Approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete for 20 mm MSA shall be taken as 1.50 percent. However, the actual values of air content can also be adopted during mix proportioning if; the site data (at least 5 results) for similar mix is available.

E-3.3 Selection of Water content and Admixture Content

The water content of concrete is influenced by a number of factors, such as aggregate size, aggregate shape, aggregate texture, workability, water-cement ratio, cement and other supplementary cementitious materials type and content, chemical admixture and environmental conditions. An increase in aggregates size, a reduction in water-cement ratio and slump, and use of rounded aggregate and water reducing admixture will reduce the water demand. On the other hand, increased temperature, cement content, slump, water-cement ratio, aggregate angularity and a decrease in the proportion of the coarse aggregate to fine aggregate will increase water demand.

The quantity of mixing water per unit volume of concrete for MSA 20 mm shall be 194 kg/m^3. The water content given is for angular coarse aggregate and for 25 to 50 mm slump. The water so estimated can be reduced by approximately 10 kg for sub-angular aggregates, 15 kg for gravel with some crushed particles and 20 kg for rounded gravel to produce same workability. For the desired workability (other than 25 to 50mm slump), the required water content may be increased or decreased by about 4 percent for each increase or decrease of 25 mm slump or may be established by trial. This illustrates the need for trial batch testing of the given materials as each aggregate source is different and can influence concrete properties. The water so calculated can be reduced by use of chemical admixture conforming to IS 9103. Water reducing admixture or super plasticizing admixtures usually decrease water content by 5 to 10 percent and 20 to 30 percent and above respectively at appropriate dosages.

E-3.4 Calculation of Cement/Cementitious Materials Content

The cement content per unit volume of concrete may be calculated from the free water-cement ratio and the quantity of water per unit volume of concrete.

The cement content so calculated shall be checked against the minimum content for the requirements of durability as per IS 456 or as specified and greater of the two values adopted. The maximum cement content shall be in accordance with IS 456 or as specified.

E-3.5 Estimation of Coarse Aggregate Proportion

Aggregates of essentially the same nominal maximum size, type and grading will produce concrete of satisfactory workability when a given volume of coarse aggregate per unit volume of total aggregate is used. Approximate values for this aggregate volume are given in Table 21 for a water-cement/water-cementitious materials ratio of 0.5, which may be suitably adjusted for other water-cement ratios, the proportion of volume of coarse aggregates to that of total aggregates is increased at the rate of 0.01 for every decrease in water-cement ratio by 0.05 and decreased at the rate of 0.01 for every increase in water-cement ratio by 0.05.

It can be seen that for equal workability, the volume of coarse aggregate in a unit volume of concrete is dependent only on its nominal maximum size and fineness modulus of fine aggregate.

For more workable concrete mixes which is sometimes required when placement by pump or when the concrete is required to be worked around congested reinforcing steel, it may be desirable to reduce the estimated coarse aggregate content determined using Table 21 up to 10 percent. However, caution shall be exercised to assure that the resulting slump, water-cement/cementitious materials ratio and strength properties of concrete are consistent with the recommendations of IS 456 and meet project specification requirements as applicable.

Table 21 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different ranges of fineness modulus of Fine Aggregate for Water-Cement/Water-Cementitious Materials Ratio of 0.50
(*Clauses* E-3.5 *and* E-3.7)

Nominal Maximum Sizeof Aggregate mm	**Volume of Coarse Aggregate per Unit Volume of total Aggregate for Different Fineness Modulus of Composite Fine Aggregate**				
	Fineness Modulus of Composite Fine Aggregate				
	1.33-1.69	1.7-1.89	1.9-2.09	2.1-2.49	2.5-3.01
(1)	(2)	(3)	(4)	(5)	(6)
20	0.72	0.70	0.68	0.66	0.64

NOTE- Volumes are based on aggregates in saturated surface dry condition.

E-3.6 Combination of Different Coarse Aggregate Fractions

The coarse aggregate used shall conform to the requirements of this standard. Coarse aggregates of different sizes may be combined in suitable proportions so as to result in an overall grading conforming to Table 7 for particular nominal maximum size of aggregate.

E-3.7 Estimation of Fine and Coarse Aggregate Contents

These quantities are determined by finding out the absolute volume of cementitious materials, water and the chemical admixture; by dividing their mass by their respective specific gravity, multiplying by 1/1000 and subtracting the result of their summation from unit volume. The values so obtained are divided into coarse and composite fine aggregate fractions by volume in accordance with coarse aggregate proportion already determined in Table 21.

The coarse aggregate and composite fine aggregate (fine aggregate and bottom ash) content are then determined by multiplying with their respective specific gravity and multiplying by 1 000. The fine aggregate and bottom ash content are then further determined by multiplying their respective percentage (as determined to prepare composite fine aggregate of required fineness modulus) with the total weight of composite fine aggregate.

E-4 TRIAL MIXES

The calculated mix proportions shall be checked by means of trial batches. Workability of the trial mix No. 1 shall be measured. The mix shall be carefully observed for freedom from segregation and bleeding and its finishing properties. If the measured workability of Trial Mix No. 1 is different from the stipulated value, the water and/or admixture content shall be adjusted suitably. With this adjustment, the mix proportion shall be recalculated keeping the free water-cement ratio at the pre-selected value, which will comprise trial mix No. 2. In additional two more trial mixes No. 3 and 4 shall be made with the water content same as trial mix No. 2 and varying the free water-cement/cementitious materials ratio by about ±10 percent of the preselected value, while satisfying the workability requirements as well.

Mix No. 2 to 4 normally provides sufficient information, including the relationship between compressive strength and water-cement ratio, from which the mix proportions can be finalized, such that the strength and durability requirements are also satisfied. Additional field trials are recommended particularly for workability requirements. The concrete for field trials shall be produced by methods of actual concrete production.

E-5 ILLUSTRATIVE EXAMPLE

An illustrative example of concrete mix proportioning is given below. This example is merely illustrative to explain the procedure and the actual mix proportioning shall be based on trial batches with the given materials.

E-5.1 Illustrative Example on Concrete Mix Proportioning

An example illustrating the mix proportioning for a concrete of M25 grade using OPC 43 Grade is given below.

E-5.1.1 *Stipulations for Proportioning*

a)	Grade designation	:	M 25
b)	Type of cement	:	OPC-43 Grade conforming toIS 269
c)	Maximum nominal size of aggregate	:	20 mm
d)	Minimum cement content and maximum Water-cement ratio to be adopted and/or Exposure condition as per Table 3 and Table 5 of IS 456		Moderate (for reinforced concrete)
e)	Workability	:	75 mm (slump)
f)	Method of concrete placing	:	Chute (Non Pumpable)
g)	Degree of site control	:	Good
h)	Type of coarse aggregate	:	Crushed angular aggregate
j)	Type of Fine aggregate	:	Composite (Natural sand andBottom Ash)
k)	Maximum cement content	:	450 kg/m3

m) Chemical admixture type : superplasticizer - normal

E-5.1.2 *Test Data for Materials*

a) Cement used conforming to IS 269 : OPC-43 Grade
b) Specific gravity of cement : 3.15
c) Chemical admixture : Not applicable
d) Specific gravity at saturated surface dry condition:
  i) Coarse aggregate : 2.75
  ii) Fine aggregate (Natural) : 2.59
  iii) Bottom Ash : 2.05
  iv) Composite Fine Aggregate : 2.40 (2.59 x 0.70 + 2.05x 0.30)
e) Fineness Modulus of Composite Fine Aggregate : 1.71 (70% of Natural fine and 30% of Bottom Ashby weight)

f) Water absorption
  i) Coarse aggregate : 0.3 percent
  ii) Fine aggregate : 0.8 percent
  iii) Bottom Ash : 0.49 percent
g) Moisture content of aggregate

  i) Coarse aggregate : 1%
  ii) Fine aggregate : 3%
  iii) Bottom Ash : 1.5%

E-5.1.3 *Target Strength for Mix Proportioning*

$f_{ck}' = f_{ck} + 1.65\,S$ *Or* $f_{ck}' = f_{ck} + X$

Whichever is higher
Where,
f_{ck}'= target average compressive strength at 28 days,
f_{ck} = characteristic compressive strength at 28 days, and *s* = standard deviation.
X = 5.5 as per Table 1 of IS 10262

From Table-2 of IS 10262, standard deviation, *s* = 4 N/mm^2.Therefore, target strength using both equations, that is,

i) $f_{ck}' = f_{ck} + 1.65\,S$

= 25+1.65x4 = 31.60 N/mm^2

ii) $f_{ck}' = f_{ck} + X$

=25+5.5 = 30.5N/mm^2

The higher value is to be adopted. Therefore, target strength will be 31.60 N/mm^2.

E-5.1.4 *Approximate Air Content*

From clause **3.2** of IS 10262, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1.5 percent for 20 mm nominal maximum size of aggregate.

E-5.1.5 *Selection of Water-Cement Ratio*

From IS 10262, the free water-cement ratio required for the target strength of 31.6 N/mm^2 is 0.49 for OPC 43 grade curve. This is lower than the maximum value of 0.5 prescribed for moderate exposure for reinforced concrete as per Table 5 of IS 456.

E-5.1.6 *Selection of Water Content*

From clause **3.3**, water content = 194 kg (for 25 mm- 50 mm slump) for msa 20 mm aggregate.

$$\text{Estimated water content for 75 mm slump} = 194 + \frac{4 \times 194}{100} = 201.76 \text{ kg}$$

As super plasticizer is used, the water content may be reduced. Based on trial data, the water content reduction of 23 percent is considered while using super plasticizer at the rate of 1.0 percent by weight of cement.

Hence the arrived water content = 201.76 × 0.77
= 155.35kg ≈ 155 kg

E-5.1.7 *Calculation of Cement Content*

Water: cement	= 0.49
Water content	= 155 kg
Hence cement content	= 316 kg

From Table 5 of IS 456, minimum cement content for 'moderate' exposure condition = 300 kg/m^3

316 kg/m^3 > 300 kg/m^3, hence, O.K.

E-5.1.8 *Proportion of Volume of Coarse Aggregate and Fine Aggregate Content*

From Table 3, the proportionate volume of coarse aggregate corresponding to 20 mm size aggregate and fineness modulus of composite fine aggregate (1.7 - 1.89) for water-cement ratio of 0.50 = 0.70.

Volume of fine aggregate content = 1 – 0.70 = 0.30

E-5.1.9 *Mix Calculations*

The mix calculations per unit volume of concrete shall be as follows:

a) Total Volume = 1 m^3
b) Volume of entrapped air = 0.015 m^3 in wet concrete
c) Volume of cement = $\frac{Mass\ of\ cement}{Specific\ Gravity\ Cement} X \frac{1}{1000}$

$= \frac{316}{3.15} X \frac{1}{1000}$ = 0.100 m^3

d) Volume of Water = $\frac{Mass\ of\ water}{Specific\ Gravity\ water} X \frac{1}{1000}$

$= \frac{155}{1} X \frac{1}{1000}$ = 0.155 m^3

e) Volume of all in aggregate = [(a-b)-(c+d)}
= [(1-0.015) – (0.10 + 0.155)]
= 0.73 m^3

f) Mass of coarse aggregate = e x Volume of coarse aggregate x Specific gravity of coarse aggregate x 1000
= 0.73 x 0.70 x 2.75 x 1000
=**1405.25 kg ≈ 1405 kg**

g) Mass of composite fine aggregate = e x volume of composite fine aggregate x specific gravity of composite fine aggregate x 1000
= 0.73 x 0.3x 2.40 x 1000
= **525.60 kg ≈ 526 kg**

h) Mass of Natural Sand & Bottom Ash = Since the composite fine aggregate of fineness modulus 1.71 was prepared by mixing natural sand and bottom ash in the ratio of 70 percent ;30 percent (by weight), therefore the mass of natural sand and bottom ash will be as calculated below:-

j) Mass of natural sand = mass of composite fine aggregate x percentage of natural sand
= 526 x 0.7
= **368.2 kg ≈ 368 kg**

k) Mass of Bottom Ash = mass of composite fine aggregate x percentage of bottom ash
= 526 x 0.3
= **157.8 kg ≈ 158 kg**

E-5.1.10 *Mix Proportions for Trial Number 1*

Cement	=316 Kg/m^3
Water	=155 Kg/m^3
Fine Aggregate (SSD)	=368 Kg/m^3
Bottom Ash (SSD)	=158 Kg/m^3
Coarse aggregate (SSD)	=1405 Kg/m^3
Free Water-cement ratio	=0.49

E-5.2 Illustrative Example On Concrete Mix Proportioning

An illustrative example of concrete mix proportioning for a concrete of M25 grade is given below. This example is merely illustrative to explain the procedure and the actual mix proportioning shall be based on trial batches with the given materials.

E-5.2.1 *Stipulations for Proportioning*

a) Grade designation	:M 25
b) Type of cement	:PPC or PSC
c) Maximum nominal size of aggregate	20 m
d) Minimum cement content and maxim Water-cement ratio to be adopted and/or Exposure condition as per Table 3 and Table 5 of IS 456	Moderate (for reinforced concrete)
e) Workability	:75 mm (slump)
f) Method of concrete placing	:Chute (Non Pumpable)
g) Degree of site control	:Good
h) Type of coarse aggregate	:Crushed angular aggregate
i) Type of Fine aggregate	:
j) Chemical admixture type	:superplasticizer - normal

E-5.2.2 *Test Data for Materials*

a) Cement used : PPC or PSC

b) Specific gravity of cement : 2.80

c) Chemical admixture : Not applicable

d) Specific gravity at saturated surface dry condition:

- i) Coarse aggregate : 2.75
- ii) Fine aggregate (Crushed) : 2.65
- iii) Bottom Ash : 1.73
- iv) Composite Fine Aggregate : 2.42 (2.65 x 0.75 + 1.73 x 0.25)

e) Fineness Modulus of Composite Fine Aggregate: 2.28 (75 percent of Conventionalfine Aggregate and 25 percent of Bottom Ash by weight)

f) Water absorption:

- i) Coarse aggregate : 0.3 percent
- ii) Fine aggregate : 0.8 percent
- iii) Bottom Ash : 0.49 percent

g) Moisture content of aggregate

i) Coarse aggregate : 1%
ii) Fine aggregate : 3%
iii) Bottom Ash : 1.5%

E-5.2.3 *Target Strength for Mix Proportioning*

$f_{ck}' = f_{ck} + 1.65\,S$ *Or* $f_{ck}' = f_{ck} + X$

Whichever is higher
Where,
f_{ck}'= target average compressive strength at 28 days,
f_{ck} = characteristic compressive strength at 28 days, and s = standard deviation.
X = 5.5 as per Table 1 of IS 10262

From Table-2 of IS 10262, standard deviation, s = 4 N/mm^2.Therefore, target strength using both equations, that is,

i) $f_{ck}' = f_{ck} + 1.65\,S$ = 25+1.65x4 = 31.60 N/mm^2

ii) $f_{ck}' = f_{ck} + 5.5$ = 25+5.5 = 30.5N/mm^2

The higher value is to be adopted. Therefore, target strength will be 31.60 N/mm^2.

E-5.2.4 *Approximate Air Content*

From clause **3.2** of IS 10262, the approximate amount of entrapped air to be expected in normal (non-air-entrained) concrete is 1.5 percent for 20 mm nominal maximum size of aggregate.

E-5.2.5 *Selection of Water-Cement Ratio*

From IS 10262, the free water-cement ratio required for the target strength of 31.6 N/mm^2 is 0.44 for PPC grade curve (curve 1). This is lower than the maximum valueof 0.50 prescribed for moderate exposure for reinforced concrete as per Table 5 of IS 456.

E-5.2.6 *Selection of Water Content*

From **3.3**, water content = 194 kg (for 25 mm- 50 mm slump) for MSA 20 mm aggregate.
Estimated water content for 75 mm slump =194 + (4 × 194/100) = 201.76 kg

As super plasticizer is used, the water content may be reduced. Based on trial data, the water content reduction of 23 percent is considered while using super plasticizer at the rate of 1.0 percent by weight of cement.
Hence the arrived water content = 201.76 × 0.77
= 155.35kg ≈ 155 kg

E-5.2.7 *Calculation of Cement Content*

Water: cement= 0.44 Water content= 155 kg
Hence cement content= 352.27 kg ≈ 352 kg

From Table 5 of IS 456, minimum cement content for 'moderate' exposure condition = 300 kg/m^3

352 kg/m^3> 300 kg/m^3, hence, O.K.

E-5.2.8 *Proportion of Volume of Coarse Aggregate and Fine Aggregate Content*

From Table 3, the proportionate volume of coarse aggregate corresponding to 20 mm size aggregate and fineness modulus of composite fine aggregate (2.10-2.49) for water-cement ratio of 0.50 is 0.66. For water-cement ratio of 0.45, it will be 0.67.
Therefore, volume of fine aggregate content = 1 – 0.67 = 0.33

E-5.2.9 *Mix Calculations*

The mix calculations per unit volume of concrete shall be as follows:

a) Total Volume = 1 m^3
b) Volume of entrapped air = 0.015m^3 in wet concrete

c) Volume of cement = $\frac{Mass\ of\ cement}{Specific\ Gravity\ Cement} X \frac{1}{1000}$

$$= \frac{352}{2.80} X \frac{1}{1000} = 0.126 \text{ m}^3$$

d) Volume of Water = $\frac{Mass\ of\ water}{Specific\ Gravity\ water} X \frac{1}{1000}$

$$= \frac{155}{1} X \frac{1}{1000} = 0.155 \text{ m}^3$$

e) Volume of all in aggregate = [(a-b)-(c+d)}
= [(1-0.015) – (0.126 + 0.155)]
= 0.704 m^3

f) Mass of coarse aggregate = e × Volume of coarse aggregate × Specific gravity of coarse aggregate × 1000
= 0.704 × 0.67 × 2.75 ×1000
=**1297.12 Kg ≈ 1297 Kg**

g) Mass of composite fine aggregate= e × volume of composite fine aggregate × specific gravity of compositefine aggregate × 1000
= 0.704 × 0.33 × 2.42 × 1000
= **562.21 Kg ≈ 562 Kg**

h) Mass of Crushed stone Sand & Bottom Ash = Since the composite fine aggregate of fineness modulus 2.28 was prepared by mixing crushed stone sandand bottom ash in the ratio of 75:25 (by weight), therefore the mass of natural sand and bottom ash will be as calculated below:-

i) Mass of natural sand = mass of composite fine aggregate x percentage of natural sand
= 562 x 0.75
= **421.50 Kg ≈ 422 Kg**

ii) Mass of Bottom Ash = mass of composite fine aggregate x percentage of bottom ash
= 562 x 0.25
= **140.5 Kg ≈ 140 Kg**

E-5.2.10 *Mix Proportions for Trial Number 1*

Cement	= 352 Kg/m^3
Water	= 155 Kg/m^3
Fine Aggregate (SSD)	= 422 Kg/m^3
Bottom Ash (SSD)	= 140 Kg/m^3
Coarse aggregate (SSD)	= 1297 Kg/m^3
Free Water-cement ratio	= 0.44

ANNEX F
(*Foreword*)

COMMITTEE COMPOSITION

Cement and Concrete Sectional Committee, CED 02

(*The Committee composition will be added after finalization*)

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