Technical Note No: 11

Sub: APRR Project: **Testing of Cement Concrete Cubes/ Cores – Acceptance Criteria of Cement Concrete works for structural and PQC works – Communicating – Reg**.

Ref: Inspection of works and verification of QC registers produced by PIUs in 12 Districts.

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1. Background: During inspections of APRRP works, the QC registers prepared by the PIU Engineers are verified about the test results and data entered by them are in accordance with the standards stipulated as per MoRD or not. During scrutiny of results posted in the QC registers some of the parameters pertaining to Cement Concrete works are not matching with the codal specifications in respect of 28 days cube strength and core strength values. The following deficiencies are noticed about the cube strength values of Cement Concrete both for CC Pavements and other CC works.

i) Most of the PIUs are showing the average 28 days compressive strength of cubes far below the required values as per IS:456-2000 (Reaffirm 2005) and Amendments there on. For example, for M30 grade concrete, average 28 days compressive strength of group of cubes is observed as 31 or 32 **N/mm²** as against the required value of **35 N/mm² for structural concrete** works.

ii) In respect of Cores extracted from hardened concrete some of the V&QC EEs are insisting the PIUs that 85% of equalent 28 day's Cube strength for all the individual cores instead of average strength of cores, which is contrary to the guidelines contained in MoRD and IS:516-2018.

Hence there is a necessity to create awareness among the field staff and Quality control wing staff based on latest specifications as per IS codes to follow at the time of testing. If the test results of the concrete work are not satisfying the codal provisions based on the results mentioned in the QC registers by PIUs, the work will be automatically rejected without further investigation by external inspecting agencies. The IS / IRC/ MoRD specifications and guidelines are narrated hereunder for guidance.

2. Acceptance Criteria of hardened concrete for structural works: as per IS 456-2000 (Reaffirmed 2005) and amendments thereon.

2.1 Acceptance Criteria

2.2 Compressive Strength

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

a) The Mean Strength determined from any Group of 4 Consecutive test results shall be **≥ (f_{ck} + 0.825 x SD) or (f_{ck} +3) N/mm² whichever is greater as per col 2 of Table 11 of IS:456.**

b) Any individual test result shall be **≥ (f_{ck}-3) N/mm²** as per col 3 of Table 11 of IS:456.

Table 8 (IS:456): Assumed Standard Deviation (SD) (Clause 9.2.4.2 and Table 11 of IS:456**)**

(Page 23, Table 8) — Substitute the following for the existing table:

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, M 55, M 60	5.0

NOTES

1 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 grading 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 1 N/mm².

2 For grades above M 60, the standard deviation shall be established by actual trials based on assumed proportions, before finalizing the mix.

In this amendment, M55 and M60 has been added in the amended version to the Grade of Concrete. Also note 2 is added.

Table 11 (IS:456): Characteristic Compressive strength compliance Requirement (Clause 16.1 and 16.3 of IS:456)

[Page 30, Table 11 (see also Amendments No. 1 and 3)] — Substitute the following for the existing Table 11:

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
	Min	Min
(1)	(2)	(3)
M 15 and above	≥ f_{ck} + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm²) or f_{ck} + 3 N/mm², whichever is greater	≥ f_{ck} - 3 N/mm²

NOTES

1 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.

2 For concrete of quantity up to 30 m³ (where the number of samples to be taken is less than four as per the frequency of sampling given in 15.2.2), the mean of test results of all such samples shall be f_{ck} + 4 N/mm², minimum and the requirement of minimum individual test results shall be f_{ck} – 2 N/mm², minimum. However, when the number of sample is only one as per 15.2.2, the requirement shall be f_{ck} + 4 N/mm², minimum.

In this amendment, The characteristic compressive strength compliance requirements are revised. In the revision it is same for M15 and above grades. Note 2 is added.

Based on above guidelines the 28 days cube strength of Cement Concrete for different Grades are worked out and given below for **Structural Concrete works.**

Compressive Strength- Acceptance Criteria(Cube Strength)

	34.2	26	24	27
	39.2	40	38	32
	44.2	45	43	37
	54.2	55	53	47
	59.2	60	58	52

Note :If age at the time of testing is more or less than 28 days then correlation between 28 days strength and strength at specified age shall be established

2.3 Flexural Strength (F_{cr}):

$$f_{cr} = 0.7 \sqrt{(f_{ck})}$$

F_{ck}: Characteristic Compressive Strength

When both the following conditions are met the concrete complies with the specified flexural strength.

a) The Mean Strength determined from any Group of 4 Consecutive test results Shall be **≥ (f_{cr}+0.3) N/mm²**

b) Any individual test result shall be **≥ (f_{cr}-0.3) N/mm²**

2.4 Quantity of Concrete:

Represented by Strength Test Results- First and Last Samples Taken. Where mean rate of sampling not specified- Maximum Quantity represented by **4 Consecutive test result shall be limited to 60 Cum.**

3. Testing of Structures

In case of doubt regarding grade of concrete used, either due to poor workmanship or based on results of cube strength tests, compressive strength tests of concrete on the basis of **Core Test** and or load test may be carried out.

3.1 Core Test

The points from which the cores are to be taken and the number of cores required shall be at the discretion of the Engineer-in-charge and shall be representative of the whole of concrete concerned.

In no case, however, shall fewer than three cores be tested. Concrete in the member represented by a core test shall be considered acceptable if the,

a) Avg equivalent cube Strength of cores **is equal to at least 85% of the cube strength of the grade of concrete specified** for the corresponding age and

b) No individual core have a strength less **than 75%**

c) In case the core test results do not satisfy the requirements of Clause 3.1 or where such tests have not been done- Load test may be resorted to as per clause 17.6 of IS:456.

3.2 Extraction of Cores:

3.2.1 Age of Concrete

As a general guideline for grades of concrete up to M25, the concrete shall be at least 14 days old before the cores are taken. For higher grades cores may be taken at an early age.

3.2.2 Location

Cores shall be preferably taken at points not near or at the edges of the concrete joints and reinforcement shall be avoided as for as possible.

3.2.3 Drilling

Unless otherwise specified, the cores shall be drilled perpendicular to the surface in such a manner as not to damage the cores.

3.2.4 Number of Cores

In no case, however, shall fewer than **three cores** be tested.

3.3 Diameter of Cores

The ratio of diameter to the nominal maximum size of aggregate shall be greater than 3. The core diameter shall generally be 100 mm to 150 mm (± 10 mm). with preferred diameter being 100 mm for nominal maximum aggregate size up to 20 mm.

3.3.1 Length/Diameter (l/d) Ratio

The preferred l/d ratio shall be 2, however, l/d values from 1 to 2 may be permitted (the length includes the capping material also).

The preferred length/diameter ratio is **between 1 and 1.2 (as per BS 1881-Part 120)**

In case of using a specimen l/d ratio smaller than 2, the test value of the compressive strength should be corrected corresponding to a value of l/d of 2 obtained from the following equation

$F=0.11N+0.78$

Where

F= Correction Factor, and

N= l/d Ratio

The product of this correction factor and the measured compressive strength for diameter less than 100 mm shall be known as the corrected cylindrical strength, this being the equivalent strength of a cylinder having a height/ diameter ratio of two. The

equivalent cube strength of the concrete shall be determined by multiplying the corrected cylinder strength by 5/4.

Diameter of Core (No. of Cores ≥ 3) mm	*Correction Factor*
75 ± 5	1.03
< 70	1.06

3.4 Compression Test:

Cores may be tested generally in **saturated** condition except if specifically required to be tested in air dry condition. For the saturated condition, soak in water at 27± 30^{c} for a minimum of 40 h and maximum up to 48 h before testing. Cores shall be removed from the water and tested while it is still wet but remove all excess surface grit and water by wiping off.

3.4.1 Placing and Testing:

The core specimen shall be placed vertically in the machine and the loading should be applied without shock and increased continuously at a rate of approximately **14N/mm^2/min** until the core specimen breaks down and no greater load can be sustained.

3.4.2 Calculation:

The measured compressive strength of core specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area, calculated from the mean dimensions of the section and shall be expressed to the nearest N/mm^2

4. Acceptance Criteria for Pavement Quality Concrete (PQC) as per IRC: 15-2017

4.1 Flexural Strength

The concrete will be said to comply with the specified flexural strength when the following conditions are met with:

i) The mean strength determined from any group of 4 consecutive samples

(each sample containing 3 beam specimens i.e., 4 x 3 =12 beam specimens) at 28 days should exceed the specified characteristic flexural strength **by at least 0.3 MPa.**

ii) The strength of any sample is not less than the specified characteristic flexural strength **minus 0.1 MPa.**

Specimen

For Example: For M 40 Gr Concrete

Flexural Strength

1) For average of 12 Beams ≥ f_{cr}+0.3N/mm^2

≥4.5+0.3=4.8N/mm^2

2) Individual beam flexure strength not less than 4.5-0.1=4.4 N/mm^2

4.2 Compressive Strength*

When both the following conditions are met the concrete complies with the specified compressive strength:

i) The mean strength determined from any group of 4 consecutive samples (4 x 3 = 12 cube specimens) at 28 days should exceed the specified characteristic compressive strength **by 3 MPa.**

ii) The strength of any sample is not less than the specified characteristic compressive strength **minus 1 MPa.**

(* Applicable for small projects, where design is based on Compressive Strength).

For Example: For **M 30 Gr** Concrete Compressive strength

1) For average of 12 cubes ≥ f_{ck}+3N/mm^2 ≥ 30+3**= 33 N/mm^2**

2) Individual Cube not less than 30-1**= 29 N/mm^2.**

5. Quality Control:

Core should be cut where quality of concrete is **suspected** at the rate of **2 cores for every 150 cum of concrete**

5.1 Size of Core: - Dia not less than 150mm, depth-300mm

5.2 Strength: - Not less than 0.8x0.85 times the corresponding **f_{ck}** of the cubes where the height to diameter ratio of the cores is two.

Where H/D ration is between 1 and 2 correction multiplying factor shall be apply

f=0.11n +0.78

Where, f= correction factor

n=height to diameter ratio

OR from the following graph.

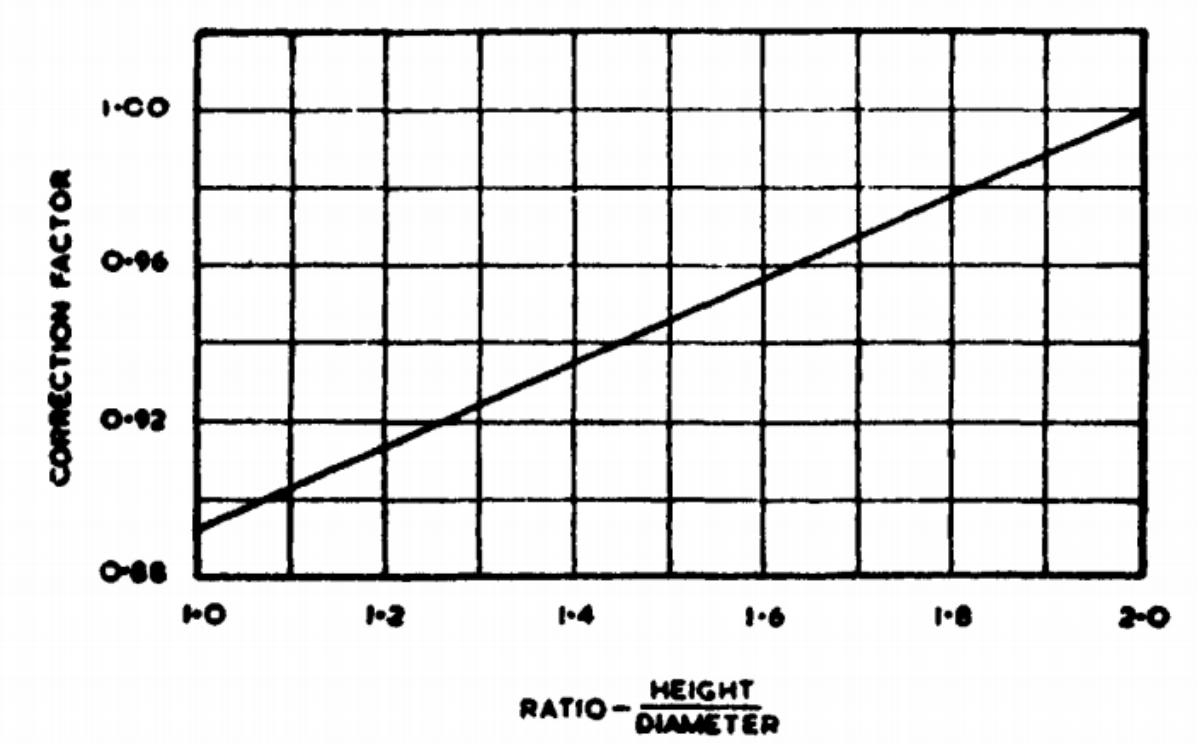

FIG 1 CORRECTION FACTOR FOR HEIGHT/DIAMETER RATIO OF A CORE

5.3 If however, the tests on cores also confirm that the concrete is not satisfying the strength requirements, then the concrete corresponding to the area from which the cores were cut should be replaced. i.e., at least over an area extending between two transverse joints where the defect could be isolated or over larger area. If necessary, as assessed by additional cores and their test results.

If approved by Engineer FWD test may be performed for assessment of the pavement.

5.4 Any concrete that fails to meet the strength requirement shall be removed and replaced at Contractor's expense.

6. In-situ Density

The density of the compacted concrete shall be such that the total air voids are not more than **3 per cent** (3 cores of minimum 150 mm diameter taken from trial length and first two km length of the pavement)

6.1 Cores removed from the main carriageway shall be reinstated with compacted concrete mix (of same design mix) used for pavement works. Before filling the fine mix, the sides shall be hacked and cleaned with water. Thereafter, cement-sand slurry shall be applied to the sides just prior to Filling the concrete mix.

7. Acceptance Criteria for Cracked Concrete Slabs

Concrete slabs may develop cracks of min or to serious nature unless appropriate precautions are taken to prevent their occurrence either during the construction phase or post-construction period. Cracks can appear generally due to the following reasons:

(a) Plastic shrinkage of concrete surface due to rapid loss of moisture
(b) Drying shrinkage
(c) High wind velocity associated with low humidity
(d) High ambient temperature
(e) Delayed sawing of joints
(f) Rough and uneven surface of the base on which concrete slabs are constructed
(g) Combination of the above factors

7.1 The slabs with full depth cracks are totally unacceptable as it amounts to structural failure. Besides, other cracks which are deep and are likely to progress in depth with time are also to be considered as serious in nature. Fine crazy cracks however, are not serious.

7.2 An acceptance criterion for cracked concrete slabs are: The acceptance/rejection criteria of cracked slab are as follows (**Clause 1501.26 of MoRD 2014):**

(i) The length of single crack in any panel shall be not more than 1500 mm, even though its depth is less than half of the slab depth.
(ii) The cumulative length of cracks with depth of crack less than half the depth of slab in a panel shall be not more than 2000 mm.
(iii) Slabs with cracks which are penetrating to more than half of the slab depth shall not be accepted. The same shall be removed and replaced by the contractor at his cost.

7.3 Acceptance criteria in Quality (1501.26 of MoRD)

Tolerance for surface Regularity, Level, Thickness and Strength:

i) Surface Regularity: ± 6mm in transverse direction and ± 7 mm in longitudinal direction when measured with 3 m straight edge.
ii) Tolerance Level: +5 mm and -6 mm (up to-8 mm at 0 to 0.3 m from the edge)
iii) Thickness: ± 10 mm.

7.4 Measurement for payment (Clause 1501.27 of MoRD):

No additional payment shall be made for extra thickness of the slab. Deficiency in thickness **up to 5 mm** and in not more than **three panels** continuously will be considered within tolerance limit and **full payment** will be made.

For determining thickness, a length 500 m will be considered as a 'lot'. This may be constructed even in more than 1 day. Part there of (500 m) shall also be considered as a lot.

KDR 20/7/21

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References:

1) MoRD: 2014
2) IRC: SP:62-2014: Guidelines for design and construction of Cement Concrete Pavements for Low Volume Roads (First Revision)
3) IRC:15-2017: Code of practice for Construction of Jointed Plain Concrete Pavements (Fifth Revision)
4) IS:456-2000(Reaffirmed 2005) and Amendment No:4 (May 2013): Plain and Reinforced Concrete – Code of Practice.
5) BS 1881-Part 120- Testing concrete.
6) IS:1199 (Part I)-2018- Method of Sampling and Analysis of Concrete.
7) IS:516 (Part-4)- 2018: Hardened Concrete - Method of Test- Sampling, Preparation and Testing of Concrete Cores.