Suggested quality assurance measures at major project sites involving concrete construction

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Site Engineers often consider that responsibility of assurance of quality in construction at a project site wrests only with Quality Control Engineer and his team which is misleading. In this paper it has been explained in detail how each and every staff in concerned departments of the Contractor including Survey, Materials Management and Safety as a team has important role in quality assurance of the finished work.

A. Quality Control and Quality Assurance in ISO [1] context.

i. Quality Control (QC): Operational techniques and activities that are used to fulfill requirements for quality.

In a project site QC activities are normally performed in site laboratory by a team of personnel known as QC team with suitable experience and training on the subject and using various equipment suited to different tests involved. Where facilities for certain tests are non-existent in site laboratory such samples are sent for test in external approved laboratory.

ii. Quality Assurance (QA): All the planned and systematic activities implemented within the quality system and demonstrated as needed, to provide adequate confidence that an entity will fulfill requirements for quality.

Thus QA is the collective responsibility of the entire project team of the Contractor involved in all aspects of execution of the project starting from initial survey till completion and handing over of the project.

iii. Role of In-charge of Quality Assurance (ICQA)

Role of ICQA is ideally that of co-ordinator for both quality control and quality assurance in the project. Being stationed at project site ICQA functions under the Project Manager (PM) but he should be under administrative control of Head of QC/QA at Registered Office (RO) / Zonal Office (ZO), who may be consulted by ICQA if needed to sort out any special problem on QC/QA matters under intimation to PM.

In discharging his duties ICQA would take necessary help from QC team and any other site staff with the consent of PM.

B. Major Responsibilities of ICQA and QA team at site

1. ICQA at project site would directly report to PM for all site matters and in latter's absence would report to PM's authorised representative.

In case there is a difference in opinion between ICQA and the PM on any QC/QA related issue which could not be resolved over discussions, the same shall be referred by PM to the Project Co-ordinator (PC) at Registered Office (RO)/ Z.O but if still unresolved it shall be referred by PM to Head of QC/QA Division at R.O. with a copy to ICQA. In no case shall such contentious issues be suppressed by the PM.

2. ICQA would be involved in preparation of the following on arrival at site in discussion with PM:

i. At some project sites only Inspection .and Test Plan (ITP) is required to be submitted for approval of Client. The same would be prepared by ICQA on the basis of contract requirements for the project. A copy of ITP covering major items of work would be prepared and got approved by the client on the basis of Tests and Standards of Acceptance included in contract specifications.

However on the basis of Client's direction it may be required to submit Field Quality Plan (FQP) (sometimes called as Project Quality Plan or Quality Assurance Plan) following ISO format on the basis of contract requirements after a thorough study of the same which shall be complied with.

All tests shall be carried out at site laboratory and / or external approved laboratory as per ITP / FQP approved by Client and their record maintained in approved formats.

ii. List of testing equipment required at site laboratory on basis of tests included as per terms of contract.

iii. Requirement of Quality Control (QC) staff for single shift/ extended shift/ round-the-clock work at site as applicable

iv. Hard copy of one set of regular use codes relevant to the contract is kept in a box file for reference of all concerned persons.

3. It would be responsibility of ICQA to prepare monthly QA report in an approved format and send to Head of QC/QA Division at R.O. / Z.O. In case at a newly opened site such format is not readily available it would be onus on ICQA to ask for a copy of such standard format from QC/QA Deptt. at R.O. through e-mail or letter.

The idea of receiving such reports in centralized in-house QC/QA Deptt. at R.O. / Z.O. would be to monitor QC/QA activities at running projects from R.O/Z.O and extend help where needed. No tampered / cooked data shall be included in reports.

4. ICQA would prepare QC organization chart with detailed duty allocation of each staff in QC team at site and send a copy to Head of QC/QA Div. at R.O. / Z.O. with updating as and when done.

5. PM would be approached by ICQA to provide a few Field Assistants (FA) say 4 to 10 Nos. through Piece Rate Workers (PRWs) / Sub-contractors depending on size of project, No. of batching plants, total working hours per day and locations from where samples are to be taken at a time etc. These FAs should preferably have some basic education and would be properly trained by ICQA and his QC team in various field duties, sample collection and tests etc. Attempt would be made by ICQA to persuade PRWs / Sub-contractors through PM to depute the same set of personnel among their workers to work as FAs in the interest of maintaining good QA at site. FAs would be utilized on rotation basis so that everyone is kept involved and has some experience for better performance than raw hands.

6. During concreting a set of 6 (six) Nos. cubes shall be taken from the same dumper / transit mixer load of concrete as per codal requirement [2,3]. In case of pile concreting also same practice shall be followed and taking one cube per pile sometimes insisted by Client shall be discouraged.

7. In case Client decides to get tested in an external approved laboratory only set of cubes available at site for 28 days' test the same shall be resisted. Because if such test results do not satisfy Acceptance Criteria due to improper calibration of press gauge in external lab it would lead to a helpless situation. Only when an extra set of cubes is available or made for the purpose such test can be conducted.

8. Daily record of temperature of concrete [2] of various grades used in project satisfying contract requirements shall be maintained in a separate Register or in a separate column in Cube Test Register.

9. ICQA shall be responsible for preparation of the following:

a) Control Chart for tests in the Format as per QMS documents and the same shall be updated on monthly basis to keep a track of tests due to be conducted and those actually conducted which shall not be less than the Nos. due.

b) Record of all tests conducted at site either in QMS Format where available or in the format issued by Client shall be maintained for future reference till completion of the project or in register where such formats do not exist but never in scribbling pad.

10. At site a file shall be maintained by ICQA containing list of all reference codes and those available at site. A hard copy of codes of regular use shall be kept in the file for reference of site staff instead of keeping all such codes in soft copy in computer.

11. 'Verified and Reviewed' stamp shall be collected by ICQA from PM and used in all test results and calibration certificates from manufacturers and external approved laboratories. Such test results shall be kept in file only after proper verification.

The same shall be signed by ICQA only and not by any of his deputies.

12. ICQA at site shall ensure that

a) In Automatic Batching Plants installed at site memory and printer are incorporated to check in particular details of mix proportions used in concrete in case of adverse results noticed during test on concrete after 7/28 days. If these accessories are missing the same shall be brought to notice of the PM by ICQA.

b) In-house calibration of batching plant [2] should be done preferably once in a month unless shorter interval is specified in contract and record of such calibration shall be maintained.

c) In case there is acute shortage of space for installation of concrete batching plant within site it is to be verified if separate bins for storage of materials can be maintained for proper functioning, using skip. If not, in discussion with PM, ready mix concrete would be procured and no batching plant would be installed at such cramped site.

13. i. Use of Polycarboxylate Ether (PCE) based chemical admixture should be made judiciously by ICQA keeping in mind that chemical reaction with it is far more complex than with Melamine or Naptha based admixture. Only in cases where slump of concrete is to be retained for 2 hours or more and / or high grade concrete i.e. M50 and above is to be produced such costly admixture may be used only after several trials for dosage, compatibility and desired strength etc.

ii. In order to sell cheaper quality PCE based admixture with low Dry Material Content (DMC) around 18 p.c. against normal DMC 36 p.c. & above at a much higher price than Naptha based admixtures some suppliers are not intentionally producing right quality of Naptha based admixtures. Using such sub-standard product concrete sometimes does not set before 18 to 20 hours while the same admixtures had served the purpose satisfactorily for so many years in the past before introduction of PCE based admixtures in the market in recent years.

To discourage such practice the supplier should be changed as first option. If such change is not possible due to contract limitations it must be insisted that the low cost PCE based admixture satisfies all test criteria as per IS 9103 – latest rev [4].

iii. Re-dosing of chemical admixture is permitted as per international practice. However with the anticipated higher dosing upto 20 to 25 p.c. extra over design mix requirement trial cubes shall be cast beforehand and strength of concrete shall be checked.

iv. ICQA is to ensure that Microsilica / Silica Fume is considered for use only in concrete of grade M60 and above unless it is mandatory to be used as per contract condition in concrete of lesser grade from point of view of durability or other special reasons. Proper trials should in any case be made with the product to check compatibility with other ingredients proposed to be used in concrete, ease of handling and feeding in decided sequence in the batching plant installed. Microsilica is almost 100 times finer than cement and is required to be handled carefully. For best results it should be added in the mixer next to addition of coarse aggregates and before addition of sand and other ingredients.

14. a. Mix design for Concrete as per specified relevant codes shall be prepared at site by ICQA and his team and trials conducted to establish designed mixes [2,5]. However, if site laboratory is not set-up and work has to be commenced, mix designs may be prepared through engineering college / approved laboratory by sending samples to them materials proposed to be used. Again trials shall be made at site to verify the test results of various mixes as per design before their acceptance.

b. Additional set of 3 Nos. concrete cubes shall be taken daily in the beginning for 10 consecutive days (after mix is satisfactorily established) for test in 56 days and 91 days to establish p.c. gain in strength of concrete compared to 28 days strength particularly for concrete with Portland Pozzolana Cement (PPC) (or OPC mixed with flyash at Batching Plant) and for concrete of grade M30 and higher. In such trials Client's representive should also be made a party.

c. It is noticed from some test results on OPC of 43 and 53 grade in particular that due to increase of C_3S content from usual 42 p.c. to around 58 p.c. and corresponding decrease of C_2S content from 28 p.c. to around 12-13 p.c. during manufacture 7 days' strength of relevant concrete is almost equal to 28 days' strength i.e. increase in strength in 28 days and beyond is marginal over 7 days' strength. This aspect shall be checked by cement mortar test at site laboratory in the beginning for the first lot of all cement received at site and periodically thereafter. Particularly when a new brand or source of cement is proposed to be used this trial is a must.

In case of doubt sample of cement shall be sent for chemical analysis in external approved laboratory.

d. ICQA shall ensure determination of Chloride and Sulphate content in concrete on the basis of chloride and sulphate content in various ingredients used in concrete which is a basic requirement as /Bureau of Indian Standards(BIS) [2] and Ministry of Road Transport and Highways(MORTH) Specifications [6]. Record of test results shall be maintained and repeat test shall be conducted every year in case of long duration projects and with change of source, if any. Results shall be verified against Acceptable Limits in relevant codes. A copy of such calculations shall be sent to Head of QA/QC Dept at R.O. / Z.O. for verification and record.

e. In case of duration of project for more than a year and with change of source of materials ICQA shall ensure that samples of all ingredient materials are tested in approved external laboratory apart from tests in the beginning of the project. Record shall be maintained of such test results.

f. Suppliers at site shall be persuaded to furnish complete test results of cement (incl. 28 days results), flyash and construction chemicals as per relevant code requirements. Incomplete results shall not be kept in record.

g. In case of construction chemicals the manufacturer shall be asked to mention target/stated values of different properties of admixtures in MTC for checking if the observed values during test on the particular batch of manufacture comply with requirements of IS 9103 vis-à-vis target / stated values [4].

h. In case cube moulds are old and worn out after prolonged use and their proper setting to required shape and size cannot be done even after cleaning such moulds shall be discarded to avoid erroneous results. Checking of moulds for right angle at all corners using a steel right angle of suitable size, dimensions of all sides and depth using a calibrated steel scale and correct match of top surface at joints and also at corners shall be done to satisfaction [3].

i) While sending samples for test in approved external laboratory only Identification (ID) mark / No. should be given with type such as OPC, PPC, PSC etc. for cement and TMT bar for reinforcement but not any Make or Grade of material. Test length for bars shall be cut between consecutive embossings normally appearing on the bar surface as per BIS norms. In view of reported malpractices followed by some testing laboratories these precautionary measures are suggested.

15. i) Agency for testing and calibration should preferably have accreditation of National Accreditation Bureau for Laboratories (NABL). Certificate of NABL with Annexures for verification of scope of accreditation shall be asked from the laboratory. Where such laboratory is not available Govt. Engineering colleges, CSIR approved laboratories, Central Soils and Materials Research Station (CSMRS),New Delhi, National Test House, National Council for Cement and Building Materials (NCCBM), Ballavgarh, Haryana, Central Road Research Institute (CRRI) and such other institutions should preferably be engaged.

ii) Copy of test results of reference equipment used in calibration of testing equipment shall be asked from testing agencies to make the report complete.

16. In case Cement, Reinforcement steel, Structural steel, Concrete or any other material supplied by Client fails to satisfy Acceptance Criteria in test in in-house or external laboratory the same shall be brought to the notice of Client by PM immediately and before further use of such material.

17. In case of failed test results of concrete cubes or otherwise Rebound Hammer Test when recommended as Non-destructive Test (NDT) should be accompanied by Ultrasonic Pulse Velocity (UPV) Test [2] to provide an estimate of the relative strength and overall quality of concrete in the structures and also help in deciding whether more rigorous tests like load testing or core drilling at selected locations are required. If the quality of concrete is assessed to be 'excellent' or 'good' by UPV method, only then the compressive strength is assessed from Rebound Hammer indices and this is taken as indicative of the strength of concrete in entire cross-section of the concrete member. Rebound Hammer calibration curve may be further cross-checked by testing against concrete cubes with known strengths.

18. It is to be ensured by ICQA that shuttering oil of proper quality and non-staining type is used for ease of de-shuttering of formwork and in no case burnt mobil oil or construction chemical shall be used.

19. All tests for Bentonite suspension recommended in relevant IS Code for Bored Cast-in-situ piles [7] should be conducted at site and record maintained. Necessary testing equipments should be ordered in the beginning for the purpose and used at site. For dry bentonite powder separate test shall be conducted at regular intervals in external laboratory apart from MTC received from suppliers for each lot. Furnishing of Manufacturer's Test Certificate shall be insisted from suppliers.

20. It is to be ensured by ICQA that MTCs for cement, flyash, bentonite powder, GGBS, construction chemicals, reinforcement bars and structural steel sections have been

signed by Quality control in-charge or Chemist of the relevant laboratory with name and designation printed on the certificate and not by only Authorised Signatory. In case of violation the matter shall be promptly reported to the PM for his necessary action with supplier for compliance. 'Claim by supplier that the report has been generated by system and hence signature is not required' would not be accepted.

21. Where Permeability test of concrete is included in scope of contract the same shall be undertaken in site laboratory by mobilising necessary equipment if the No. of tests involved is substantial. However, if only a few tests are to be conducted mould should be procured and concrete sample after curing should be sent to approved external laboratory for test where such facilities are available. Results of such tests shall be kept in record.

22. a. It is to be ensured by ICQA that all testing equipment received at site are in working order with latest calibration certificate. In case anyone of them is found defective, old and worn out particularly from used lot transferred from a closed site and is not in workable condition the same shall be brought to the notice of PM for rejection and replacement by new ones.

b. While ordering for testing equipment for site laboratory only those required for tests in scope of work shall be included in indent.

23. In case of tests e.g. Radiographic tests, Schmidt hammer test, Pile integrity tests, Ultrasonic Pulse Velocity test and Core test etc. done through outsourced agencies ICQA shall verify and ensure that the agencies have requisite qualifications wrt. past experience, suitable calibrated equipments, and qualified people to undertake the job.

24. Supply order on Ready-mix Concrete (RMC) Suppliers

Immaturity and irresponsibility have been noticed in performance of RMC suppliers in several cases. Due to exercise of poor control in the plant, concrete meant for one site has been sent to another, grade of concrete received is different from that ordered, 28 days' concrete strength fails to satisfy Acceptance Criteria etc. putting the main contractor in embarrassing situation.

In view of such occurrences while placing order for supply of RMC to a reputed supplier the following should be mentioned in Terms and Conditions of supply so that the RMC supplier is also held responsible for breach of contract:

i) Acceptance Criteria of concrete as per IS 456 [2] or MORTH Specs [6]. or Indian Railway Standard (IRS) to be intimated to the supplier.

ii) Mix design details for different grades of concrete proposed by RMC supplier complying specification requirement are subject to approval of Client.

ii) Results of tests on all ingredients used in concrete as per relevant standards i.e. BIS, MORTH Specs., IRS or Field Quality Plan approved by Client (a copy shall be enclosed) to be submitted by RMC supplier.

iv) Chloride and sulphate content in concrete on the basis of chloride and sulphate content in all ingredients of concrete to be confirmed by RMC supplier with calculations and the same should be within limits as per relevant specifications.

v) In case test results on cubes from concrete supplied by RMC supplier do not satisfy Acceptance Criteria all costs pertaining to subsequent Non-destructive Tests (NDT), rectification, replacement, idle charges and liquidated damages imposed, if any on this account shall be reimbursed to the Co. by the RMC supplier.

25. i. Certificate from local Pollution Control Board for operation of Concrete Batching Plant should be obtained for maximum estimated output per day / month basis as per local norms.

ii. Permission from local Ground Water Control Board should be taken if ground water is pumped for use in construction or for drinking purpose particularly in Notified Areas in metropolitan cities.

26. a. Keep internal record of samples i.e. Batch / Week No., Challan No. for cement, fly ash, microsilica, chemical admixtures etc. sent to external approved laboratory for testing in order to trace the same particularly in case test results are not found satisfactory.

b. In case of reinforcement bars sent for testing in external approved laboratory keep a second set of samples in site laboratory so that in case results of tests of first set are reported to be not satisfactory the second set may be sent for test as allowed as per stipulations of the relevant code i.e. IS 1786 [8].

27. Purchase and Store

a. In case of all materials received in site store First In First Out (FIFO) principle shall be strictly followed.

b. Shelf life mentioned in case of construction chemicals, paint, curing compound etc. should be strictly observed. Accordingly materials having specified shelf life should be ordered in phases in limited quantities which can be used up before shelf life is expired.

c. Timber, PVC pipes, construction chemicals etc. whose properties are likely to be affected due to direct sunlight should be stored in sheds.

d. In case of supply of cement, reinforcement bars or structural steel sections through dealers/stockists authentication must be obtained from these agencies in their letter head and signed by Proprietor / Director / General Manager that against the batch of production by the main Producer / Manufacturer (by name) for which Manufacturer's Test Certificate (MTC) is enclosed, ____ tonnes have been supplied to (Name of the Contractor), _____ site.

This is required to ensure that the right material is being received at site against the certificate and not the satisfactory certificate only.

e. Provision of storage facilities for all major materials shall be checked by ICQA and any deficiency noticed shall be brought to knowledge of PM for early rectification.

A sample of standard storage of cement is shown in Figure 1

f. In supply orders for reinforcement bars, structural steel sections and H. T. Strands in particular permissible manufacturing tolerance as per relevant BIS code shall be mentioned apart from variation allowed in ordered quantity. Similarly variation allowed in ordered quantity for cement, fly ash, GGBS, bentonite powder etc shall be mentioned alongwith permissible weight variation in bags / bulker and in case of shortfall beyond limit payment would be made on the basis of actual quantities received.

Figure 1. Storage of bagged cement (Courtesy: Concrete practice by cement & concrete association, UK) [10]

g. Care shall be taken by ICQA that bins for storage of coarse aggregates and sand are properly built with paving and drainage facilities to avoid contamination of aggregates and sand with soil, dust and other deleterious materials during movement of heavy vehicles carrying aggregates or concrete.

h. Periodic check for unit weight of reinforcement bars, H. T. strands and rolled steel sections procured by the Contractor or supplied by Client received at site shall be done to ascertain if rolling margin is within specified tolerance limits since payment by Client / reconciliation is done on unit wt/ meter length basis.

Poor quality of H.T. strands may lead to snapping of cable during stressing as shown in Figure 2.

i Periodic reconciliation of concrete quantity received from RMC Suppliers or produced in site batching plant shall be made against theoretical quantity billed and considered for payment by Client to ascertain variation between the two quantities .

j. In supply order for bentonite powder for execution of bored piling work in order to make the specification complete mention 'Bentonite powder manufactured to IS 6186 – 1986 (latest revision) and to satisfy requirement of stabilisation of pile bore as per IS 2911 (Part 1) Sec. 2' – latest revision [7].

Figure 2. Poor quality of H.T. strands

k. Selection of quarry / source of supply of stonechips / stone metal and sand shall be done in advance. No dead stone or hand broken metal shall be used in construction work. Los Angeles Abrasion value, Aggregate Impact value, Flakiness and Elongation Index values shall satisfy the specification requirements for stonechips [9].

l. Correct relevant code with latest amendment / revision No. and / or relevant technical specifications shall be mentioned in P.O.s.

m. In supply order for sand required 'Zone' shall be specified [9] in Purchase Order(P.O).

n. Where 'Royalty payment' is involved in procurement of aggregates (coarse / fine) 'Proof of royalty payment for full quantity of material supplied shall be furnished with each challan' to be included in 'Other Terms' of P.O.

o. Capacity of drum for chemical admixture and supply of drum on returnable basis shall be included in other terms of P.O. for chemical admixture in liquid form.

28. In view of non-uniformity expected in mixing of cement / sand mortar by hand mixing which may result in disputes with Client attempt should be made to mix cement and sand for preparation of mortar for masonry as well as plastering work using a standard mechanical mixer of suitable size.

29. Particularly where locally available river sand is of finer variety (Zone IV classification) [9] or where coarse sand for use in concrete is scarce and / or very expensive due to transport from a long distance, high royalty payment etc. attempt shall be made to use crushed/manufactured sand as alternative which is a good if not better substitute for river / pit sand and such use is permitted in relevant BIS Code i.e. IS : 383. The proposal for use of crusher sand/manufactured sand in full or part of total fine aggregate requirement should be given to Client / Consultant in the beginning itself when trial mix design is made with the same and details should be submitted for approval .

30. Even if it is not insisted by Client practice should be followed at site to prepare detailed Work Procedure for major items of work including resource requirement during tenure of contract and get the same approved by Client / Consultant in advance in the interest of the project.

31. a. In projects where construction of foundations (piled or open) is included in scope of Contractor the Client shall be requested to provide a copy of sub-soil investigation report from which chloride and sulphate content in soil and ground water would be checked.

Also in case of fly over and bridge projects where it is mandatory to conduct detailed sub-soil investigation at pier / abutment locations as per contract the scope of such investigation shall include among others test for chloride and sulphate content in soil and ground water.

In view of reported failure of foundation with in-situ reinforced concrete in ground water / soil with high chloride / sulphate content adequate precautions are required to be taken [2].

b. 'Requirement for concrete Exposed to Sulphate Attack' as per Table 4 in IS 456 : 2000 [2] should then be studied properly. Where chloride content is high in soil / ground water Sulphate Resisting Portland cement would not be suitable. In such case Ordinary Portland Cement with increased cover and dense concrete with low water/cement ratio is recommended for use but where chloride content is very high and there is chance of disintegration of in-situ reinforced concrete in such cases precast concrete of high strength should be used so that concrete attains strength before being subject to chloride attack. But where both chloride and sulphate content are high stipulation in Note 7, Table 4 of IS 456 : 2000 [2] should be followed in which case cement of special requirement may have to be ordered.

c. It should be seen from the Sub-soil Investigation Report that recommendations of specialist agency involved in sub-soil investigation are being followed in execution. Otherwise the matter should be brought to the notice of the Client / Consultant.

32. Prevention of cracks in concrete.

It is a very common occurrence in most of the project sites where this phenomenon is normally ignored stating that such cracks are plastic / shrinkage / temperature cracks and not structural cracks, so not harmful. But this argument is baseless and most of these cracks are preventable unless these are due to settlement and / or other structural reasons. Attempt should be made by all Engineers at site to produce crackfree structures in view of serious adverse effect of such cracks due to subsequent ingress of harmful chemicals, moisture and gases prevalent in air and surrounding such structures which would lead to fast deterioration of the structures. Types of cracking normally seen in concrete with their primary cause are shown in the annexure Table A1 and Figure A1 [11]

Bearing in mind that sunrays and surface wind are both equally dangerous in producing cracks on green concrete surface mainly due to evaporation loss, such cracks can

be prevented by adopting one or more of the following measures :

i) Subsequent to finishing of concrete within next 1½ to 2 hours (depending on ambient temperature and / or intensity of surface wind) when surface of concrete has been just dry with no impression appearing when pressed by finger the surface of concrete has to be covered by plastic sheet or hessian cloth. Alternatively curing compound is to be spread where finished area per hour is quite large e.g. PQC in concrete roads to prevent loss of water from green concrete by evaporation during hydration stage.

Sprinkle water on hessian cloth surface after sometime when final set of concrete is started i.e. when a person can stand on the concrete surface.

Also to prevent washout of green concrete before or after compaction and finishing during rains enough covering material shall be mobilised for the purpose.

ii) Finishing gang comprising mason / helper and at least one Engineer / Supervisor should be kept at site at least for 1½ to 2 hours after finishing of concrete surface to check development of any crack and arrange for covering of concrete surface even if finishing is completed at night. If any crack is developed during this period when concrete is still green final finishing on the concrete surface using steel trowel should be done to remove such cracks.

Also if any excess bleeding water gets accumulated on top after finishing of surface the same shall be soaked using sponge or hessian cloth and not allowed to evaporate on its own nor any dry cement be applied at this stage.

When surface gets dry finishing should be done for the second time.

iii. It should be the duty of the Engineer / Supervisor attending concreting previous day or night to inspect the concrete surface for any visible cracks next morning particularly before curing is started. If after taking all precautions still some fine cracks have developed such areas would be isolated creating barriers with cement / sand mortar normally used for ponding. Then dry cement powder should be pressed by hand on the fine cracks. Such isolated areas would be kept covered for 4 to 6 hours before water curing is started here while in rest of areas of concrete surface curing by ponding water or using wet hessian cloth would be started as per specification.

iv. ICQA would conduct prior inspection of covering and curing arrangement of exposed concrete surface after compaction and finishing and if found inadequate he would bring the same to notice of the Project Manager.

33. Installation of bored cast-in-situ piles / precast concrete piles

a. Right length of Kelly bar for installation of bored cast-in-situ pile of designed length shall be mobilised with Hydraulic Rig.

b. Inspection of joints in telescopic Kelly bar and between end piece and drilling tool shall be done at predetermined intervals and in case of any doubt so that none of the costly components is lost in the bore during installation of pile.

c. Hydraulic Hammer of required capacity should be mobilised to drive precast concrete / steel sheet piles to avoid fall of hammer through abnormal height causing damage of pile heads.

d. Use pump of adequate capacity for flushing / cleaning of pile bore according to dia and depth of pile. For example during installation of a bored pile 1200 mm dia or more of length 25 m and above it would not be possible to clean base of pile using only 15 H.P. pump. In such case pump of capacity 40 H.P. and above should be mobilised. Also location of pump should be as near the bore as possible to minimise frictional loss in pipe length between pump and the bore location for a very effective cleaning of pile base.

34. a. Capacity of pile founded in compressible / clayey soil

Capacity of pile when founded in compressible / clayey soil should be decided judiciously taking into consideration long term settlement as well since settlement from test load normally applied for 24 to 36 hours may not give the correct picture of extent of total settlement under sustained load in such category of soil. Allowable settlement with type of cladding material used and capacity of piles under group action also should be given due consideration.

b. No bore well for withdrawal of ground water at site shall be located in building area on open / pile foundation to avoid excessive settlement during drawdown of ground water table. Such borewell should be located away from influence zone of drawdown curve in such borewell.

35. Acceptance Criteria as included in relevant section of the contract shall be studied carefully by ICQA and the same shall be incorporated in ITP. In case there is any special criteria deviating from IS 456 / MORTH / Indian Roads

Congress(IRC) Specs included in contract document the same shall be brought to notice of PM.

36. Incomplete Test Results from manufacturers and external laboratories.

It must be ensured that external approved laboratories furnish in test reports accurate results of tests conducted on different materials. Vague recording e.g. chloride content in 20 mm aggregate less than 0.01 p.c. mentioned in one such report is not acceptable. It may mean that the party has not conducted any test and has entered instead arbitrary values. Party should be reminded that payment is made for proper test and for furnishing of accurate result based on the test done and not for such hypothetical values. If however due to limitation of capacity of the testing equipment available with the laboratory accurate result could not be furnished by the agency test should be conducted in an alternate laboratory.

It is not possible to draw any conclusion on value of chloride content in concrete with such data which is a very important parameter for durability of concrete nor such result can be submitted to Client.

37. Spillage of diesel / petrol is to be prohibited on bituminous road.

Action of diesel / petrol on bituminous mix freshly laid or on compacted bituminous macadam / bituminous concrete / asphaltic concrete / mastic asphalt layers is severe and it may sometimes result in disintegration of the mix. Thus spillage of diesel / petrol from running DG set, Vibrating engine, Compactor or any such machine shall be strictly prohibited.

38. In projects where RCC / Hume pipes and RCC manhole covers are specified and the same are procured from outsourced agencies satisfactory test results on all ingredients used in concrete including reinforcements and also for chloride and sulphate content in concrete used in manufacture of RCC pipes and manhole covers shall be obtained from manufacturers for record. The same holds good if manufacture is done by the contractor at site or in plant owned by the contractor.

39. Concrete produced with PPC (or mixing flyash with OPC in Batching Plant) would need curing for more duration [2] preferably 10-14 days against 7 days normal for concrete with OPC in order to gain required strength.

40. Each Transit Mixer load of concrete dispatched from Batching Plant to site(s) of construction should be identified by type of Cement, Admixture (Chemical and Mineral) used particularly when more than one brand of cement / admixture is in use at site. Such details shall also be included in a column created for the purpose or in Remarks Column in the Format for maintaining cube test results which would be of use in case of adverse test results subsequently reported, if any.

41. During concreting of End block in prestressed concrete girder or Pier Segment in case of segmental bridge construction additional care shall be taken in compaction of concrete in this zone in view of congestion of reinforcements, helicals, sheathing, cone etc. so that during subsequent stressing of cables the Anchor Blocks under high pressure are not pushed inside unsound concrete.

A case of unsound concrete in end block of a PSC girder as noticed at a site is shown in Figure 3 and one with good quality concrete is shown in Figure 4.

42. Staging and Formwork

a) No bent, worn out old scaffolding pipes shall be used in staging [6]. Bent pipes in good condition shall be straightened before use.

b) For vertical pipes only Class 'C' MS pipes shall be used while in longitudinal and transverse direction class 'B' pipes may be used.

c) Spacing of horizontal and vertical pipes shall be decided on the basis of vertical load on each vertical pipe and its safe load carrying capacity, height of staging etc. In case of staging height more than 6^{M} and high intensity of loading proposed scheme for staging may be prepared from site, get approved

Figure 3. Unsound concrete in end block of a PSC girder

Figure 4. Good quality concrete in end block of a PSC girder

by design section at R.O and the scheme approved shall be strictly followed at site to avoid any collapse of staging.

One sample of staging meant to carry heavy load from cast-in-situ deck superstructure is shown in Figure 5

b) Formwork shall be removed promptly and not left in place beyond the period required. After removal, formwork shall be stored properly for reuse for desired number of repetitions.

Precast pretensioned girders cast with steel formwork are stacked in yard after curing and before shifting to location are shown in Figure 6.

43. Reinforcements

a. Bar Bending Schedule (BBS) should be done by engineers with past experience and once approved by relevant authority, a copy should be issued to Reinforcement Foreman with instruction to produce a sample of each bent bar and fit the same in prototype (get the same checked). The concerned engineer must check and get any modification if necessary incorporated before starting mass production to avoid unnecessary wastage of time and money.

b. No separate hand written copy of BBS transferred from official printed copy shall be issued to Reinforcement Foreman.

c. Knots in binding wire used for tying of reinforcements should preferably be placed inside and not in clear cover zone which plays an important role in protection of reinforcements from corrosion.

Figure 5. Sample of staging meant to carry heavy load from cast-in-situ deck superstructure

Figure 6. Precast pretensioned girders cast with steel formwork, stacked in yard

d. Chemical analysis of reinforcement bars [8] shall be conducted in external approved laboratory at intervals alongwith test for mechanical properties particularly when during bending of bar, crack is noticed or it breaks. Tests should be conducted before use of such bars in the project irrespective of them being purchased in-house or supplied by client.

e. One set of rings / links shall be tied to column reinforcements just above finished level of slab so that during compaction of concrete the vertical bars are not displaced from desired location warranting joggling / bending of bars. After finishing of slab surface the set of links / rings shall be cleaned of mortar by wire brush before it dries up.

44. Concrete placing and compaction

a. In case of jobs with large No. of repetitions in particular e.g. precasting of segments, launching of girders etc. checklist shall be prepared for various actions involved and these should be closely monitored to avoid complacency which may lead to catastrophe.

b. Precast segments shall not be lifted in the bridge / flyover span for dry matching and further activities if the specified strength in concrete has not been attained.

c. Vibrator Operators shall be trained properly for satisfactory compaction of concrete by vertical immersion of nozzle as shown in Figure 7 (Courtesy: Concrete Practice by Cement & Concrete Association, UK) [10] and also for compaction with long shafts particularly where height of single lift in column / shear wall etc is 2 m or more.

Figure 7. Poker vibrator in use [10]

d. Proper stopper shuttering shall be provided vertically in predetermined construction joints in slab and beams [2] taking precautions to avoid leakage of mortar as far as practicable. Formation of cold joint by leaving uncompacted concrete at such locations shall be avoided.

e. In isolated column footings / pile caps proper compaction of entire concrete including column base must be done before finishing.

45. Survey

a. Precision survey equipment shall be mobilised at sites including total stations at major sites. At piling sites during setting out and installation of piles particularly at single pile and 2–pile groups adequate care shall be taken to avoid high static eccentricity requiring redesign of pile cap and installation of extra piles in extreme cases.

b. In high rise buildings in particular resting on pile foundation or otherwise settlement of foundations shall be monitored jointly with Client's representative at intervals of 2 to 3 months as agreed by marking level on column surface at about 1 m. above raft / footing level. Also tilt of corners of large and tall buildings shall be monitored using precision theodolite / total station.

46. In case at a project site more than one brand of same type of cement (e.g. OPC, PPC, PSC) is used with more than one brand of chemical admixture alongwith any mineral admixture e.g. Fly ash / GGBS / Silica Fume/Rice Husk Ash etc then field trial shall be made with possible permutation of use of each combination of cement, chemical admixture and mineral admixture to check compatibility with respect to slump retention and gain in strength with age of concrete to satisfy contract requirements. Only the combinations with satisfactory results shall be used in the project.

47. In order to achieve proper quality of cement brickwork and plastering detailed work procedure following contract specification shall be prepared and first circulated among concerned site staff and PRWs involved in the works. Then sample panel shall be constructed as per procedure by skilled masons as demonstrated by concerned Site Engineer in various sections before site staff and foremen etc prior to proceeding with mass construction of such work.

48. Safety

Charity should begin at home. Every staff at project site should first be concerned of his own safety. In case any unsafe practice is noticed by any staff attempt shall be made by the same person first in his own capacity to remedy the situation failing which the issue shall be referred out to Safety Officers / Section-in-charge / Project Manager without blaming why Safety Dept did not look into the matter and had not taken action before.

49. Project Managers to note

a. Visit QC laboratory at least once a week to check quality records including adverse results, if any.

b. Sit with QC staff once in a month for 10/15 minutes to discuss problems faced by them, if any and also check their duty allocations to cover entire scope of QC work.

c. Sit once in a fortnight with all Construction Engineers, involved in Quality Assurance to keep a track of overall QC performance in the project, discuss Non-Conformance Reports (NCRs) if any and methods of improvement of the system.

d. Plan in advance for resources so that job progress does not suffer on account of shortage of staff and workers, machinery and materials.

e. Prepare overall completion schedule in the beginning of the project squeezing contractual completion period by 2-3 months and then prepare monthly, weekly and daily target. Closely monitor progress against target every day and attempt shall be made to make-up shortfall first within the week failing which the shortfall should be made up during the concerned month.

f. As a matter of principle refrain from sending reply to any Client's / PMC's letter immediately on receipt when the issue is still hot. Try to take suitable action as required and send written reply after taking action. However early reply may be sent if any query is needed to be clarified. In any case in any contract a minimum period of 7 days - normally 14 to 21 days is allowed for the Contractor to reply to any letter from Client unless the issue is of emergency nature and immediate action is warranted.

g. If any specific deployment of staff and/or plant has been included in contract the same shall be brought to notice of Project Co-ordinator at R.O and followed up for fulfilment to avoid penal action by Client.

h. A copy of Site Instruction (SI) issued by Client shall be collected and Action Taken Report shall be submitted when action has been taken to avoid penal action by Client at a later date.

i. Responsibility of each staff at site should be clearly defined so that in case of any problem in one particular area the person concerned is held responsible and accountable.

Figure 8. Curing water recirculation in manufacture of long pretensioned girders

50. Special precautions to be taken in 'Curing of Concrete'

It is very often noticed at project sites that there is considerable delay in placing concrete cubes in curing tank after demoulding from steel moulds. Again curing of set concrete is neglected after 2 or 3 days of concreting unless the issue is vigorously pursued by Client's Engineers. Due to such neglect desired concrete strength is not achieved and Factor of Safety considered in design gets substantially reduced. Such reduction in strength is reflected in Annexure, Figure A2 'Properties of Concrete' [11] showing 'Influence of moist curing on the strength of concrete with a water / cement ratio 0.50' in Annexure.

In order to mininmise wastage of curing water recirculation of such water has been tried in manufacture of long pretensioned girders cast in a large pit below ground level as shown in Figure 8.

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6. Specification for road and bridge works, Ministry of Road Transport & Highways, Govt of India, 5th revision.
7. Indian standard code of practice for design and construction of pile foundation, part 1, section 2 –Bored cast-in-situ concrete piles, IS 2911:2010,BIS,New Delhi
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10. 'Concrete Practice' by Cement and Concrete Association, UK.
11. 'Properties of Concrete',4th Edition by A.M. Nevill

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ANNEXURE

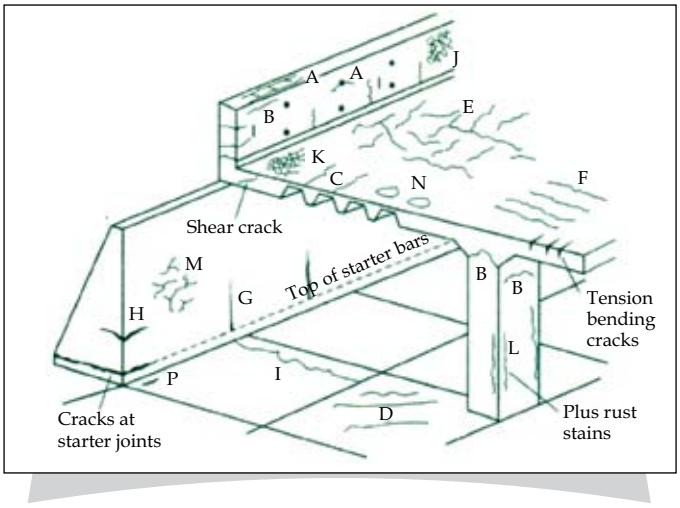

Figure A1. Schematic representation of the various topics of cracking which can occur in concrete. Source: Figure 10.12 (Page 528) Properties of Concrete by A.M.Neville,4th Edition [11]

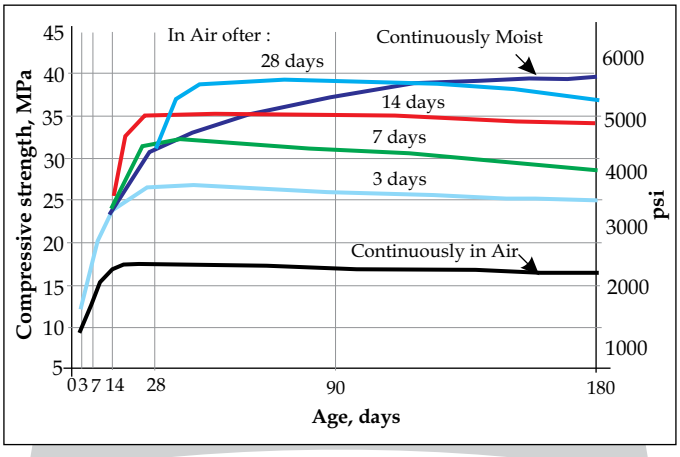

Figure A2. Influence of moist curing on the strength of concrete with a water/cement ratio of 0.50 Source: Figure 7.6 (Page 323) Properties of Concrete by A.M.Neville,4th Edition [11]

Table A1. Classification of intrinsic cracks

Type of cracking	Symbol in Fig.	Subdivision	Most common location	Primary cause (excluding restraint)	Secondary causes / factors	Remedy (assuming basic redesign is impossible); in all cases reduce restraint	Time of appearance	Reference in this book
Plastic settlement	A	Over reinforcement	Deep sections	Excess bleeding	Rapid early drying conditions	Reduce bleeding or revibrate	10 min to 3 h	pp. 399 and 424
	B	Arching	Top of columns					
	C	Change of depth	Trough and waffle slabs					
Plastic shrinkage	D	Diagonal	Pavements and slabs	Rapid early drying	Low rate of bleeding	Improve early curing	30 min to 6 h	pp. 398 and 423
	E	Random	Reinforced concrete slabs					
	F	Over reinforcement	Reinforced concrete slabs	Rapid early drying or stel near surface				
Early thermal contraction	G	External restraint	Thick walls	Excess heat generation	Rapid cooling	Reduce heat and / or insulate	1 day to 2 or 3 weeks	pp. 394 and 399
	H	Internal restraint	Thick slabs	Excess temperature gradients				
Long-term drying shrinkage	I		Thin slabs and walls	Inefficient joints	Edcess shrinkage inefficient curing	Reduce water content Improve curing	Several weeks or months	p. 441
	J	Against formwork	Walls	Impermeable formwork	Rich mixes poor curing	Improve curing and finishing	1 to 7 days, sometimes much later	p. 525
Crazing	K	Floated concrete	Slabs	Over trowelling				
Corrosion of reinforcement	L	Carbonation	Columns and beams	Inadequate cover	Poor quality concrete	Eliminate causes listed	More than 2 years	p. 565
		Chloride						
Alkali-aggregate reaction	M		Damp locations	Reactive aggregate plus high-alkali cement		Eliminate causes listed	More than 5 years	p. 517
Blister	N		Slabs	Trapped bleed water	Use of metal float	Eliminate causes listed	Upon touching	p. 528
D-cracking	P		Free edges of slabs	Frost damaged aggregate		Reduce aggregate size	More than 10 years	p. 544

Source: Table 10.8 (Page 526), Properties of Concrete by A.M.Neville, 4th Edition [11]