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Quality Assurance and Quality Control of Hydro Power Projects

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Abstract: Hydropower projects are basically designed for the development of irrigation and electricity through the construction of dams. Initially, dams were built only for storing rain water to prevent flooding but now a days the river valley projects are an integrated system of controlling floods, generating electricity, accomplishing irrigation supplies, development of fisheries and tourist spot etc. The extreme geographical and environmental conditions of these projects make it more susceptible towards deterioration and durability losses. Hence having a defined quality management plan, review of quality objectives is having paramount significance. In this paper component of quality management program and sphere of each component for river valley projects has been conversed. It is also envisaged to share the important aspects of quality assurance and quality control program, embracing site inspections and investigations of construction materials, end products etc. scribbled out for hydro projects where CSMRS is part of consultancy services, primarily for quality assurance and quality control.

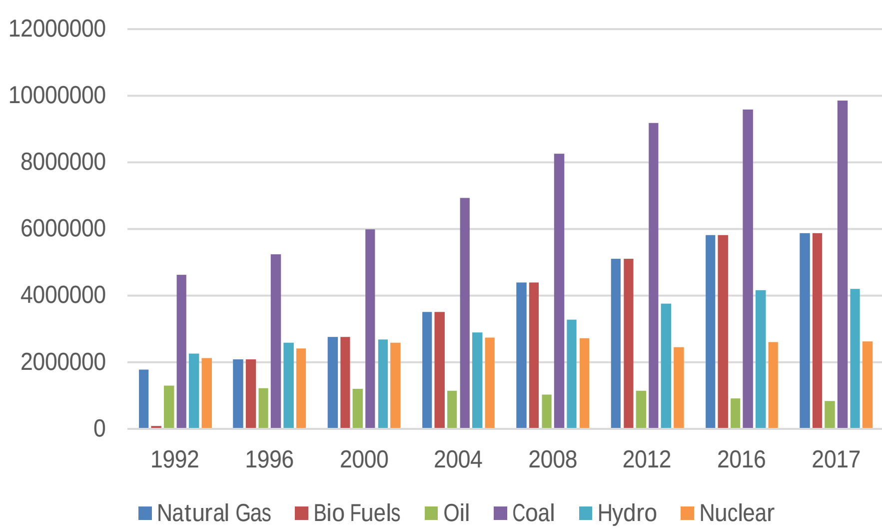
I. INTRODUCTION

Hydropower is extracted from the natural potential of usable water resources. Any water resource programme of which a Hydropower scheme may form part has environmental and social impacts, which must be taken into consideration at the initial planning stage. Also legal and political implications must be carefully considered.

One of the most important factors affecting any hydropower development is cost of the scheme. With the rising costs and shortage of resources, economic comparisons with various energy sources (e.g. thermal plants - oil, coal, nuclear etc.) have to be made. In this, the fact that, unlike the fuel costs of the hydropower plant, the costs of fuel for power generation by a conventional thermal plant rise at least with inflation, makes hydroelectric plants economically advantageous, particularly in the long term.

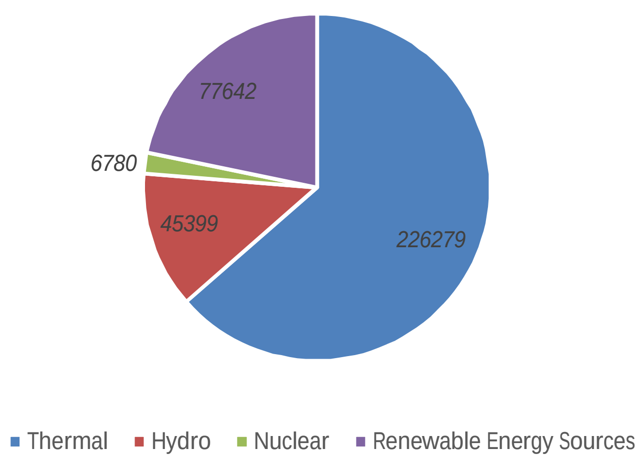
The percentage share of Hydro worldwide among all electricity generation sources such as coal, oil, natural gas, nuclear, wind, solar, geothermal etc. is approximately seventeen percent [2]

FIGURE 1. Yearwise Global Energy Supply Mix in GWh



In Indian scenario the present installed capacity of Hydro power as on 31.03.2019 is 45399 MW, which is approximately 13 percent of total installed capacity considering coal, lignite, gas, diesel, wind, bio-power, solar and nuclear etc. Though total electricity generation in India during Apr-18 to Mar-19 is 1249 BU and the contribution of hydro power towards this is 135 BU. It is approximately 11 percent of the total electricity generation. The electricity generation targets for hydropower sector up to Mar-19 were 8.31 BU which is about 8 percent of total power generation till Mar-18. The actual growth of 8.3 percent has been observed against this target. [3]

FIGURE2. All India Installed Capacity in MW as on 31 March'19



Thus, the role of Hydropower towards electricity generation, as a renewable energy source is pivotal in the growth of any country. These projects also ingests a lot of natural resources during construction phase in form of aggregates, sand, cement steel etc. which are limited in nature. Hence by adopting and implementing a proper Quality Management System, these projects can rationalize the usage of natural resources by means of (a) It provides a fundamental idea on optimum quantity usage of these resources (b) Also delivers a niche to the project by enhancing the service life with added durability. Project performance is therefore generally still evaluated in terms of the "iron triangle" of schedule, cost and quality performance. [4]

II. PROJECT QUALITY MANAGEMENT

Project Quality Management thus comprises of three elements: Quality Planning, Quality Assurance (executing the plan) and Quality Control (QC). A more structured approach for any hydro power project is to draft a quality management program, devise a quality management process, trained supervision on the process, and implement a control system, and review performance and results. Continuously improve the process where possible.

Failure to meet project quality requirement can have a number of negative connotations on the project delivery process. It creates extra work for the parties involved, though it may negatively influence the designer and the owner to some extent. It can damage business relationships and possibly lead to time-consuming and costly litigation for contractors. In a. research study conducted a few years ago, the findings revealed that costs associates with rework (having to redo a step or portion of construction due to poor craftsmanship or change in plan) were as high as 12 percent of the total project cost and required as much as 11 percent of the total project working hours. [5]

A. Quality Assurance (QA) and Quality Control (QC)

If QA is the "Healthy Lifestyle" to prevent nonconformities, QC is seen as checks to verify that the healthy lifestyle is pursued as well as the "medicine" to eliminate (or preferably to prevent) defects and other non-conformities when the healthy lifestyle proves insufficient. [6]

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B. Quality Assurance

The planned and systematic activities implemented in a quality system so that quality requirements for a project will be fulfilled. QA is not only required on each individual project to ensure compliance with requirements, a second element is inter-project continuous improvement that is facilitated by systematic project close-out. Hence, in a project environment, QA consist of Project Quality Assurance plus Continuous Improvement.

C. Quality Control

Quality Control is set of activities for ensuring quality in products. The activities focus on identifying defects in actual product developed before its release. Two facets of project quality control are planned QC work and ad hoc problem solving. Planned QC work consists of activities that can be planned to a relative level of detail beforehand. Ad hoc problems are obviously unforeseen hitches, and contingency reserves in budgets and schedules should make provision for activities to investigate and rectify such problems. A tabular illustration of QA v/s QC aspects are designated as Table -1

Table 1. Representation of QA v/s QC Characteristics

Quality Control	Quality Assurance
Product	Process
Reactive	Pro-active
Line Function	Staff Function
Find the defects	Prevent the defects
Walk through	Quality Audit
Testing	Defining Process
Inspection	Selection of tools
Checkpoint Review	Trainings

Project Quality Planning Quality planning should include decisions regarding actions required to meet quality requirements and the planned quality actions often entail the use of specific QA and QC techniques. The QA and QC techniques therefore need to be decided upon during quality planning. [7]

In the case of projects to develop new systems, Project Quality Planning involves decisions regarding:

1) Requirements that need to be met (as embodied in agreed specifications and standards), including benchmarking against other projects.
2) Actions required in the overall project plan to meet the required specifications and standards, including the tools and techniques that would be used in QA and QC.
3) Metrics to be used to determine whether the specifications and standards have been met.

III. ENACTMENT OF QA & QC STRUCTURE

For accurate enactment of QA & QC master plan at Hydropower projects, three key steps which may be undertaken are as below:

A. Education and Training System

Education and training of each staff have been the most important to satisfy the required quality. Therefore routine educational sessions by the QA/QC manager/instructors and on-the-job training by the experienced professionals should also be incorporated into the QA/QC system.

B. Document Management System

Documentation should be quite exact and smooth from testing to filing. Therefore all necessary data should be collected and inputted into PC by the document controller on daily basis and inputted data should have been checked by the engineer i/c periodically. This documentation management system should be incorporated into the QA/QC system.

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C. Test Result Analysis System

The quality of material estimated may be unstable. Therefore continuous quality stability analysis of material is very important to control the quality of concrete. The variation of aggregate and cement quality should be checked continuously by the charts and the mix proportions of concrete should be reviewed every month according to the test results. Therefore test result analysis has to be incorporated into the documentation of the QA/QC system.

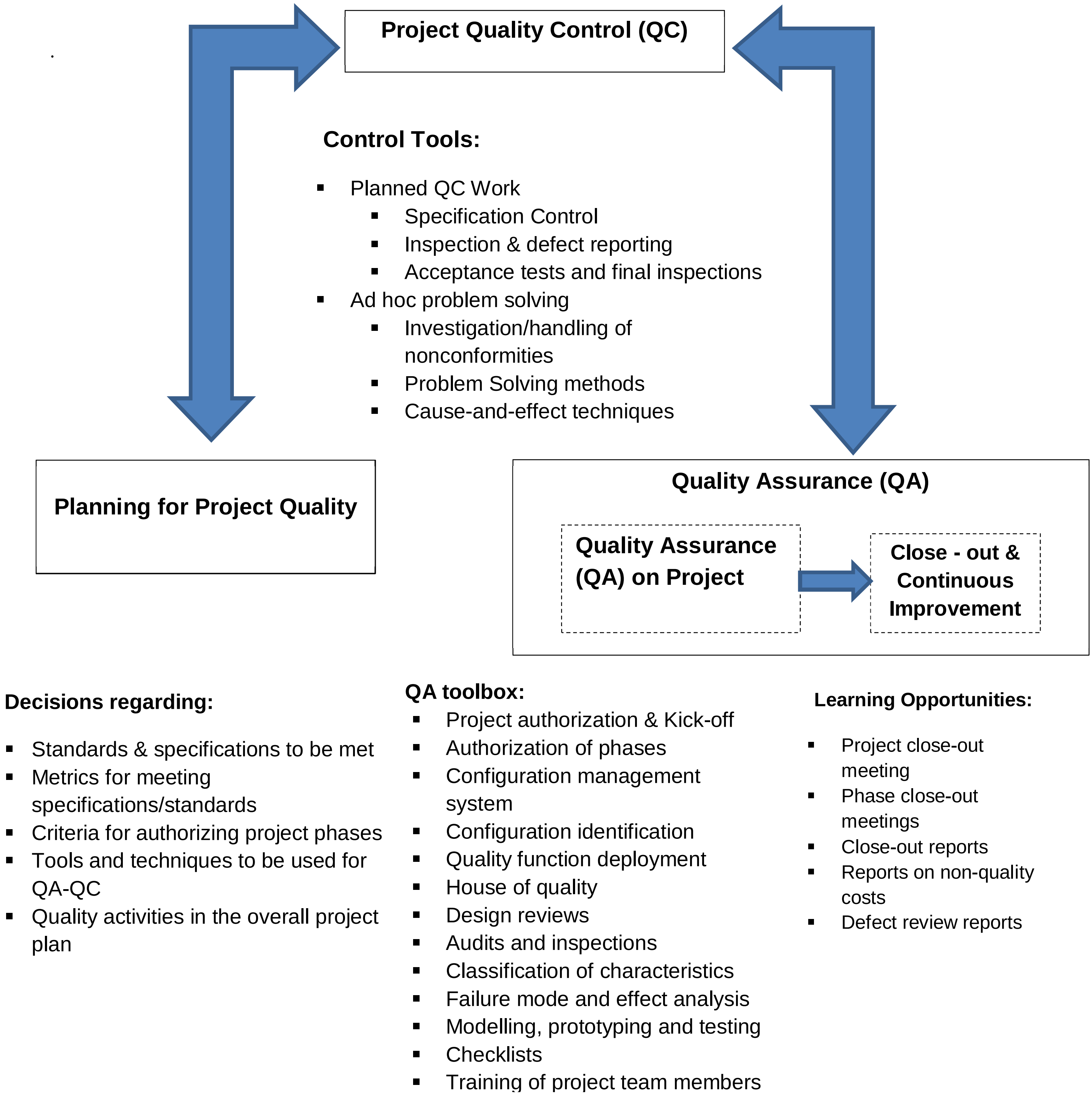

Figure ~~1~~ 3. Proposed quality management framework for system development projects adapted from Nicholas and Steyn [8].

IV. ACCEPTANCE TESTS AND INSPECTIONS

Acceptance tests and inspections are vital modules of quality control in a hydro power project. Acceptance tests are categorized as:

1) Investigation of construction materials such as cement, aggregate, sand, construction water, admixtures, rebar and structural steel, cement capsule, resin capsule etc. These tests are carried out on regular intervals or defined frequency based on the material quantity and/or manufacturing batches, prior to their use at site. Test Procedure and acceptance criteria may follow national or international standards i.e. BIS, ACI, ASTM, BS and EFNARC etc. The methodology of test methods and frequency of these tests are also integrated in project technical specifications or quality manual. Investigations such as alkali aggregate reactivity, which are highly disruptive in nature and are very likely for hydraulic structures such as dam, spillway, HRT etc., should be carried out in preconstruction phase.
2) Investigations required to be carried out during construction phase to check whether the fresh properties of product are in line with specifications or not. E.g. measuring slump and temperature of freshly made concrete mix. Fibre evaluation of steel fibre reinforced shotcrete, determining the consistency, density and flow of grout mix, L-box, U-box, J-ring and V-funnel investigations for self-compacting concrete etc.
3) For finished products such as concrete, shotcrete etc. investigations can be classified further as (a) Tests which are carried out on specimens which are well-preserved up to certain age e.g. for concrete - cores, cubes, cylinders, beams etc. These specimens are ideally considered as true representation of end product and should be kept in humidity and temperature controlled environment conditions as per test specifications. (b) Tests which are conducted to diagnose the structural integrity after a certain amount of time such as non-destructive tests. The results of these tests can be examined in light of the destructive investigations and by this way one can obtain a fair idea of strength development, structural integrity etc. (c) Investigations are also required to check the actual performance of any structure/component/material such as integrity tests of rock bolts, pull out test of shotcrete-rock interface, extraction of cores at any given day and determination of compressive/tensile strength etc.
4) Apart from field and laboratory investigations it is also imperative to calibrate all the test equipment including batching plant for concrete production periodically. The documentation and frequency of calibration should be followed as per field quality plan.
5) QC Testing as required by the contract specifications, the contractor should establish a test program to ensure that all required testing is properly identified, planned, documented and performed under controlled and suitable environmental conditions, including cleanliness. Testing shall be performed in accordance with written test procedures in the Quality Control Plan. Such test procedures shall incorporate or reference the requirements as contained in the contract technical specifications, codes, and industry standards. As per the QCP, the contractor shall submit the test procedures to the project authority for review and acceptance prior to their implementation.
6) QA testing is provided for the verification of the adequacy and effectiveness of the contractor's QC testing. QA testing is performed by the project authority and is independent of and in addition to QC testing performed by contractors. QA testing may be performed on a pre-established schedule. QA testing will be performed by or under supervision of the QA staff to validate the contractor's QC sampling and testing. Such testing may be performed by third party testing services. More frequent testing during initial start-up may be necessary to verify the process is under control and complies with the technical specifications of the construction contracts. In lieu of performing independent tests the project authority may choose to witness QC testing or conduct tests on split samples from QC testing. CSMRS is also involved in providing consultancy services as third party for Quality Assurance and Quality Control of civil works for hydro projects across India.

A. Inspection of Site

A four-phase inspection program shall be followed for each definable feature of the work. [9]

1) Preparatory Inspection

a) Ensure that preparatory inspections include a review of contract requirements.
b) Ensure that all materials and/or equipment have been tested, submitted, and approved.
c) Ensure that provisions have been made to provide required testing.
d) Examine work area to ascertain that all preliminary work has been completed.
e) Examine materials, equipment, and samples to ensure that they conform to approved drawings or submittal data, all materials and/or equipment are on hand, and all monitoring and measuring equipment is properly calibrated and in proper working condition.

2) Initial Inspection

a) An initial inspection to be carried out as soon as a representative portion of the particular feature of work has accomplished
b) Examine the quality of workmanship.
c) Review control testing for compliance with contract requirements.
d) Review dimensional aspects of the work.
e) Record initial inspections in QC documentation as required by specification.

3) Follow-Up Inspection

a) Ensure continuing compliance with Contract requirements.
b) Ensure continuing compliance with control testing until completion of particular feature of work.
c) The inspection staff records follow-up inspections in their daily inspection report.
d) Conduct final follow-up inspections and correct test deficiencies prior to the addition of new features of work.

4) Completion Inspection

a) Develop a "check list" of items that do not conform to the approved plans and specifications.
b) Include the punch list in the construction QC documentation.
c) Perform a second completion inspection after check list items have been completed and the CM has been notified by the contractor.

V. METHOD AND FREQUENCY OF TESTS

The Frequency Manual is a tabulation of various items of materials and tests normally used in the construction of Hydropower Structures. The manual specifies the minimum
Schedule necessary to satisfy the requirements for acceptance samples and tests for each item. The location (i.e. job site, source, mixing plant etc.) from which samples are to be taken or tests conducted may also specified for each item.
Each sample is required to represent no more than the quantities listed by the Job Control Frequency of the manual. The frequency of samples or tests applies to quantities shown or fractions thereof. Many of the items listed allow small quantities of the material to be accepted without samples or tests. When this procedure is permitted, the quantities are specified as approximate amounts. The frequencies herein are the minimum required. The Project Authority always has the right and responsibility to have a questionable product re-tested. A representative format for documentation of test frequency in accordance with test protocols and requisite quantities of sampling is presented at Table.2 which is tentative only and may wary from project to project.

Table 2. Construction materials tests based on protocol and frequency

S. No.	Material	Tests	Relevant BIS Codes	Frequency	
				Site Lab	External Lab
1	Coarse Aggregate	Elongation & Flakiness index	383 & 2386-1	Once a week	Once in two months
		Water Absorption	383 & 2386-3	Once a week	
		Specific gravity	383 & 2386-3	Once a week	
		Soundness	383 & 2386-5	Once a week	
		Gradation	383 & 2386-3	With each lot	
		Impact value	383 & 2386-4	With each lot	
		Crushing value	383 & 2386-4	With each lot	
		Abrasion value	383 & 2386-4	With each lot	

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		Alkali Aggregate Reaction			
		a) Mortar Bar test	2386-7		Once in Six months or change of source
		b) Accelerated Mortar bar test	ASTM C1260		Once in Six months or change of source
2	Fine Aggregate	Specific gravity	383 & 2386-3	Once a week	Once in two months
		Soundness test	384 & 2386-5	Once a week	
		Gradation	385 & 2386-3	With each lot	
		Fineness Modulus	386 & 2386-3	With each lot	
3	Cement	Physical properties			
		a) Compressive strength Mpa	269, 455, 1489 (Part 1 & 2), 4031 (respective parts), 8112 & 12269	Monthly once	Once in two months or with change of source
		3 Days (72+1h) in Mpa			
		7 Days (168+2h) in Mpa			
		28 days (672+4h) in Mpa			
		b) Fineness (m2/Kg)			
		c) Soundness			

S.No.	Materials	Tests	Relevant BIS codes	Frequency	
				Site Lab	External Lab
	Cement	By Autoclave method (Maximum % increase in length of bar)	269, 455, 1489 (Part 1 & 2), 4031, 4032 (respective parts), 8112 & 12269	Monthly once	Once in two months or with change of source
		By Le Chatelier Method (in mm)			
		e) Setting time			
		Initial setting time (minutes), min.			
		Final setting time (minutes), max.			
		Chemical composition, Maxm, %			

		Loss on ignition			
		MgO			
		SO3			
		Insoluble Residue			
		Total Sulphur content			
		Alkali			
4	Construction Water	Chemical requirement Maximum permissible limits of solids for water used for mixing and curing of concrete			
		a) Chloride, mg/l	3025 (Part 32)		Once in every season or change in source of water
		Reinforced cement concrete			
		Plain cement concrete			
		b) Sulphate, mg/l	3025 (Part 24)		
		c) Organic, mg/l	3025 (Part 18)		
		d) Inorganic, mg/l	3025 (Part 18)		
		e) Suspended matter, mg/l	3025 (Part 17)		
		f) pH (not less than)	456		

S. No.	Materials	Tests	Relevant BIS codes	Frequency	
				Site Lab	External Lab
5	Rebar / Reinforcement Steel	Manufacturer's test certificate for each batch / lot to be submitted regularly by the contractor.	1786		(i) Under 10 mm one test sample from each lot or part thereof. (ii) 10 to 16mm each lot of 45T (iii) Over 16mm one sample from each lot of 50t or part thereof.
		Mechanical properties			
		a) 0.2% proof stress / Yield stress MPa (minimum)			
		b) Percentage elongation on gauge length 5.65x square root of cross sectional area of test piece (Minimum%)			
		c) Tensile strength MPa (minimum)			
		d) Bend test (One test per lot of 40 tone or part thereof)			
		e) Rebend test			
		upto 10mm			
		Over 10mm			

		Chemical composition (Maximum, %) a) Carbon b) Sulphur			One test sample from each lot
		c) Phosphorous			
		d) Sulphur and phosphorous iii. Test / checks for rolling tolerance Yield strength Ultimate strength Manufacturer's test certificate for each batch / lot to be submitted regularly by the Mechanical properties a) 0.2% proof stress / Yield stress MPa (minimum)	1786	One test sample from each lot	Once in each lot (i) Under 10 mm one test sample from each lot or part thereof. (ii) 10 to 16mm each lot of 45T (iii) Over 16mm one sample from each lot of 50t or part thereof.
		b) Percentage elongation on gauge length 5.65x square root of cross sectional area of test piece (Minimum%)			
6	Admixture	pH % Dry Material content, by wt. % Ash content, by wt. % Chloride, by wt.	9103		Once in each lot. 4 grab samples shall be taken with each grab (of 1 litre) sample representing 9000 liters of Admixture grab (of 1 litre) sample representing 9000 liters of Admixture.
7	Concrete	Fresh Concrete			
		a) Workability of concrete mixes	456, 516 & 1199	Once in each shift for each location or when any change in workability is noticed.	

		b) Sampling for Compressive strength			
		c) Air content			
		d) Unit weight			
		e) Temperature of concrete			
		Casting of cubes	456, 516 & 13311 (respective parts)	0-5 m^3 : 01 6-15 m^3 : 02 16-30 m^3 : 03 31-50 m^3 : 04 4 plus one additional sample for each additional 50m^3 or part thereof	Monthly once
		Hardened Concrete			
		In situ cores from Hardened Concrete			As and when required

S.No.	Materials	Tests	Relevant BIS codes	Frequency	
				Site Lab	External Lab
8	Resin Capsule	a) Gel time i. Slow set capsule ii. Fast set capsule b) Compressive strength after one hour c) Pull out test of 1.5 meter long bolt after 5 minutes	As per Manufacturer Test Certificate (MTC)	Three samples per batch.	One sample per lot.
9	Rock Bolts	i. Manufacturers certificate for each batch / lot to be submitted regularly by the contractor ii. At least 2% of rock bolts i.e., 1 in 50 rock bolts installed are to be tested for a maximum pull out load of 3T/m or 80% of the elastic limit whichever is smaller. Note: The rock surface around the drilled hole to receive the bearing plate shall be chipped smooth or covered with a smooth quick set cement pad. Retightening of rock bolts in 10m of blasting area.			One test for 50 Rock Bolts installed.

VI. DISCUSSION AND CONCLUSION

Like all energy and water management options, hydropower projects have negative and positive environmental and social impacts. On the environmental side, hydropower may have a significant environmental footprint at local and regional levels but offers advantages at the macro-ecological level. With respect to social impacts, hydropower projects may entail the relocation of communities living within or nearby the reservoir or the construction sites, compensation for downstream communities, public health issues etc. A properly designed hydropower project may, however, be a driving force for socioeconomic development.

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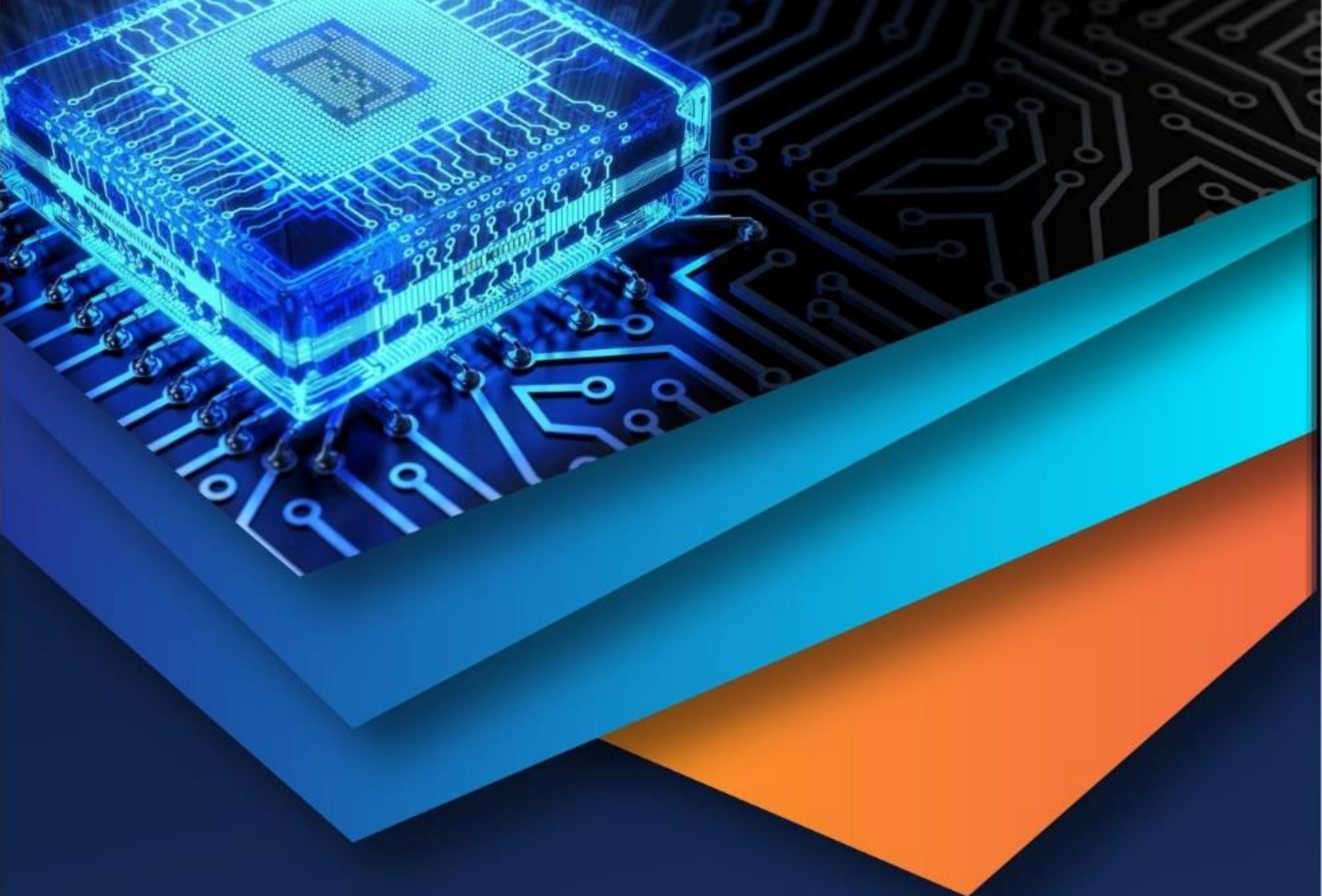

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