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Application of Lean Six Sigma in cast in-situ construction

AsmitaGhule[1], Prof.SatishWaysal[2]

[1]PG Scholar, Construction Management, Karmaveer Adv. Bbaburao Ganpatrao Thakre College of Engineering, Nashik, India-422013;
[2]AssistantProfessor,Department of Civil Engineering, Karmaveer Adv. Bbaburao Ganpatrao Thakre College of Engineering, Nashik, India-422013;

Abstract

Construction sector is living in continuous change environment. Rapid growth of construction industry and increasing requirements, demands of customer towards the safety, quality assurance has put pressure on construction companies for implementing advance quality tools. This paper studies the implementation of Lean Six Sigma in construction industry to reduce the deviation and variation in the process of construction activities. The DMAIC (Define, Measure, Analysis, Improve, Control) approach of six sigma and tools of each stage of this methodology is been discussed in this paper. A case study of a residential building has been carried out which demonstrates the application of Lean Six Sigma principles to some construction works: R.C.C work, brickwork and plastering. A defect assessment sheets were prepared for every work and the current sigma level of each has been computed. DMAIC methodology has been applied to improve the quality standards and reduce the wastages and variation in the process by analyzing the defects, their severity and root causes. The study aim at understanding the need of construction industry and customer requirements from quality perspective and fulfill them with the principles of Lean Six Sigma. The results of study suggest that the proper management and minor changes in the work procedure will help to achieve the desire quality standards.

Keywords: Lean Six Sigma, DMAIC methodology, quality standards, case study.

1 Introduction

The aim of construction project management is to satisfy the customer requirements and demands, delivering the safe and secure, qualitative and financially feasible project. Now a day's customer requirements towards the quality assurance are increased, as this is one time investment sector. Quality control and quality assurance are very essential parameters to maintain the standards and productivity on site, so it is essential to check the quality of ongoing process of construction activities. The problem is the variation and deviation in the work process, which is censorious to the quality. One popular approach to reduce the variation and for process improvement is Lean Six Sigma. It is a statistical approach, which is combination of two different process improvement methodologies, but there focus is on the different parameters of the process. Lean focuses on waste reduction and six sigma focuses on quality of the product by reducing the defects.

Toyota production is a birthplace of Lean manufacturing. It is based on the theory of continuous improvement of the process by eliminating wastage. Lean focus on the customer viewpoint, customer voice and gives a maximum value during production. Where, six sigma is a derived from the Greek alphabet and was first developed by the Motorola in 1986. The main objective is to analyses the causes of defects and removing it from the process of production. This paper studies the lean six sigma as one combine statistical approach with major aim to reduce the defects and wastage from the process. The paper describes the basic methodology of DMAIC approach, which is a five-stage improvement process. A case study of one residential building has done to which this methodology has been applied to reduce the defects and to ensure the quality of construction.

2 Concept of lean six sigma

- **Lean**

Taiichi Ohno, who was an engineer in Toyota production, proposed the theory of lean production and now it has become a fundamental business philosophy. The theory is based on the concept of elimination of waste from the workflow. The three kinds of works were identified form Toyota production system: Waste of time and materials, variations in the workflow and overload of workers etc. In Lean methodology, there is a continuous focus on customer and lowering the cycle time of process by eliminating all the wastage from the process.

- **Six sigma**

Six sigma has two different meanings- one from quality management and another one is from statistical prospective. In quality management it is a set of tools, used to improve the quality of the product by reducing the defects in the product. It helps to analyses the causes of defects and removing it from the process of production. In mathematical statistic, 'σ' is standard deviation and six sigma means the standard normal distribution, elucidated by the symmetrical bell shaped curve. In six sigma, it considers range from -6σ to +6σ, which includes 99.9997% of data, therefore it gives close to zero defects in the outcome. It provides a five-stage process improvement methodology- DMAIC. The steps are:

1. Define: This is the first step in which need, requirement, expectation and voice of customer is need to define. More precisely, we have to identify which process, product, or service need improvement. The scope of project will decide in this stage.
2. Measure: the selected existing process is measure, evaluated and compare in this step. The current effectiveness of process is evaluated with the help of data collection plan and then the goals are set.
3. Analyze: in this phase, data collected regarding the process is analyzed to find out the root cause of defect or problems. The factors which are affecting the efficiency of the process is find out in this stage with the help of cause and effect diagram, Pareto chart or control charts, TRIZ, scatter diagrams etc.
4. Improve: solution to the problems analyzed is found out in this improve stage. It focuses on the use of various experimentation and statistical techniques like brain storming, mind mapping, mistake proofing, value stream mapping etc. to generate possible improvements to reduce defects and variations.
5. Control: this is the last stage of DMAIC approach in which the control plans are established to ensure that the problems causing variation and defects are eliminated from the process. The new modified process is implemented and the performance of this process is also measure

3 Research methodology

3.1 Applying lean six sigma in construction

Lean Six sigma has been used in manufacturing industry. Now this paper gives detail about how this methodology can be used in construction industry. A case study of one residential building has done to which the DMAIC methodology is applied to some activities like RCC work, brickwork and plastering work. For the data, collection a quantitative study approach has adopted in which observation method of data collection has used to collect all the data related to site. A defect assessment sheet has prepared for every work from which the sigma level of current work is calculated. From the analysis of data collected the sigma level of each work is:

Table 1: Sigma level

Sr. No	Work name	DPMO	Yield	Sigma level
1	Concreting work	31746.032	96.825	3.356
2	Brick work	25541.126	97.446	3.451
3	Plastering work	38764.266	96.124	3.265

To calculate the sigma level, the Defects per Million Opportunities (DPMO) need to calculate. From the standard six-sigma table, the sigma level of current work has been worked out. The mathematical expression for DPMO is:

$$\text{DPMO} = \frac{\text{No.of 'X' in data assessment sheet x } 100000}{\text{No.of opportunities of defects x No.of units}}$$

3.2 DMAIC methodology

After estimating the sigma level, the DMAIC methodology has applied to improve the quality of work as follow:

1. Phase: Define

The factors, which are censorious to quality, are identified to address the problem with the help of project charter

Table 2: Project Charter

Project Title: Defects reduction in construction	
Purpose for selecting the project: It is difficult to maintain the quality parameters in cast in situ construction as the site conditions are different than the factory or laboratory environment. It may result in to the poor quality of work and increase in wastage or resources and time overrun. So to avoid these things a site project is selected to improve the process by applying Lean six sigma.	
Project Objective: To reduce the defects and wastages of material by applying Lean Six Sigma in concreting, brickwork and plastering work.	
Voice of the Customer (VOC)	Quality of structure within the budget and without compromising the safety.
Focus of project:	Main activities of construction- concreting, brickwork and plastering work.
Team members:	Contractor, project manager, quality supervisor etc.
Expected Benefits:	Considerable reduction in waste and defects in the structure.
Expected Customer Benefits:	Will get quality home with required safety standard.

Furthermore, to understand the process of construction the SIPOC diagram is used as depicted in the following table:

i. R.C.C. Work:

Table 3: SIPOC for RCC

Supplier	Input	Process	Output	Customers
Builder	1. Cement 2. Aggregate 3. Sand 4. Water 5. Steel 6. Binding wires 7. Batching plant 8. Transit mixer 9. Wheel barrows 10. Shuttering 11.Screeds 12. Vibrator 13. Shovel 14. Measuring tape 15.Float, trowel 16. Spirit Level	1. Cleaning the surface 2. Setting out position of each structural member according the structural drawing in which dimensions and location of each member is given 3. Place reinforcement as instructed in drawing 4. Fix the formwork of each member 5. Pouring concrete in member 6. After stripping time remove formwork 7. Curing of member	Finished concrete member	Flat owners

ii. Brick Work

Table 3: SIPOC for Brick Work

Supplier	Input	Process	Output	Customers
Builder	1.Bricks 2. Mortar 3. Mortar pan 4. Wheel barrows 5. Trowel 6. Spirit level 7. Tape measure 8. Plumb bob 9. Line and pins 10. Water level 11. Spades 12. Mason Square 13. Jointer	1. Line out the area with measuring tape. 2. The bricks 1st laid dry along with a string tightly stretched between cornerstones. 3. Then each brick is removing and lay over a bed of mortar. 4. Check each course for alignment, level and verticality. 5. Mortar with mix ratio of 1:4 is prepared and thickness of mortar joint is 10 mm. 6. Raked out the mortar from the joint with a trowel of each course. 7. Complete the height of wall up to 1 meter in a day.	Brick walls	Flat owners

iii. Plastering work:

Table 4: SIPOC for Plaster Work

Supplier	Input	Process	Output	Customers
Builder	1.Cement 2.Sand 3.Water 4.Finishing trowel 5.Window trowel 6.Corner trowel 7. Mixing bucket 8. Plasterer float 9. Scarifiers	1. Roughen the entire masonry wall 2. Clean the joint and surface of wall 3. Fixing dots on the wall to get uniform thickness of plastering 4. Screeds are formed in between the dots 5. Applying the first coat of 12 mm thick plaster by means of trowel 6. Leveling the surface by means of flat floats and straight edges 7. After setting of first coat, roughen it with scratching tool to form a key to the second coat 8. The thickness of finishing coat is 2 to 3 mm and applies it with wooden floats 9. after completing it, keep sprinkling water for 7 days min	Finished wall surface	Flat owners

2. Phase: Measure

In measure phase the Pareto charts has used which helps to identify the significant factors which need to focus more and allows the better use of resources.

i. R.C.C Work

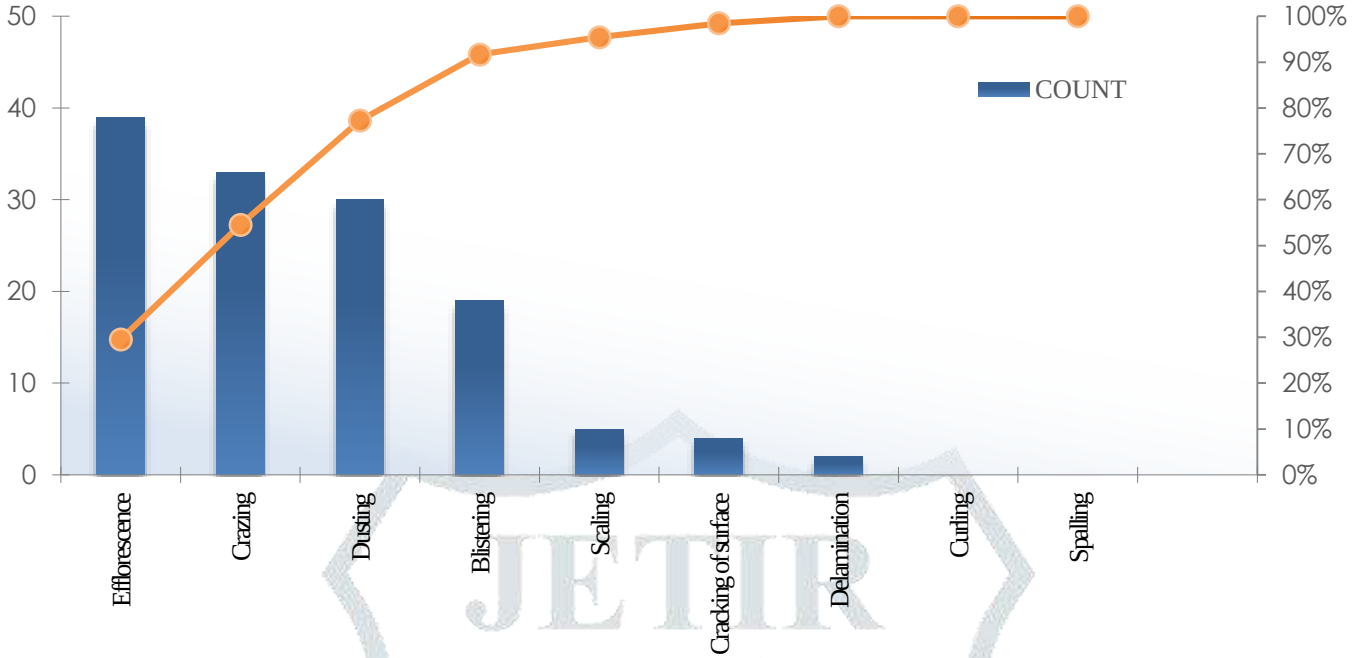

Figure no 1: Pareto chart of R.C.C work

ii. Brick Work

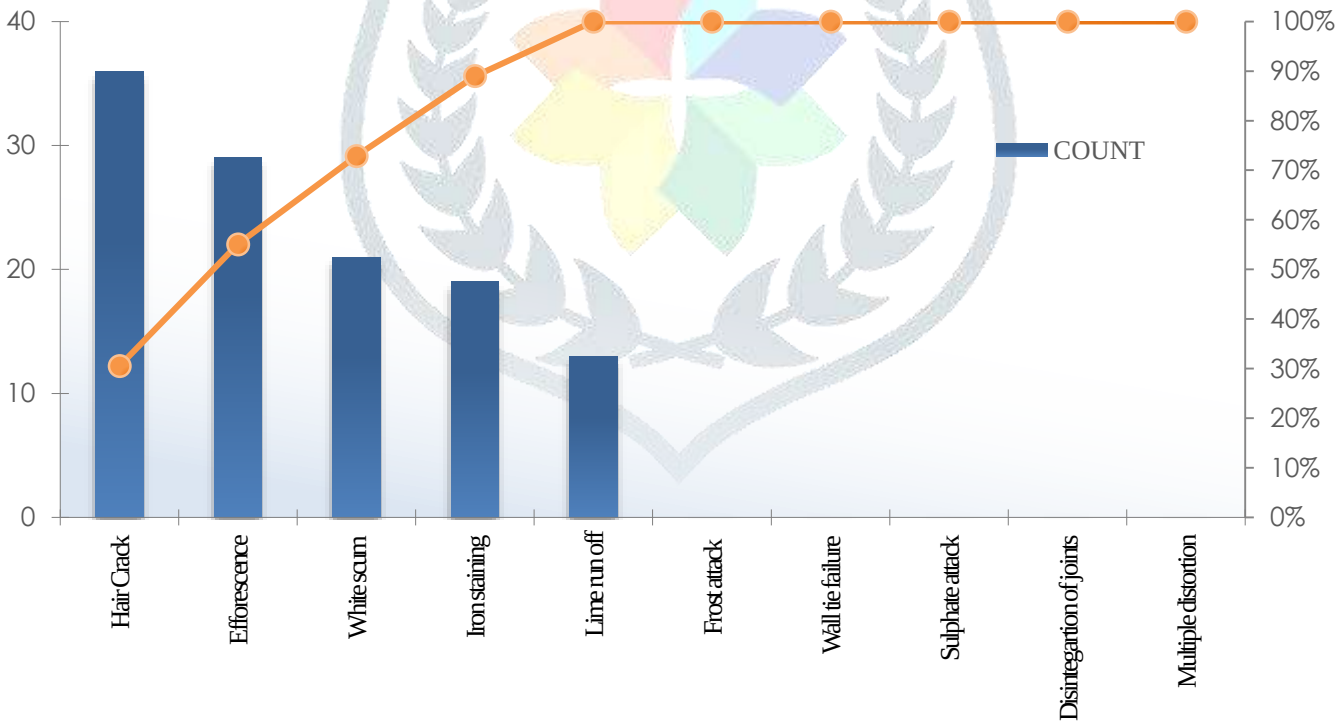

Figure no 2: Pareto chart of Brick Work

iii. Plastering Work

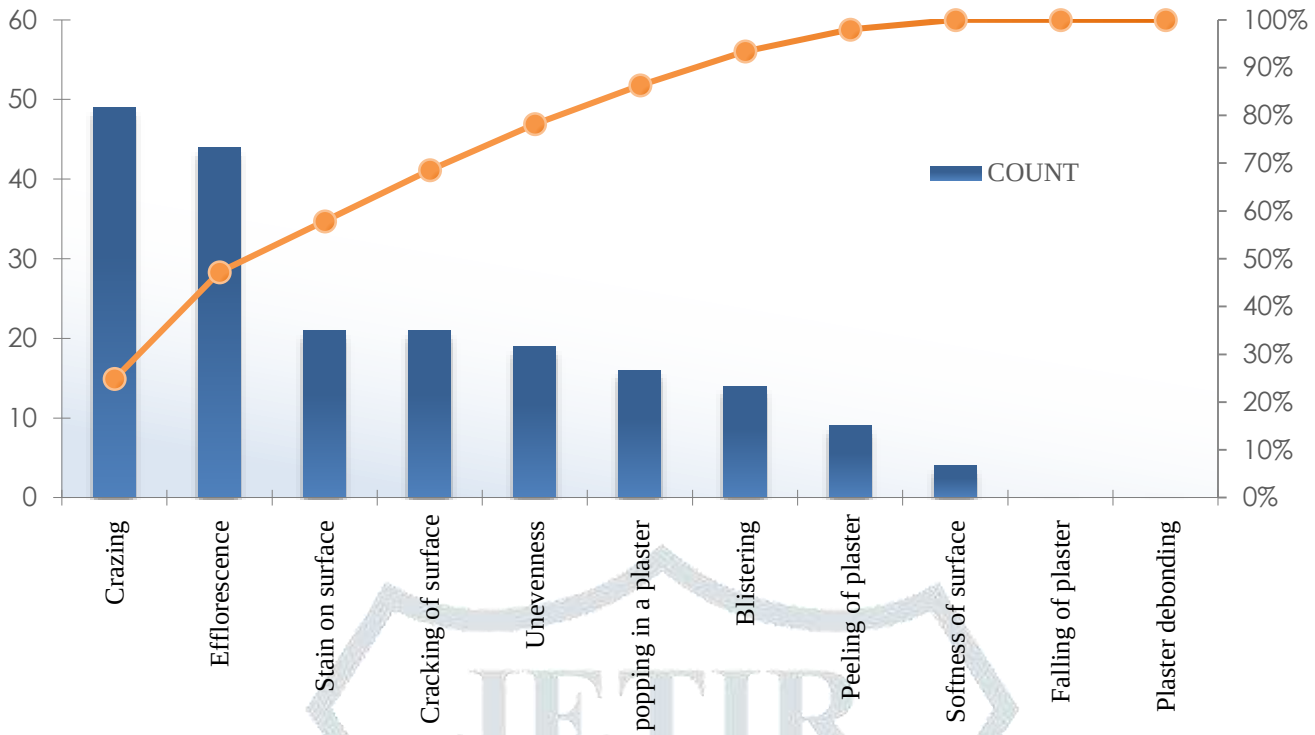

Figure no 3: Pareto chart of plastering work

3. Phase: Analysis

In analysis phase, Cause and Effect diagram has used to analyse the current outcome and the factors influencing the outcome. The diagram gives a graphical representation between the outcome and the influencing factors, helps to understand the causes behind the defects.

i. R.C.C Work

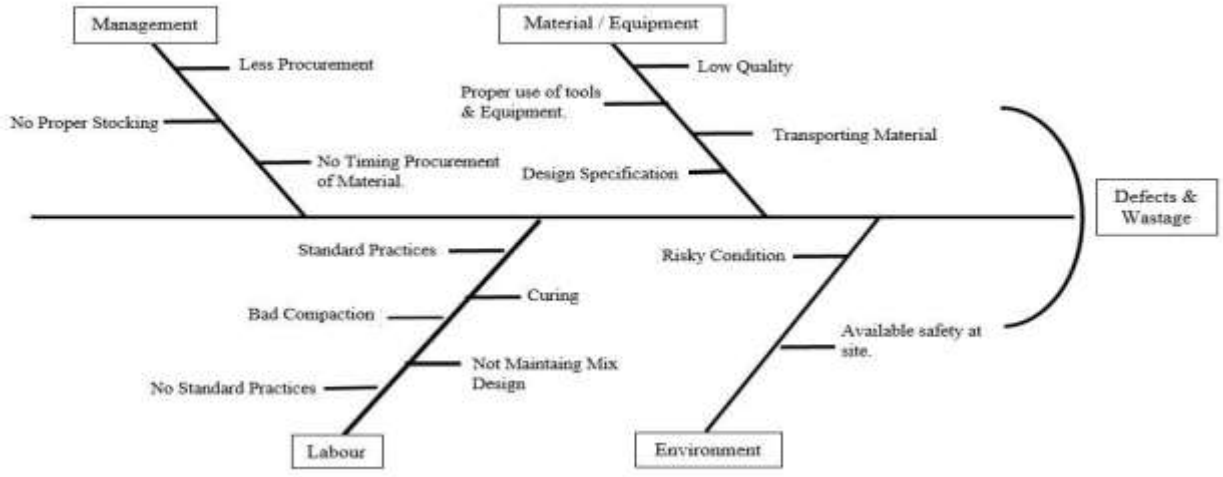

Figure no 4: Ishikawa Diagram for RCC Work

ii. Brick work

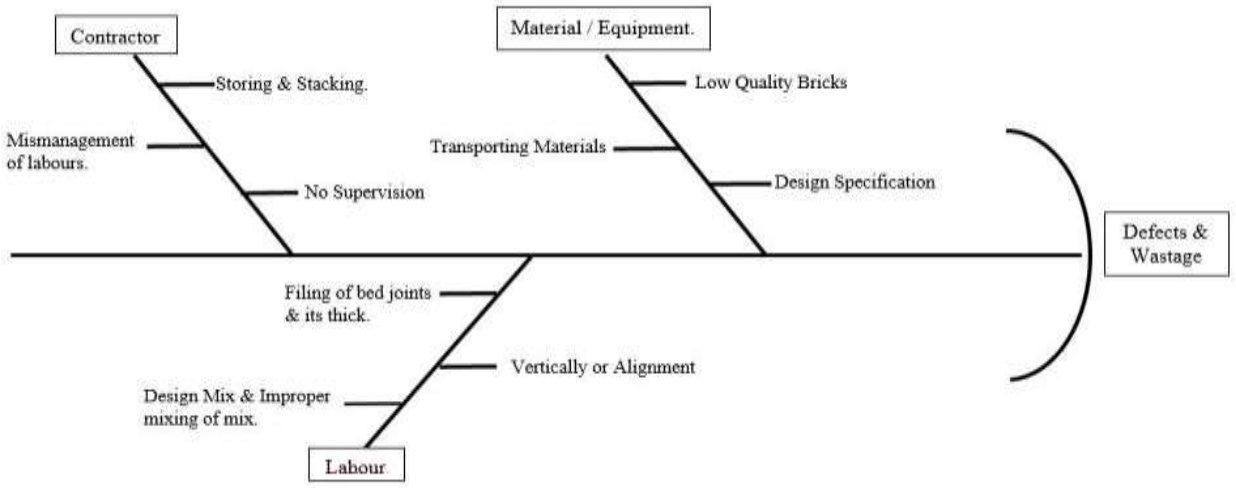

Figure no 5: Ishikawa Diagram for Brick Work

iii. Plastering work

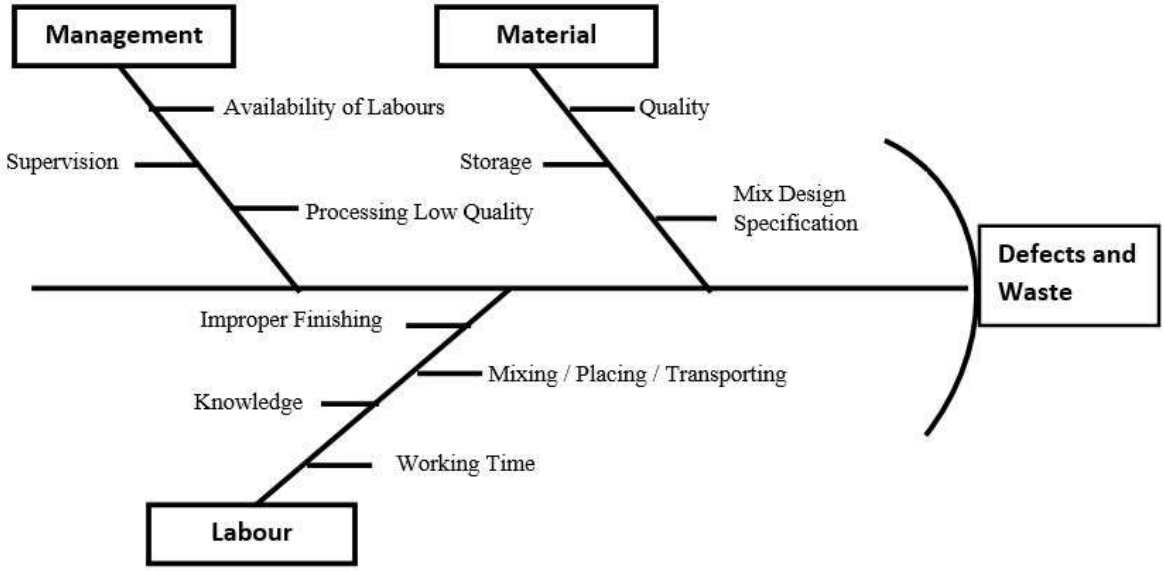

Figure no 6: Ishikawa Diagram for Plastering Work

4. Phase: Improvement- Corrective Actions

i. R.C.C work

- Improve supervision of work
- Execution of work as per given design specification and standards
- Quality and waste control audit
- Co-ordination between contractors and workers
- Making inventory plans
- Attention towards maintaining stock of materials at site
- Improving work safety at site
- Checking availability of equipment and tools prior the start of work
- Checking quality of material while receiving at site
- Allocating skilled workers for important and tedious works

ii. Brick work:

- Use of class 1 bricks
- Proper supervision of brick bonds with maintaining uniformity
- Pressure washing of efflorescence and lime run out
- Sealants can be applied on the surface of wall
- Giving attention to uniform bed thickness throughout the work
- Following a proper mix design mix of mortar and standard practices at site
- Proper care should be taken during transporting bricks and while placing them

iii. Plastering work:

- Curing should be given more attention
- Curing of base coat 1 day before plastering must be don

- Following standard practices of plastering with given mix design.
- Well-graded sand free from bulking and organic impurities should be used
- Surface of plaster should be prepared first before starting of work
- Level marks should be made to avoid uneven surface

5. **Phase: Control**
   Control plan will help us to keep a check on the various preventive measures, which are taking to achieve the desired result. The checklist prepared for defect analysis can be used to check the improvement in work. Establishing a performance measure, monitoring and controlling team to check the improvement in the process.

4 Conclusion

Quality is one of the crucial parameter considered in construction world. However, completing work within the stipulated time period without compromising the quality is one of the major managerial and challenging tasks faced by construction firm. In maintaining the quality, various factors, which have a high impact on quality, need to be identified so that work can be executed with required quality standards. This paper has studied different construction activities like R.C.C Work, brickwork and plastering work of residential building. To find out the root causes of defects occurred, its impact on quality and the measures to reduce them, a systematic framework of DMAIC methodology based on six-sigma principle has been used. The various tools has been used in each step of DMAIC approach which gives a brief and close check on each activity of construction, it increases the quality and at the same time it will helpful to maintain the time period.

5 Future Scope of work

The research of study is mainly focused on the conceptual framework for finding out root causes behind defects, lowered quality standards and for applying lean six sigma. It is an advance quality control tool, which uses many quality management tools in its methodology. In this study, this technique has applied to three activities of construction i.e. RCC work, Brick work, plastering work. Further, it can be apply to various construction activities where quality plays an important role. However, to apply this paper based research work in actual site practices it need some standard guidelines to be set and knowledge about the same should be given to the project managers.

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