Root Cause Analysis of Defects in Buildings

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Abstract- *Time, Cost, Quality are three basic parameters of any construction project. As far as construction work is considered, Quality is always compromised over another two parameters. Though it is a fact that poor quality affects directly or indirectly to customer, builder and contractor; still quality gets neglected many times. To tackle any defect it is necessary to find out its root cause. Without knowing root cause, it is impossible to overcome that defect. In Root Cause Analysis (RCA) is the process of identifying causal factors using as tructured approach with techniques designed to provide a focus for identifying and resolving problems. Tools that assist groups or individuals in identifying the rootcauses of problems are known as root cause analysis tools.*

Every equipment failure happens for a number of reasons. This study aims that the analysis of root cause for various construction defects. 5-why technique is used for analysis which is an iterative question-asking technique used to explore the cause-and-effect relationships underlying a particular problem. Another method for inter-relating causal factors, Relative important index is used for ranking the defects. By using RII formula the factor which are responsible for the defects are ranked. The analysis is done which shows the most responsible factors affecting the defects in construction projects. Also the factors responsible by organization lever were analyzed.

Keywords- Construction; Cost .Time, Quality, Money, Machinery, Material, Methodology and Manpower.

I. INTRODUCTION

The construction industry's reputation has been stained by poor quality performance. Construction defects decrease the satisfaction of property owners and erode the confidence of the financiers, buyers, and end users of construction projects. Total construction costs are increased by lost productivity, higher rework and insurance costs. Defective construction undermines the reputations of affected contractors and threatens their profitability.

Unsurprisingly, defects are one of the major causes of dispute and construction litigation. There is often disagreement when it comes to identifying what a construction defect is. This, of course, will be down to the differing viewpoints and interests of those who are asking the question and/or making the determination. These parties typically include the builder, developer, contractor, subcontractor, material supplier, product manufacturer and homeowner.
There is a big difference between a construction defect and a nuisance claim such as quaking floor or conditions resulting from lack of maintenance or normal wear and tear. Construction defects could range from complex foundation and framing issues, which threaten the structural integrity of buildings, to aesthetic issues such as improperly painted surfaces and deteriorating wood trim around windows and doors. Ultimately, with respect to construction defects, prevention is a better strategy than mitigation, and mitigation is a better strategy than litigation.

Hence detection of root cause of any construction defect is significant work. Without knowing root cause; it is impossible to overcome that defect. So Root cause analysis for various construction activities is needed to improve three basic parameters of any project i.e. Time, Cost, and Quality.

II. RESEARCH OBJECTIVE

Study and rectification of defects during various construction activities:

As main aim of dissertation is root cause analysis; it is necessary to study type, nature, severity of defects. With this study it will be easier to analyse stepwise responsible factors for defects.

Analysis of defects using 5-why technique:

There is need of analysis of rectified defects. To analyse defects thoroughly; 5-why technique is used. It will help to understand flaws in procedure which are contributing to defects.

Segregation of responsible factors or parties for defects:

After identifying root causes it is necessary to segregate them. Without segregation it will not be possible to suggest strategic process for defect prevention.

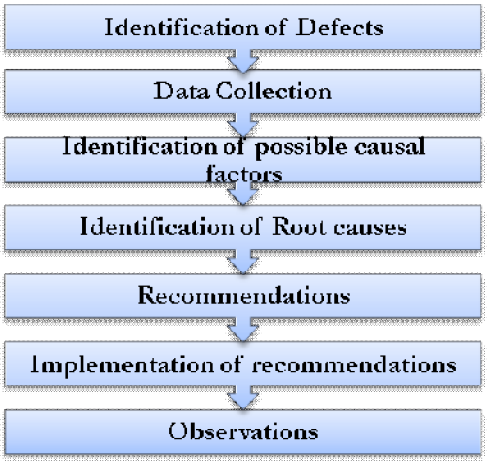
Strategic process for Construction defect prevention:

At last, strategic process will be suggested to minimize or stop malpractices which cause defects.

III. METHODOLOGY

Based on the literature reviewed methodology for research work is outlined. This chapter highlights detailed methodology of research and Study area details.

As mentioned in the scope of research; five activities are taken into account for study. Steps mentioned below are repeated for every activity for root cause analysis. Methodology is broadly divided into five steps as shown below-



Identification of defects:

The term defect is explained in chapter 2.It is necessary to identify any problem to think about its solution. Problem identification will help to understand severity of defect. In this step problem and its detail description, its effects will be briefly discussed.

Data collection:

After identifying problem it is necessary to prove its existence. There is need to analyse a situation fully before moving to factors that contributed to the problem. Data collection will be done in such a way to answer questions like what proof do you have that the problem exists ? How long has the problem existed ? What is the impact of the problem? Data will be in format of actual photographs, reports generated at site etc.

1) Identification of possible causal factors:

To identify causal factors 5-why technique will be used. It's a very important step as it is going to decide root cause for defect. During this step some questions like what sequence of events leads to the problem? What conditions allow the problem to occur? What other problems surround the occurrence of the central problem? Must be answered.

2) Identification of Root causes:

In this root cause will be finalized on the basis of analysis of causal factors. Main problem, generated problems, responsible factors, root cause of defect generation will be identified in this step.

3) Recommendations:

What should be the strategic procedure or solution needed to minimize defects will be suggested under this step.

Implementation of Recommendation:

What should be the action plan carry out to full fill the need of recommendations and to minimize the defects in future at other location on construction site.

Observations:

Also observe the same kind of situation at different location for next month of period and close the defects which observed previously.

IV. OBSERVATIONS AND FINDINGS

Defects that appear during construction or within a relatively short time after completion, are usually caused by poor quality materials, improper mix design, lack of proper placing and curing procedures, or poor workmanship. The repair of defects is both difficult and costly. The best repair work will not be as good as an original properly finished surface. Every effort should be made both prior to and during construction to avoid the use of materials or construction practices that can cause defects.

After finalizing methodology, detailed root cause analysis is done for various construction activities. There are five major on-going activities and 5 defects per activity are taken into account for root cause analysis. Thus, this chapter focuses on root-cause analysis of defects.

- **Defects in RCC**
- Honeycombing
- Steel Exposure
- Cracking
- Blistering
- Dusting

- **Defects in BRICKWORK**
- Breakable blocks
- Uneven brick size
- Crack at the joint of the beam & wall
- Plumb out
- Cracks at Brick joint

- **Defects in PLASTERING**
- Major Cracks
- Varying thickness of plaster
- Crazing
- Debonding
- Lack of Hardness

B. *Defects in Reinforced Cement Concrete (RCC)*

RCC activity is major activity in any type of construction as strength of structure depends on it. It is necessary to defects and malpractices regularly occurring during this activity. But only identification of defects is not going to solve the purpose hence it is necessary to find out root cause of every defect.

1) Honeycombing:

Honeycombing refers to voids in concrete caused by the mortar not filling the spaces between the coarse aggregate particles. It usually becomes apparent when the formwork is stripped, revealing a rough and 'stony' concrete surface with air voids between the coarse aggregate. Sometimes, however, a surface skin of mortar masks the extent of the defect. Honeycombing may extend some depth into the member. Honeycombing is always an aesthetic problem, and depending on the depth and extent may reduce both the durability performance and the structural strength of the member.

Identification of Defect:

During deshuttering of various structures it has been found that structures were showing not only lot of honeycombing but also steel reinforcement protruding out in the case of columns.

Data Collection

Photos showing honeycombing at structure

Identification of possible factors

Few of mentioned or combination of mentioned factors are responsible for honeycombing.

- Increased W/C ratio: Increase W/C ratio makes concrete more workable hence aggregates get separated from homogeneous mixture and it leads to honeycombing.
- Inadequate vibration: Compaction is very important procedure during casting. It reduces voids in mix. Inadequate vibration gives rise to more number of voids which results into honeycombing.
- Placing of concrete from more height: It causes separation of aggregates and liquid component of mix. Loss of water and separation of aggregates further results into honeycombing.
- Inappropriate proportion of aggregates: Excess quantity of aggregates leads to honeycombing.
- Voids in shuttering material: Voids in shuttering material leads to loss of water from mixture. This imbalances concrete mix. This results into honeycombing.
- Improper covering: Due to inadequate covering steel touches shuttering material. This avoids concrete mix to cover steel. It leads to protruding steel reinforcement.

Identification of Root Cause

- **1-Why** = Honeycombing observed due to improper Vibration and placing of concrete
- **2-Why** = Ignorance of labour about vibration and placing is due to less comfort level at work
- **3-Why** = Comfort level is low because of high height column so they used to get filled at a time instead levelwise
- **4-Why** = No levelwise filling to save time and shuttering material
- **5-Why** = Pressure for completion and use of conventional shuttering material as it saves cost to contractor

As shown in Fig ,it is clearly seen that negligence about technical things like vibration, placing of concrete leads to honeycombing defects. This negligence is occurred due to lack of knowledge and motivation. Finally Out of three major factors i.e. Time, Cost Quality; Quality gets compromised over time and cost

Recommendations

To minimise the incidence of honeycombed concrete:

- Ensure the mix has sufficient fines to fill the voids between the coarse aggregate.
- Use a mix with appropriate workability for the situation in which it is to be placed.
- Ensure the concrete is fully compacted and the placing methods minimize the risk of segregation.
- Check that the formwork is rigid and well braced, the joints are watertight and any penetrations through the formwork e.g. form ties, are properly sealed.

V. ROOT CAUSE ANALYSIS

In detailed observations of defects, their cause-effects, procedural lacunas etc. explained. As mentioned earlier total 25 defects are taken into consideration on a sample basis. It is observed that most of defects are occurring due to human factor. Many interwoven factors make identification root cause complex as multiple factors are responsible for it.

Present Scenario

Table Error! No text of specified style in document..1: Break-up of Construction Costs

	Materials %	Construction Equipment %	Labour %	Finance %	Enabling Expenses %	Admin. Expenses %	Surplus %
Building	58-60	4.5	11-13	7-8	5.5-6.5	3.5-4.5	5-6
Roads	42-45	21-23	10-12	7-8	5.5-6.5	3.5-4.5	5-6
Bridges	46-48	16-18	11-13	7-8	5.5-6.5	3.5-4.5	5-6
Dams, etc	42-46	21-23	10-12	7-8	5.5-6.5	3.5-4.5	5-6
Power	41-43	21-24	10-12	7-8	5.5-6.5	3.5-4.5	5-6
Railway	51-53	6-8	16-18	7-8	5.5-6.5	3.5-4.5	5-6
Mineral Plant	41-44	20-22	12-14	7-8	5.5-6.5	3.5-4.5	5-6
Medium Industry	50-52	7-9	16-18	7-8	5.5-6.5	3.5-4.5	5-6
Transmission	49-51	5-7	19-21	7-8	5.5-6.5	3.5-4.5	5-6

Source: Construction Industry Development Council Survey

As shown in above table, almost half of the construction cost expenditure is done on human factor involved in Construction. Still achievement of zero defects is acts as a Myth till date. As per survey of Construction Industry Development Council survey, 70-80% defects are observed in residential and office buildings as shown in following graph -

Diagnosis is the essential first step in dealing with defects. It requires scientific investigation of defects. The efficient and effective investigation and correction of defects is often spoiled by failure to distinguish symptom and cause and the over enthusiastic starting of repairs before completing diagnosis.

To deal with this complexity root causes, they are divided into five broad categories as Money, Machineries, Material, Management of Time and Manpower. As said solely or in combination of these factors are responsible for defects, it is necessary to find out inter-relationships between all these factors. For mentioned purpose relationship matrix for every activity is formed. A basic statistical model also developed to priotorized classes of root causes. Such study will be helpful for designing Quality management system to achieve Zero Defect Target.

RELATIVE IMPORTANT INDEX:

Relative Importance Index method helps to determine the relative importance of the various factors affecting on defects. In this scale 1 represents no effect, 2 represents slight effect, 3 represents significant effect, 4 represents very significant effect and 5 represents extremely significant effect.

RELATIVE IMPORTANT INDEX (RII)

$$RII = \frac{(5n_1+4n_2+3n_3+2n_4+1n_5)}{5(n_1+ n_2 +n_3 +n_4 +n_5)}$$

The RII was used to rank (R) the different factors affecting on defects. These rankings made it possible to cross-compare the relative importance of the factors as perceived by respondents. Each individual factors's RII perceived by all respondents should be used to assess the general and overall rankings in order to give an overall picture of the major defects.

VI. RESULT

As explained in chapter 6, root causes of various construction activity defects are analysed. Thischapter summarizes study work carried out.

HONEYCOMBING				
SR.no	RESPONSIBLE FACTOR	RII	RII (%)	RANKING
1	MATERIAL	0.410	10.10	2
2	EQUIPMENT	0.390	9.61	3
3	QUALITY CONTROL	0.260	6.40	8
4	POOR MIX DESIGN	0.200	4.93	12
5	INAPPROPRIATE PROCEDURES	0.280	6.90	6
6	LACK OF EXPERIENCE	0.270	6.65	7
7	POOR MONITORING AND CONTROL	0.360	8.87	4
8	CURING	0.100	2.46	15
9	WORKABILITY	0.440	10.84	1
10	CEMENT CONTENT	0.330	8.13	5
11	POOR PLANNING	0.250	6.16	9
12	POOR COMMUNICATION	0.220	5.42	11
13	INADEQUATE FUND ALLOCATION	0.130	3.20	14
14	TOO MANY RESPONSIBILITIES	0.190	4.68	13
15	POOR WORKMANSHIP	0.230	5.67	10
		4.060	100.000	

1. HONEYCOMBING

From the above analysis for defects on Honeycombing we choose the top five factors from the ranking that influence the most .The first five factors are

1. Workability , 2. Material , 3. Equipment , 4.Poor Monitoring and control , 5. Inappropriate Procedures.

- For different defects top 5 factors are considered with high percentage of effectiveness which with proper monitoring can reduce the defects. Controlling on these top factors time, cost and manpower can be saved.

2. STEEL EXPOSURE

From the above analysis for defects on Steel exposure we choose the top five factors from the ranking that influence the most .The first five factors are

1. Poor Monitoring and control , 2. Poor Workmanship , 3. Quality Control , 4. Workability, 5. Lack of Experience.

For different defects top 5 factors are considered with high percentage of effectiveness which with proper monitoring can reduce the defects. Controlling on these top factors time, cost and manpower can be saved

VII. CONCLUSION

Total 15 different defects of three different activities are considered for study. Various defects are rectified and thoroughly studied.

- For different defects top 5 factors are considered with high percentage of effectiveness which with proper monitoring can reduce the defects. Controlling on these top factors time, cost and manpower can be saved.
- Finding of root cause is not linear process; it becomes very complex due to involvement of various components and participant.

Scope for future work

- This study is carried out for five activities and 25 defects. There is scope to consider other various defects.
- In this study 5-why technique is used for root cause analysis; there is further scope to use various techniques like fish bone diagram, cause-effect analysis etc.
- There is scope to use statistical methods for finding out inter relation between contributing factors to defect.

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