

Development of Construction Quality Assessment Model for RCC Footing

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Abstract— Any constructed facility should conform to predetermined quality standards and specifications in order to serve the purpose of a facility. It should satisfy the owner's quality needs, expectations and aspirations about the constructed facility which are the key objectives of a contractor. But unfortunately, most of the times it is a common issue that constructed facilities fail in satisfying the predetermined quality standards, specifications and owner's expected level of quality. This is mainly because of ignorance and misconception on the part of owner's representative who accepts sub-standard. Most of the present methods of quality audit being subjective in nature, there is an emergent need to develop a comprehensive, rational, sensible and objective post occupancy quality measurement model for a constructed facility which would give a clear idea about how contractors are using resources and attaining desired workmanship. The present study was undertaken to develop construction quality index model for a RCC footing of Nashik region in India. The developed model would be helpful in examining the quality level achieved by a RCC footing and to compare the RCC footing as well as contractors. This model would remain as prime basis for rating the quality of RCC footing and contractor's ability in providing quality facilities.

Key words: Acceptance Quality Characteristics (AQC's), Construction Quality Characteristics (CQC's), Construction Quality Index (CQI) Model

I. INTRODUCTION

Any construction project management has two philosophies, i.e. time-driven and cost-driven. Managing cost of construction project with completion in time with high quality and achievement of objectives is called project management. A project shall have its own characteristics set aside so that it can be completed within budget and time. As cost and time for a construction project are interdependent, these shall be carefully planned. An increase or decrease in construction project time affects the budget of construction projects. These set characteristics define the projects and helps in completing the project in time. Builders often treat low quality construction work no differently with high quality construction work. As a result of this misperception owners are not penalizing the contractors for their poor work. Also cost of construction is increasing with low quality work. For that reason many contractors are taking advantage of the owners' reluctance to penalize them which ends up in low quality facilities. Therefore, there is an emergent need to rate the quality of a facility and providing compensation to contractor accordingly.

II. NEED & SCOPE OF STUDY

The scope of the study is as under:

- To evaluate the contractor's product or service from a quality perspective.
- To determine the contractor's compensation.
- To calculate the bonuses/penalties to a contractor for a project.
- To calculate cost required for work and its assessment.
- To change the contractor's qualification status if quality of all the contractor's facilities are quantified in a long run.

This kind of quality quantification will increase the awareness in a contractor towards quality which leads to improvement in quality of construction.

III. OBJECTIVE OF THE STUDY

The objective of the study is:

- To study the concept of construction Quality index (CQI) and its related terms to quantify the quality of Rcc Footing of residential building.
- To collect Construction Quality Characteristics (CQC) related to materials and workmanship in constructing Rcc Footing of residential building from IS code, Research Paper, text books.
- To collect Cost Quotation related to materials testing and workmanship in constructing Rcc Footing of residential building from DCR
- To sieve the CQCs which are collected from literature survey and to add necessary CQCs for the same from construction experts.
- To analyze the collected data which will help to formulate quality index for building facility in further study along with cost optimization.

IV. METHODOLOGY

A. Flow Chart of Methodology

For getting AQC's from the listed CQC's, the respondents were asked to tick mark and put on the rates required for the test n workmanship the prescribed CQC which they felt right for post occupancy quality assessment of Residential Footing. At the end of the Survey form, one section was provided for their suggestions if they felt other CQC's have to be added for post occupancy quality assessment. For their convenience, CQC's were divided layer wise, where in respondents can think over the same from quality assessment prespective before they tick mark the CQC.

B. Methodology Outline

- 1) A comprehensive literature review to understand the definitions and terminology related to quality in construction and its measurement.
- 2) Identifying and collecting Construction Quality Characteristics and cost of testing related to a particular

- facility from literature review, IS code, text books, research papers and site visit.
- 3) Constructing a draft questionnaire incorporating the collected Construction Quality Characteristics (CQC's).
 - 4) Conducting pilot survey to check the correctness of the questionnaire.
 - 5) Modifying questionnaire based on the relevant inputs from the pilot survey.
 - 6) Analyzing the responses using a statistical method to calculate the weighting factors.
 - 7) Formulating Construction Quality Index with the help of Construction Quality Characteristics and their weighting factors by using a statistical tool.
 - 8) Analyzing results, conclusions and recommendations from the inferences.

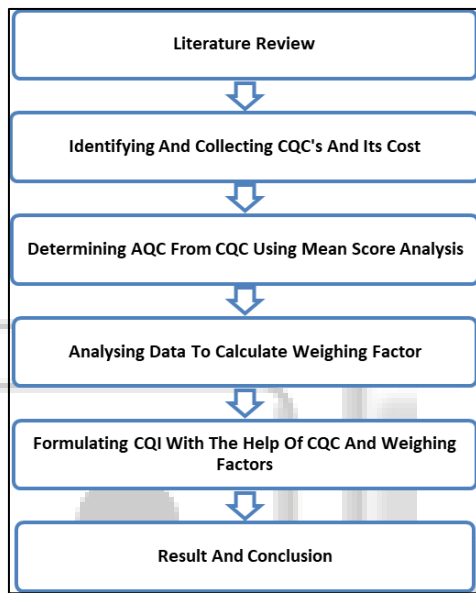


Fig. 1: Flow chart of Methodology

V. DATA COLLECTION & ANALYSIS

This chapter includes

- 1) Data collection in the form of CQCs and its related cost for constructing footing of residential building from extensive literature survey of research papers, text books, IS specification and code books.
 - 2) Preliminary survey with construction experts to get recommendation for more CQC's and sieve AQC's from CQCs.
- 1) Construction Quality Characteristics (CQCs)
CQCs are inherent facility characteristics which can be measurable at the time of construction that significantly effects the facility performance and quality which will be under the direct control of the contractor
 - 2) Construction Quality index (CQI)
CQI is “a rational measure of overall quality of a constructed facility that is calculated by determining the quality of individual components and linking them to obtain a composite quality index for the job.”

A. CQCs Related To Materials Testing

CQCs related to materials are composed of raw material tests and in-process inventory tests. The following were the CQCs related to materials, collected from literature survey of

research papers, Text books, IS codes and experts. The following were the CQCs related to workmanship, collected from literature survey of research papers, IS 10262 RA(2014)concrete mix design, IS 456-2000 RA(2011)coarse and fine aggregate. A total of 37 CQCs related to materials were collected from literature survey which is as shown in the Table I

Foundations Steps	Coc's Related To Material Testing	Cost (Rs.)
EXCAVATION	Seismic test	
	Plate load test	500/-
	Penetration test	5000/-
	Split spoon test	3000/-
	Proof test by core drilling	1000/-
	Vibration test	45000/-
BASE COURSE	Dynamic load test	
	Dry density of compacted layer	500/-
	Sieve analysis of coarse aggregate	500/-
	Water absorption of coarse aggregate	300/-
	Aggregate impact value	500/-
	Aggregate crushing value	500/-
	Aggregate crushing value	1000/-
	Aggregate abrasion by los angles test	500/-
	Specific gravity	500/-
	Silt content	500/-
PCC	Soundness by Le-chateliers method	500/-
	Standard consistency of cement	2900/-
	Initial and final setting time of cement	600/-
REINFORCEMENT	Tensile test	
	Ultimate strength	1000/-
	% elongation	
	Torsion test	
	Izod Impact test	600/-
	Bending test	300/-
	Rockwell hardness test	300/-
Single & double shear test	600/-	
FORMWORK	Surface finish of form work	
CONCRETING OF FOOTING	Soundness of cement	500/-
	Los angles abrasion value	1000/-
	Aggregate impact value	500/-
	Aggregate impact value	500/-
	Alkali aggregate reactivity	300/-
	Water cement ratio	1200/-

	Slump test Comp strength of concrete tube Flexural strength of conc beam	
POST CONCRETING	Honeycomb Spalling and dusting Cracks Depressions Bulges Abrupt irregularities Rebound hammer test Compressive strength	2000/- 2000/- 1200/-
	Total cost of all test for material	76,800/-

Table 1: COC's Related to Material Testing & Its Related Cost for Constructing RCC Footings

B. CQC's Related To Workmanship

It is equally important to measure CQC's related to workmanship along with CQC's related to materials as it measures the degree of workmanship utilized in constructing a RCC footing. The following were the CQC's related to workmanship, collected from literature survey of research papers, Text books, IS codes, IS 10262 RA(2014)concrete mix design, IS 456-2000 RA(2011)coarse and fine aggregate. A total of 28 CQC's related to workmanship were collected from literature survey as shown in the Table II.

Foundations Steps	Coc's Related To Workmanship	Costs (In Rs)
EXCAVATION	Setting of corner benchmark Marking position Setting for ground level Setting for top level Excavation to apparent depth Constructing dewatering level Constructing protecting level	2600/- *As per site condition
BASE COURSE	Dressing of loose material Marking of cut off level	512/-
PCC	Surface level Layer thickness Marking canter line	640/-
REINFORCEMENT	Cantering Setting of corner benchmark Minimum rebar size	2880/-

	Cover n spaces for reinforcement	
FORMWORK	Joint sealing Marking concrete level Tolerance of position of formwork	2560/-
CONCRETING OF FOOTING	Surface levels Surface regularity Alignment of joints Surface texture Tolerance for level and alignment Alignment of embedded item such as anchor	1280/-
POST CONCRETING	Level of finished concrete Alignment of finished concrete Surface texture	320/-
	Total cost of workmanship for 1 footing	10,792/-

Table 2: CQC's Related To Workmanship in Constructing A RCC Footing

Note: Workmanship is calculated as per footing studied at site (size: 8x8)

C. Photos Related to Testing & Workmanship of CQC's



Fig. 1: Demarkation Of Plot



Fig. 2: Excavation Work For Footing



Fig. 3: Excavation Part 2



Fig. 7: Post Concreting Work



Fig. 4: Formwork For Footing & Column



Fig. 8: 1st phase Completed



Fig. 5: Casting of Footing and Column



Fig. 9: Part Work Completed



Fig. 6: Casting Work of Second Phase



Fig. 10: Vibrator Dressing of Base Course

The vacant cell against a CQC was given a score of 0 (Zero) and calculating the mean score for all CQCs. The CQCs with mean score ≥ 0.5 were selected as AQC's for further analysis indicating agreement of 10 respondents which is as shown in the Table III.

Residential Footing Layer	CQC's related to materials and workmanship	Respondents										Mean Score
		1	2	3	4	5	6	7	8	9	10	
EXCAVATION	Plate load test	0	0	1	1	0	1	1	0	0	1	0.5
	Sismic test	1	1	0	0	1	0	0	1	1	1	0.6
	Penetration test	0	0	0	0	0	0	0	0	0	0	0
	Split spoon test	0	0	0	0	0	0	0	0	0	1	0.1
	Core drilling	1	1	0	0	1	0	0	1	1	1	0.6
	Vibration test	0	0	0	0	0	0	0	0	0	0	0

	Dynamic load test	0	1	1	0	0	0	0	0	0	1	0.3
	Setting of benchmark	1	1	1	1	1	1	1	1	1	0	0.9
	Marking position	1	1	1	1	1	1	1	1	1	1	1
	Setting for ground level	0	0	0	0	0	0	0	0	1	1	0.2
	Excavation to app depth	0	0	0	0	0	0	0	0	0	1	0.1
	Setting for top level	0	1	1	0	0	0	0	0	1	1	0.4
	Dewatering level	1	1	1	1	1	1	1	1	1	1	1
	Protecting level	0	1	0	0	0	0	0	0	1	1	0.3
BASE COURSE	Dry density of comp layer	0	1	1	1	0	1	1	0	1	1	0.7
	Sieve analysis	1	1	0	1	1	0	0	1	1	1	0.7
	Water absorption	1	1	1	1	1	1	1	1	1	1	1
	Agg impact value	1	1	1	0	1	0	0	1	1	1	0.7
	Agg Crushing value	0	0	0	1	1	1	1	0	0	0	0.4
	Abrasion by los angles tst	0	0	1	0	0	0	0	0	0	1	0.2
	Specific gravity	1	1	0	1	1	1	1	1	1	1	0.9
	Silt content	0	0	0	0	0	0	0	0	0	1	0.1
P.C.C	Dressing of loose mtrl	1	1	1	1	1	1	1	1	1	1	1
	Marking of cut off level	0	0	1	0	0	0	0	1	1	1	0.4
	Soundness test	1	1	1	1	1	1	1	1	1	1	1
	Standard consistency test	1	1	1	1	1	1	1	1	1	1	1
	Initia n final setting time	1	1	1	1	1	1	1	1	1	1	1
	Surface levels	1	1	1	1	1	1	1	1	1	1	1
	Layer thickness	1	1	1	1	1	1	1	1	1	1	1
	Marking centre line	1	1	1	1	1	1	1	1	1	1	1
REINFORCEMENT	Tensile test		1	1	1	1	1	1	1	0	1	0.8
	Ultimate strength	1	1	1	0	1	1	1	1	1	1	0.9
	% elongation	0	1	1	0	1	1	1	1	1	1	0.8
	Torsion test	1	1	1	1	1	1	1	1	1	1	1
	Izod impact test	1	0	0	0	0	0	0	0	0	0	0.1
	Bending test	0	1	1	1	1	1	1	1	1	1	0.9
	Hardness test	1	0	0	0	0	0	1	0	1	1	0.4
	Single & double shear tst	0	0	0	0	0	0	0	0	1	0	0.1
	Centering	1	1	1	1	1	1	1	1	1	1	1
	Setting of corner benchmark0	0	0	1	0	0	0	0	0	1	1	0.3
	Minimum rel bar size	0	0	0	1	0	0	0	0	1	1	0.3
	Cover and spaces	1	1	1	1	1	1	1	1	1	1	1
FORMWORK	Surface finish of formwork	0	1	0	0	0	0	0	0	1	1	0.3
	Joint sealing	0	1	1	1	1	1	1	1	0	1	0.8
	Marking conc level	1	1	1	0	0	1	1	0	1	1	0.7
	Tolerance of pos of formwork	0	1	0	0	0	0	0	0	1	1	0.3
CONCRETING OF FOOTING	Soundness of cement	1	1	1	1	1	1	1	1	1	1	1
	Los angles abrasion	0	0	0	0	0	0	0	0	0	1	0.1
	Aggregate impact value	0	0	0	0	0	0	0	0	1	1	0.2
	Alkali agg reactivity	0	0	0	0	0	0	0	0	1	0	0.1
	Water cement ratio	1	1	0	1	1	1	1	1	1	1	0.9
	Slump test	1	1	1	1	1	1	1	1	1	1	1
	Comp strength of conc	1	1	1	1	1	1	1	1	1	1	1
	Flexural strength	0	0	0	0	0	0	0	0	0	1	0.1
	Surface levels	1	1	1	1	1	1	1	1	1	1	1
	Surface regularity	1	1	1	1	1	0	1	1	0	1	0.8
	Alignment of joints	0	1	0	0	0	1	1	0	1	0	0.4
	Surface texture	0	0	0	0	1	0	0	0	1	1	0.3
	Tolerance of level	0	0	0	0	0	0	1	0	0	1	0.2
Alignment of anchor	0	1	1	0	1	1	1	0	1	1	0.7	
POST CONCRETING	Honeycomb	0	1	1	0	1	0	0	0	0	1	0.4
	Spalling and dusting	0	0	0	0	0	0	0	0	0	0	0
	Cracks	0	1	1	1	0	1	0	0	0	1	0.5
	Depressions	0	0	0	0	0	0	0	0	0	1	0.1

	Bulges	0	1	0	0	0	0	0	0	0	0	0.1
	Abrupt irregularities	0	0	0	0	0	0	0	0	1	0	0.1
	Rebound hammer test	1	1	1	1	1	1	1	1	1	1	1
	Compressive strength	1	0	0	0	1	1	0	1	1	1	0.6
	Level of finish conc	0	0	0	1	0	0	0	0	1	1	0.3
	Alignment of conc	0	0	0	0	0	0	0	0	0	0	0
	Surface texture	1	1	1	1	1	0	0	1	1	1	0.8

Table 3: Mean Score Analysis of CQCs

D. Acceptance Quality Characteristics (AQC's)

AQC's are the CQCs that are measured for acceptance purposes of the project. From the mean score analysis, 38 AQC's were selected out of 71 CQCs. The remaining 33 CQCs were dropped for further analysis to develop a manageable construction quality index

FOUNDATIONS STEPS	COC'S RELATED TO MATERIAL TESTING	COST (rs)
EXCAVATION	Seismic test Plate load test Proof test by core drilling	500/- 5000/- 45000/-
BASE COURSE	Dry density of compacted layer Sieve analysis of coarse aggregate Water absorption of coarse aggregate Aggregate impact value Specific gravity	500/- 500/- 300/- 500/- 500/-
PCC	Soundness by Le-chateliers method Standard consistency of cement Initial and final setting time of cement	500/- 2900/- 600/-
REINFORCEMENT	Tensile test Ultimate strength % elongation Torsion test Bending test	1000/- 600/- 300/-
FORMWORK	Surface finish of form work	
CONCRETING OF FOOTING	Soundness of cement Water cement ratio Slump test Comp strength of concrete cube	500/- 500/- 300/- 1200/-
POST CONCRETING	Cracks Rebound hammer test Compressive strength	2000/- 2000/- 1200/-
	Total cost of all test for material goes for:	60,300/-

Table IV: AQC's Selected Related to Materials 38 AQC's selected

FOUNDATIONS STEPS	COC'S RELATED TO WORKMANSHIP	COSTS (in Rs)
EXCAVATION	Setting of corner benchmark Marking position Constructing dewatering level	2000/-
BASE COURSE	Dressing of loose material	448/-
PCC	Surface level Layer thickness Marking canter line	512/-
REINFORCEMENT	Cantering Cover n spaces for reinforcement	2240/-
FORMWORK	Joint sealing Marking concrete level	2048/-
CONCRETING OF FOOTING	Surface levels Surface regularity Alignment of embedded item such as anchor	960/-
POST CONCRETING	Surface texture	320/-
	Total cost	8528/-

Table 5: AQC's Selected From CQCs Related To Workmanship

VI. CONCLUSION

The purpose of conducting preliminary survey with construction experts helped to:

- Study construction Quality index (CQI) and its related terms to quantify the quality of building facility ie. Residential Footing
- Identified suitable measurement scales for Construction Quality Characteristics of materials and workmanship and its cost to quantify quality by determining acceptance quality characteristics (AQC) from CQC from construction experts.
- Incorporated Construction Quality Characteristics related to Levels of Footing system in the development of quality index which gives more contribution in quantifying quality of the same. This will result in developing a manageable quality index.
- Got necessary recommendations from the construction experts as a guideline for further study to formulate construction quality index for building facility.

- Quantify quality which will increase the awareness in a contractor towards quality which leads to improvement in quality of construction.
- Total cost of all testing goes for 76,800/- from survey it is observed that basic testing of material to quantify quality can be done in 60,500/- (saved 16,300/- for material testing) For workmanship cost per footing was 10,792/ which has drop down to 8,528/- (saved 2,264/- per footing) Therefore reduction in costing achieved

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