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Description on Sampling and Complying for Acceptance Criteria of Concrete

(As per the IS: 456-2000, 4th Rev., Including Amend. No.1 and 2)

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Abstract: ***Most of cases there are lot of confusions on acceptance and finalization of strength of the concrete for various grades. It was clearly mentioned in IS code, even though various interpretations on understanding the same. To overcome this issue here it is clearly described the acceptance and finalization of the concrete strength. In this paper, it is described based on IS: 456-2000, 4th revision amendment No. 1 and 2.***

Keywords: Sampling, Concrete, Strength Comply, Acceptance Criteria, Grade

1. Introduction

As Per IS: 456-2000, the sampling and strength of designed Concrete-Mix:-

In all the cases, the 28-days compressive strength shall alone be the criterion for acceptance or rejection of the concrete, as per the IS: In order to get a relatively quicker idea of the quality of concrete, optional test for 7 days' compressive strength of concrete be carried out.

As per IS: 456, Cl: 15.1.1 it is mentioned that the Table 2 shall alone the criterion for acceptance or rejection of the concrete.

15 SAMPLING AND STRENGTH OF DESIGNED CONCRETE MIX

15.1 General

Samples from fresh concrete shall be taken as per IS 1199 and cubes shall be made, cured and tested at 28 days in accordance with IS 516.

15.1.1 In order to get a relatively quicker idea of the quality of concrete, optional tests on beams for modulus of rupture at 72 ± 2 h or at 7 days, or compressive strength tests at 7 days may be carried out in addition to 28 days compressive strength test. For this purpose the values should be arrived at based on actual testing. In all cases, the 28 days compressive strength specified in Table 2 shall alone be the criterion for acceptance or rejection of the concrete.

(Respective Screen Short: of IS: 456-2000)

The part of the Table-2, Popular-Grades given below:-

Grade designation Characteristic Strength (Fck)
M-20 20 N/mm^2
M-25 25 N/mm^2
M-30 30 N/mm^2
M-35 35 N/mm^2

IS 456 : 2000

Table 2 Grades of Concrete
(Clause 6.1, 9.2.2, 15.1.1 *and* 36.1 *)*

Group	Grade Designation	Specified Characteristic Compressive Strength of 150 mm Cube at 28 Days in N/mm^2
(1)	(2)	(3)
Ordinary Concrete	M 10	10
	M 15	15
	M 20	20
Standard Concrete	M 25	25
	M 30	30
	M 35	35
	M 40	40
	M 45	45
	M 50	50
	M 55	55
High Strength Concrete	M 60	60
	M 65	65
	M 70	70
	M 75	75
	M 80	80

NOTES
1 In the designation of concrete mix M refers to the mix and the number to the specified compressive strength of 150 mm size cube at 28 days, expressed in N/mm^2.
2 For concrete of compressive strength greater than M 55, design parameters given in the standard may not be applicable and the values may be obtained from specialized literatures and experimental results.

(Respective Screen Short: of IS: 456-2000)

2. Acceptance Criteria

The acceptance criteria of concrete described here. The criteria-is mandatory to verify the various necessities of the code had to be complied before rejecting the concrete, as per Cl: 15.1.1 and table 2.

As per IS: 456-2000 Cl.16.1 for the acceptance, compressive Strength of specified grade to comply both the conditions should be met with:
a) The mean strength determined from any group of four

consecutive test results should comply with the appropriate limits Column (2) as given in Table-11, and

b) Any individual test result complies within the appropriate limits Col. (3) as given in Table-11.

16 ACCEPTANCE CRITERIA

16.1 Compressive Strength

The concrete shall be deemed to comply with the strength requirements when both the following condition are met:

a) The mean strength determined from any group of four consecutive test results compiles with the appropriate limits in col 2 of Table 11.

b) Any individual test result complies with the appropriate limits in col 3 of Table 11.

(Respective Screen Short of: IS: 456-2000)
The table-11of IS: 456-2000 details given below:-

Table 11: Characteristic Compressive Strength Compliance Requirement

Specified grade (1)	Mean of the group of 4 non-overlapping consecutive test results in N/mm^2 (2)	Individual test results in N/mm^2 (3)
M-15	>/=fck+0.825x Established standard deviation (rounded off to nearest 0.5N/mm^2) or fck + 3 N/mm^2, whichever is greater	>/=fck–3 N/mm^2
M-20 or above	>/=fck+0.825x Established Standard deviation (rounded off to nearest 0.5 N/mm^2) or **fck + 4 N/mm^2,** whichever is greater.	**>/=fck– 4 N/mm^2**

Table 11 Characteristic Compressive Strength Compliance Requirement

(*Clauses* 16.1 *and* 16.3)

Specified Grade	Mean of the Group of 4 Non-Overlapping Consecutive Test Results in N/mm²	Individual Test Results in N/mm²
(1)	(2)	(3)
M 15	≥ f_{ck} + 0.825 × established standard deviation (rounded off to nearest 0.5 N/mm²) or f_{ck} + 3 N/mm², whichever is greater	≥ f_{ck} N/mm²
M 20 or above	≥ f_{ck} + 0.825 × established standard deviation (rounded off to nearest 0.5 N/mm²) or f_{ck} + 4 N/mm², whichever is greater	≥ f_{ck} N/mm²

NOTE—In the absence of established value of standard deviation, the values given in Table 8 may be assumed, and attempt should be made to obtain results of 30 samples as early as possible to establish the value of standard deviation.

(Respective Screen Short: of IS: 456-2000)

Note: In absence of established standard deviation, the values given in Table-8 of IS: 456-2000maybeassumed. **So, the (Table 8 of IS: 456-2000) Assumed Slandered Deviation can use in absence of (ESD) Estimated slandered deviation, (SD) Standard Deviation and other Assumed calculations also.**

Table 8 Assumed Standard Deviation
(Clause 9.2.4.2 and Table 11)

Grade of Concrete	Assumed Standard Deviation N/mm²
M 10, M 15	3.5
M 20, M 25	4.0
M 30, M 35, M 40, M 45, M 50	5.0

NOTE—The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate gradings and moisture content; and periodical checking of workability and strength. Where there is deviation from the above the values given in the above table shall be increased by 1N/mm².

(Respective Screen Short of: IS: 456-2000)

3. Frequency of Sampling of Concrete

The minimum sampling frequency of concrete should be as per Cl: 15.2.2. At least one sample shell be taken from each shift. When concrete is produced at continuous, the frequency of sampling may be agreed upon mutually by supplier and purchaser. It means that, the quantity of sample collection of concrete cubes will also depend on both the parties (i.e. as per agreed FQP, Field Quality Plan).

15.2.2 ***Frequency***

The minimum frequency of sampling of concrete of each grade shall be in accordance with the following:

Quantity of Concrete in the Work, m³	*Number of Samples*
1 - 5	1
6 - 15	2
16 - 30	3
31 - 50	4
51 and above	4 plus one additional sample for each additional 50 m³ or part thereof

NOTE—At least one sample shall be taken from each shift. Where concrete is produced at continuous production unit, such as ready-mixed concrete plant, frequency of sampling may be agreed upon mutually by suppliers and purchasers.

(Respective Screen Short: of IS: 456-2000)

3.1 Sample of Concrete for Test

The 6 nos of Cubes of 150x150x150 mm size shall be cast, 3for7-days testing and 3 for 28-days testing.

A set of 3-cubes (3-specimens) shall made a-sample for testing at 28-days of average-value (As per IS: 456-2000 Cl: 15.3). Note that, the meaning of individual test results means the average of 3-cubes/specimens (i.e. a-sample), but not individual cube.

3.2Test Results of Samples

As per IS: 456-2000; Cl: 15.4, the test results of the sample shall be the average of the strength of three-specimens. The individual variation of each cube/specimen should not be more than +/-15% of the average. If more, the test results of the sample are invalid.

15.4 Test Results of Sample

The test results of the sample shall be the average of the strength of three specimens. The individual variation should not be more than ±15 percent of the average. If more, the test results of the sample are invalid.

(Respective Screen Short: of IS: 456-2000)

3.3When the (Fck+4), Acceptance criteria applicable? (As per Cl: 6.1.1),

Whenever the concrete is produced at continuously, at least it should have 4-consecutive test samples capacity of concrete to fulfill the Column (2) of Table-11, and if one of the test-result (i.e. any individual test results, as per column (3) of table-11), found >/=Fck-4 value of that 4-consecutive test-results.

So, it is clear that the (Fck+4) and (Fck-4) criteria of table-11 applicable for bulk quantity of concrete works which should have at least 4-consicutive tests. Up to 3-samples capacity of concrete works, the table-11 not applicable. For those concrete works follow the Characteristic Compressive Strength (Fck) table-2.

If the concrete volume 4 or more samples capacity, check once with acceptance criteria and comply with table-11, if found any one sample's value less than Fck-value, than take conclusion by applying column (2) & (3) of table-11, conform for accept or reject.

4. Case Study and Justification of (F_{CK}+4) Acceptance Criteria

(As per Cl: 6.1.1),

Example: Considering the M25 grade:

Justifying acceptability criteria:-

For M25, it is clear from Table 11, Column (3) the Individual Test Result's data set should be equal or more than 21 N/mm² (i.e. >/= Fck-4). It is important to note here the numerical value 21 is less the number 25 representing the grade of M25-concrete.

CASE-I: Test sample's results (For 4-samples)

Note-28 days' average value (with its each cube-value of 3nos indicated in the bracket) in N/mm².

(i) 30 N/mm²; (26, 30, 34 N/mm2)
(ii) 22 N/mm²; (19.5, 22, 24.5 N/mm2)
(iii) 35 N/mm²; (30, 35, 40 N/mm2)
(iv) 29 N/mm²; (25, 29, 33 N/mm2)

- The above test sample results one of the value is 22 N/mm^2, i.e. less than (Fck) 25 N/mm^2 as per table-2, it is not accepted. But, comply with table-11, before rejecting.
- As per table-11 Col. (3), this is acceptable for individual Test Result criterion, i.e. the value 22 N/mm^2 is within the limits of >/=Fck-4=21 N/mm^2, then also comply with table-11 Col. (2).
- As per table-11 Col. (2), this is acceptable for mean value of 4-consecutive (Non overlapping) test results criterion, i.e. the mean value of above is 29 N/mm^2 is within the limits of >/=Fck+4=29 N/mm^2, and
- Finally, the concrete of all samples accepted.

Case-II: Test sample's results (For 4-samples)

(i) 30 N/mm^2; (26, 30, 34 N/mm2)
(ii) 20N/mm^2; (17, 20, 23 N/mm2)
(iii) 34N/mm^2; (29, 34, 39 N/mm2)
(iv) 29N/mm^2; (25, 29, 33 N/mm2)

- The above test sample results one of the individual value is 20 N/mm^2, i.e. less than (Fck) 25 N/mm^2 as per table-2, it is not accepted. But, comply with table-11, before rejecting.
- As per table-11 Col. (3), this is also not acceptable for individual Test Result criterion, i.e. the value 20 N/mm^2 is out of the limits of >/=Fck-4=21 N/mm^2, then also comply with table-11 Col. (2).
- As per table-11 Col. (2), this is also not acceptable for mean value of 4-consecutive (Non overlapping) test results criterion, i.e. the mean value of above is 28.25 N/mm^2 is out of the limits of >/=Fck+4=29 N/mm^2, and
- Finally, the concrete of sample (ii) is not-accepted.

Case-III: Test sample's results (For 4-samples)

(i) 33N/mm^2; (28.5, 33, 37.5 N/mm2)
(ii) 21N/mm^2; (18, 21, 24 N/mm2)
(iii) 22N/mm^2; (19.5, 22, 24.5 N/mm2)
(iv) 38N/mm^2; (37, 38, 39 N/mm2)

- The above test sample results two of the individual values are 21 N/mm^2& 22 N/mm^2, i.e. less than (Fck) 25 N/mm^2 as per table-2, it is not accepted. But, comply with table-11, before rejecting.
- As per table-11 Col. (3), this is acceptable for individual Test Result criterion, i.e. the values are 21 &22 N/mm^2 is within the limits of >/=Fck-4=21 N/mm^2, then also comply with table-11 Col. (2).
- As per table-11 Col. (2), this is not acceptable for mean value of 4-consecutive (Non overlapping) test results criterion, i.e. the mean value of above is 28.5 N/mm^2 is out of the limits of >/=Fck+4=29 N/mm^2, and
- Finally, the concrete of samples (ii) & (iii) are not-accepted.

Case-IV: Test sample's results (For 4-samples)

(i) 33N/mm^2; (28.5, 33, 37.5 N/mm2)
(ii) 23N/mm^2; (20, 23, 26 N/mm2)
(iii) 24N/mm^2; (20.5, 24, 27.5 N/mm2)
(iv) 39N/mm^2; (38.5, 39, 39.5 N/mm2)

- The above test sample results, two of the individual values are 23 N/mm^2& 24 N/mm^2, i.e. less than (Fck) 25 N/mm^2 as per table-2, these two are not accepted. But, comply with table-11, before rejecting.
- As per table-11 Col. (3), this is acceptable for both the individual Test Result criterion, i.e. the values are 23 & 24 N/mm^2 is within the limits of >/=Fck-4=21 N/mm^2, then also comply with table-11 Col. (2). (***Note: Here the criterion is that, individual test results only, not both the results).*** But,
- As per table-11 Col. (2), this is acceptable for mean value of 4-consecutive (Non overlapping) test results criterion, i.e. the mean value of above is 29.75 N/mm^2 is within the limits of >/=Fck+4=29 N/mm^2, so
- Finally, with concrete of samples (ii) & (iii), one sample accepted usually higher value sample (iii) and lower value sample (ii) only not-accepted.

Case-V: Test sample's results (For 6-samples; i.e. more than 4-samples)

(i) 30 N/mm^2; (26, 30, 34 N/mm2)
(ii) 22N/mm^2; (19.5, 22, 24.5 N/mm2)
(iii) 35N/mm^2; (31, 35, 39 N/mm2)
(iv) 29N/mm^2; (25, 29, 33 N/mm2)
(v) 30 N/mm^2; (26, 30, 34 N/mm2)
(vi) 23N/mm^2; (20, 23, 26 N/mm2)

a) The above test sample results two of the values are 22 N/mm^2& 23 N/mm^2, i.e. less than (Fck) 25 N/mm^2 as per table-2, two values are not accepted. But, comply with table-11, before rejecting.
b) As per table-11 Col. (3), these are acceptable for individual Test Result criterion, i.e. the value 22 N/mm^2& 23 N/mm^2 are within the limits of >/=Fck-4=21 N/mm^2, then also comply with table-11 Col. (2).
c) As per table-11 Col. (2), this is acceptable for mean value of 4-consecutive Non-overlapping consecutive test results criterion, i.e. consider the mean value of
   - First 4-values is 29 N/mm^2 is within the limits of >/=Fck+4=29 N/mm^2, and balance value (vi) is not accepted. OR
   - Last 4-values is 29.25 N/mm^2 is within the limits of >/=Fck+4=29 N/mm^2, and balance value (ii) is not accepted.
   - It means, don't overlap the mean of any 4-values, for acceptance criteria.
d) Finally, the concrete of one sample is accepted and another one is not-accepted.

Case-VI: Test sample's results (For 4-samples)

(i) 30 N/mm^2; (26, 30, 34 N/mm2)
(ii) 28N/mm^2; (24, 28, 32 N/mm2)
(iii) 28N/mm^2; (24, 28, 32 N/mm2)
(iv) 29N/mm^2; (25, 29, 33 N/mm2)

- The above test sample results, the values are above 25 N/mm^2, i.e. more than (Fck) 25 N/mm^2 as per table-2. (***Note: These all the values are accepted so not required to comply with table-2).*** Even-though, comply with table-11.

- As per table-11 Col. (3), this is acceptable for individual Test Result criterion, i.e. all the values are more than 21 N/mm^2 is within the limits of >/= Fck-4= 21 N/mm^2, also comply with table-11 Col. (2).
- As per table-11 Col. (2), this is acceptable for mean value of 4-consecutive (Non overlapping) test results

criterion, i.e. the mean value of above is 28.75 N/mm^2 is out of the limits of >/=Fck+4=29 N/mm^2, but

- Finally, the concrete of all samples accepted, based on table-2.

Case-VII: Test sample's results (For 1-sample)

(i) 30 N/mm^2; ($_{26, 30, 34 N/mm2}$)

- The above test sample results, the value is above 25 N/mm^2, i.e. more than (Fck) 25 N/mm^2 as per table-2**.** ***(Note: The value is accepted so not required to comply with table-11, because not have 4-values to take mean of them).***
- Finally, the concrete of the sample is accepted, based on table-2.

Case-VIII: Test sample's results (For 3-samples)

(i) 29N/mm^2; ($_{25, 29, 33 N/mm2}$)
(ii) 22N/mm^2; ($_{19.5, 22, 24.5 N/mm2}$)
(iii) 25N/mm^2; ($_{21.5, 25, 28.5 N/mm2}$)

- The above test sample results, the values above 25 N/mm^2 are accepted i.e. more than/equal to (Fck) 25 N/mm^2 as per table-2, and less than Fck-value are not accepted. ***(Note: The values are accepted as per table-2, and not required to comply with table-11, because not have 4-values consecutives to take mean of them).***
- Finally, the concrete of two sample (i) & (iii) are accepted, and sample (ii) not accepted, based on table-2.

4.1 Summary of Case Study

S. No.	Case Study No.	Acceptance as per (Fck) (IS: 456-2000 Table-2)	Acceptance as per (Fck+4) (IS: 456-2000 Table-11)
1	Case-I	Fail	Pass
2	Case-II	Fail	Fail
3	Case-III	Fail	Fail
4	Case-IV	Fail-2 samples	Fail-1 sample
5	Case-V	Fail-2 samples	Fail-1 sample
6	Case-VI	Pass	Not applicable. Based on IS: 456-2000, Table-2 (F_{CK}) fulfilled for all the samples.
7	Case-VII	Pass	-Do-
8	Case-VIII	Pass	-Do-

5. Conclusion

The above described case study on non-acceptability of some of the concretes are valid even when we observe that some of the 4-test values are numerically less than the characteristic strength (Fck), indicated by the specified grade of concrete.

In the present case, if consisting of four test sample results, the M25-Grade concrete has the characteristic strength (Fck) of 25N/mm^{2}for less-than 4-nos of consecutive values. And it is seen that each of the test results has to be more than or equal to 21 N/mm^2 the criterion given in Column (3) of Table 11 of IS: 456-2000, it should be recognized here that, the test sample's individual test results of any concrete sample. The sample's average needs to be checked against the criterion given in Column (2) of Table 11 of IS: 456-2000.

In addition to above description. . . .
The cement required quantity (Min.) for M25-grade is 300-kgs /m^3, as per IS: 456-2000, Table-5. (Annexure-1, Attached for same).

The minimum recommended grade of concrete for Reinforcement-works is M20 as per IS: 456-2000, point e, at Page No.1, of IS code. (Annexure-2, Attached for same).

Notes:-

a) Here, it is described only on sampling, complying for acceptance criteria of concrete, with case-study.
b) The Process of concrete, mix design, testing procedures etc. are not discussed here.
c) In this paper, the total description as per the IS: 456-2000, 4th Rev., Including amend. No.1 and 2, latest amends (if any) not described here.

Annexure 1
Table-5 of IS: 456-200, The Cement required quantity (Min.) for various-grades of concrete.

Table 5 Minimum Cement Content, Maximum Water-Cement Ratio and Minimum Grade of Concrete for Different Exposures with Normal Weight Aggregates of 20 mm Nominal Maximum Size

(Clauses 6.1.2, 8.2.4.1 *and* 9.1.2)

Sl No.	Exposure	Plain Concrete			Reinforced Concrete		
		Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete	Minimum Cement Content kg/m^3	Maximum Free Water-Cement Ratio	Minimum Grade of Concrete
1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	Mild	220	0.60	–	300	0.55	M 20
ii)	Moderate	240	0.60	M 15	300	0.50	M 25
iii)	Severe	250	0.50	M 20	320	0.45	M 30
iv)	Very severe	260	0.45	M 20	340	0.45	M 35
v)	Extreme	280	0.40	M 25	360	0.40	M 40

NOTES

1 Cement content prescribed in this table is irrespective of the grades of cement and it is inclusive of additions mentioned in 5.2. The additions such as fly ash or ground granulated blast furnace slag may be taken into account in the concrete composition with respect to the cement content and water-cement ratio if the suitability is established and as long as the maximum amounts taken into account do not exceed the limit of pozzolona and slag specified in IS 1489 (Part 1) and IS 455 respectively.

2 Minimum grade for plain concrete under mild exposure condition is not specified.

(Respective Screen Short: of IS: 456-2000)

Annexure-2

The minimum recommended grade of concrete for reinforcement works is M20 asper IS: 456-2000, point-e), at Page No.1 of IS code.

Some of the significant changes incorporated in Section 2 are as follows:

a) All the three grades of ordinary Portland cement, namely 33 grade, 43 grade and 53 grade and sulphate resisting Portland cement have been included in the list of types of cement used (in addition to other types of cement).

b) The permissible limits for solids in water have been modified keeping in view the durability requirements.

c) The clause on admixtures has been modified in view of the availability of new types of admixtures including superplasticizers.

d) In Table 2 'Grades of Concrete', grades higher than M 40 have been included.

e) It has been recommended that minimum grade of concrete shall be not less than M 20 in reinforced concrete work (*see also* **6.1.3**).

f) The formula for estimation of modulus of elasticity of concrete has been revised.

g) In the absence of proper correlation between compacting factor, vee-bee time and slump, workability has now been specified only in terms of slump in line with the provisions in BS 5328 (Parts 1 to 4).

(Respective Screen Short: of IS: 456-2000)

References

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Author Profile

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