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Implementation of Six Sigma for Quality Evaluation of RMC Plant with Dmaic Methodology

Darpan Keshore*, Dr Nitin Joshi**,
Harish Kumar Dwivedi***,
*Graduate Scholar, IES IPS Academy, Indore (MP),
**Professor, IES IPS Academy, Indore (MP),
***Asst Professor, IES IPS Academy, Indore (MP),

Abstract : **The study has been carried out to evaluate the steep rise in the production of ready mix concrete (RMC) in India due to ever increasing demand of concrete from the infrastructure as well as the real estate sector. There are lots of RMC plant that do not attain there desired goals due to the poor quality performance and manufacturing lead time. This study aims to identify and analyze the major quality factors for RMC plant at Indore.**

The feedback of company identified with customer satisfaction survey which is ranked using relative important index (RII) scale. The research is to demonstrate the use of Six Sigma and lean Six Sigma methodologies in quality of concrete and lead time measurement with DMAIC approach in RMC plant at Indore. The existing sigma level of the company has been found to be 2.03, it shows poor level of company. In order to validate manufacturing system's current status, improvement potential and solutions, statistical tools such as excel state software and linear regression analysis were used. This ensured that all decisions were based on actual data. As a result of this study a set of solution were developed.

Keywords : Dmaic, Dfss, Rmc, Fifo, Lean, Six Sigma

I. INTRODUCTION

The construction industry in India has seen a remarkable growth in the recent time due to flourishing of infrastructure and real Estate projects the production of ready-Mix concrete (RMC) in order to cope with the continuously increasing demand from the construction industry. Ready-mix concrete is concrete that is manufactured in a factory or batching plant, according to a set recipe, and then delivered to a work site by truck mounted in–transit mixers. one of the biggest challenges faced by the RMC manufacturing is to consistently supply the desired quality of concrete to the customers.

The main objective of any type business is to make profit for increasing the growth of company, the selling price should increase and the manufacturing cost and manufacturing time should come down. Since the price is decided by the competition in the market, hence the only the way to increase the profit is to cut down the manufacturing cost which can be achieved only through continuous improvement in the company's operation. Six sigma quality programs provide an overall framework for continuous improvement in the process of an organization. Six sigma uses facts, data and root cause to solve problems.

In this study the quality improvement tools six sigma is implemented in a RMC plant which make mass production of concrete. Six sigma is suitable for construction process improvement Heon et al. (2008)

Six sigma is a quality improvement program that aims to reduce the number of defects to as low as 3.4 parts per million (Sokovic, 2005). Six sigma is reportedly easier to apply than many other quality management programs because it provides information about the change needed and the programs to execute the change.

The strategy is used is a five step improvement process: Define measure, analyze, improve and control (DMAIC). Lean manufacturing is a system of techniques and activities for running a manufacturing or service operation. First time the term "lean production" was used in an article was in 1988 by John Krafcik. The article was called "Triumph of the Lean Production System" and it was based on comparing the production systems of different car manufacturers.

The basic goal in any manufacturing industry is to achieve the quality product with minimum time and stipulated budget. The construction and manufacturing industry being one of the most dynamic, complex, fragmented, schedules and resources industry, it is always facing serious problem like low quality, low productivity and more manufacturing time of product etc, (Sokovic et al. 2005). Improvement of construction quality with quality improvement tools is beneficial on broad level projects. (Sawant and Pataskar, 2014). RMC plant produces more than 100 cubic meter concrete per day and cannot inspected properly before delivered to customer. Industry were facing critical quality related problems and sometimes rejection of lots at customer end. There are number of studies which use six sigma tools for quality evaluation of product but in all study only few related to the construction and manufacturing industry. Maximum RMC plants are facing the problem related to the quality and time management.

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II. METHODOLOGY

The methodology of Six Sigma and lean tools with DMAIC methodology is adopted for carrying out the research which is discussed in detail in this section.

a) Factors affecting quality and manufacturing and quality lead time.

A number of quality related and manufacturing lead time factors were identified for the ready mix concrete plant, on the basis of working operation in total 4 factors are finalized to make part of the survey questionnaire.

A questionnaire was aimed to rate those initially identified 4 factors of quality evaluation and operation according to their severity level on the given scale, RMC plant at Indore. A total of 50 respondents were selected for the survey.

b) Ranking of quality and time management factors.

A five point scale ranging from 1-5 was adopted to assess the degree of agreement of each factor where 1 means Poor, 2 means average, 3 means good; 4 means very good and 5 means excellent. This five-point scale was converted to a Relative Importance Index (RII) for each individual factor, using the following formula, as adopted by Chan and Kumaraswamy (1997) and Assaf et al (1995).

$$(RII) = \Sigma W / (H \times N)$$

Where ΣW is the total weight given to each factor by the respondents, which ranges from 1 to 5 and is calculated by an addition of the various weightings given to a factor by the entire respondent, H is the highest ranking available (i.e. 5 in this case) and N is the total number of respondents that have answered the question. The RII value range from 0 to 1 (0 as not inclusive); and the higher the RII, the more important is the cause of the delays.

c) Six Sigma approaches with DMAIC methodology.

The term "sigma" comes from the Greek letter σ which is the symbol for standard Deviation of a population in statistical mathematics. When a process is running at a 6σ level it means that the process is six standard deviations away from the customer Specification limits, in other words only average of 3.4 defects are produced per million Products.

- Prepare a project charter.
- Collect data like number of defected units and total number of units manufactured.
- Determine DPMO (defects per million opportunities)

$$DPMO = \frac{\text{No of Defected Units x 1000000}}{\text{Total No of Opportunities (Total units)}}$$

- To obtain current sigma level converts DPMO to sigma level conversion table.
- To obtain current Manufacturing lead time and order purchase system.
- Set a target and work in direction with planned approach to increase sigma level of an organization.

d) Lean Six Sigma Approach.

The main principles behind lean are presented in addition; some extensions such as Little's Law are presented to help illustrate the effects and dependencies between different manufacturing parameters. LSS is an integration of both Lean and Six Sigma philosophies and the reasons behind LSS creation mainly lie in the synergies these two distinct methods offer for each other. LSS has the same DMAIC improvement process as the original Six Sigma, but in addition to Six Sigma tools, Lean tools are also incorporated into the different steps. Whereas Six Sigma mainly focuses on defect and variation reductions, Lean ads more focus on process standardization and simplification as well as waste reduction during the manufacturing process Pepper & Spedding, (2010). Most recognized contributor to the creation of Toyota production system (TPS) was a Toyota motor company employee called Taichi Ohno who worked nearly sixty years at Toyota, starting from 1932. Main idea behind TPS was to eliminate all waste, which was defined to be "anything other than the minimum amount of equipment, materials, parts, space and time which are absolutely essential to add value to the product". (Modig & Åhlström, 2013)

e) Tools used

Six sigma has two methodologies DMAIC and DMADV. DMAIC is used to improve quality for existing business. Therefore DMAIC using MS Excel software implemented for defect measurement and analysis to improve quality in RMC plant. Improvement plan is suggested to improve quality and control plan is prepared to monitor over improvement plan in RMC plant producing concrete. The tools used for DMAIC implementation are

- Define : SIPOC- Supplier input process output
- Measure: Sigma level determination.
- Analysis: Statistical quality control using frequency distribution, cause and effect diagram.
- Improve: corrective action plan
- Control: checklist to control action plan.

III. DATA COLLECTION

This section describes the execution of the improvement project of RMC manufacturing process. The project was done using the Six Sigma DMAIC process with lean tools incorporated into the different steps.

a) SIPOC

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Whenever we want to start any process improvement activity, it is important to get the high level understanding of the process.

Table 1.1 SIPOC Analysis for RMC

Supplier	Inputs	Process	Output	Customers
RMC Plant	1.Cement 2.Sand 3.Aggregate 4.Water 5.Admixture 6.Batch Machine	1. Pumping of raw material 2. Batching of raw material according to the grade of concrete. 3. Dry mixing 4. Wet mixing 5. Weighting and filling in transit or non transit miller 6. Delivery through mixer/ miller 7. Sampling / cube casting 8. Quality control during casting	Ready mix concrete (RMC)	Builder or Owners

b) *Measure*With the problem defined, the next step is to identify all the related processes and their current capabilities. RMC manufactured using raw material like cement, sand, aggregate and fly ash. Most of the defects are contributed by raw materials. RMC inspected for these 17 defects lot at plant out of 6 defects lot, 10 defects were encountered in 132 samples in survey after that, time to know the manufacturing lead time process

c)

Table 1.2 : Test Report of Fine Aggregates

S.No	Test Name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Permissible limit
1	Fineness Modulus	2.34	2.56	2.76	2.74	3.82	2.2- 3.2
2	Silt & Clay	2.80 %	1 %	1.10 %	2.10 %	2.1 %	Max 5%
3	Specific Gravity	2.67	2.75	2.67	2.65	2.68	-----
4	Water Absorption	0.9 %	0.78 %	0.67	0.8 %	1.50 %	Max 2%

Table 1.3 : Test Report of Coarse Aggregates

S.No	Test Name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Permissible limit
1	Fineness modulus	5.90	7.2	6.20	6.32	7.1	Max 6.9 (20 mm)
2	Specific gravity	2.92	2.65	3.12	2.59	2.74	-------
3	Water absorption	0.9%	2.10%	0.9%	1.2%	2.12%	Max 2 %
4	Crushing value	22%	28%	29%	26%	42%	Max 30%
5	Impact value	25%	26%	28%	30%	38%	Max 30%
6	Abrasion value	15%	155	16%	23%	25%	Max 30%

Table 1.4 : Test Report of Cement

S.No	Test Name	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Permissible limit
1	Fineness of Cement	2.50%	2.69%	2.56%	4%	4.2%	Max 5%
2	Consistency of Cement	30%	30%	30.12%	32	32%	-------
3	Initial Setting Time	125min	130 min	140min	120min	156min	Min. 30min.
4	Final Setting Time	260 min	250 min	240min	235min	300min	Max 10 hrs
5	Compressive Strength (7days)	35 N/mm^2	34.78 N/mm^2	35.96 N/mm^2	34.20 N/mm^2	35.20 N/mm^2	Min 70%

Table 1.5: Check sheet of defects in Raw material and concrete cubes

S.No	Defects Factors	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6
1	Dimension of Cube	1	0	0	0	0	0
2	Rate of Loading	0	0	0	0	0	0
3	Temperature of Water	0	0	0	0	0	0
4	Moisture Content	0	0	0	0	0	0
5	Dosing of Admixture	0	0	0	0	0	0
6	Compaction	0	0	0	1	1	0
7	Fineness Modulus	0	1	0	0	2	---
8	Water Absorption	0	1	0	0	1	---
9	Impact Value	0	0	0	0	1	---
10	Crushing Value	0	0	0	0	1	----

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The graph below presents the Defects Factors and the Number of Defects

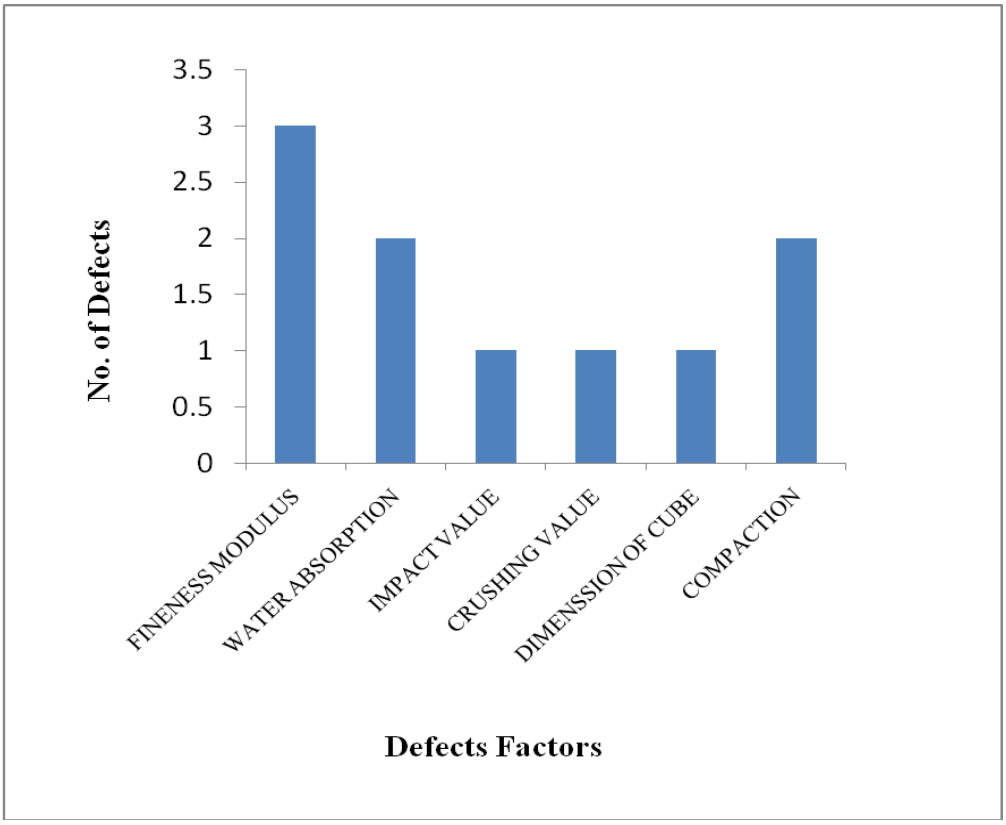

Fig. 1.1: Defects Calculation Graph

IV. RESULTS

The overall four factors that were considered for Customer Satisfaction Survey and Relative Importance Index (RII) method were performed. The various results thus obtained are discussed in the subsequent paragraphs

a) Customer satisfaction and relative importance index (RII) report

The customer satisfaction survey gives the information about the satisfaction level of some factors such as quality at site, punctuality at site, speed of operation and coordination with engineer. The overall report of the survey is shown in below Table 1.6

Table 1.6: Customer Satisfaction Survey and RII report

S.No	Factors	Excellent	Very Good	Good	Average	Poor	RII
1	Quality at Site	0	0	25	25	0	0.50
2	Punctuality at Site	0	0	3	39	8	0.38
3	Speed of Operation	0	0	10	31	9	0.40
4	Co- ordination with Engineer	0	0	37	13	0	0.54

b) Outcomes of Quality Measurement

Various defects factors are tabulated below

Table 1.7 : Total Defects Report

S.No	Defects Name	No. of Defects
1	Dimension of Cube	1
2	Rate of Loading	0
3	Temperature of Water	0
4	Moisture Content	0
5	Compaction	2
6	Fineness Modulus	3
7	Water Absorption	2
8	Impact Value	1
9	Crushing Value	1
	Total	10

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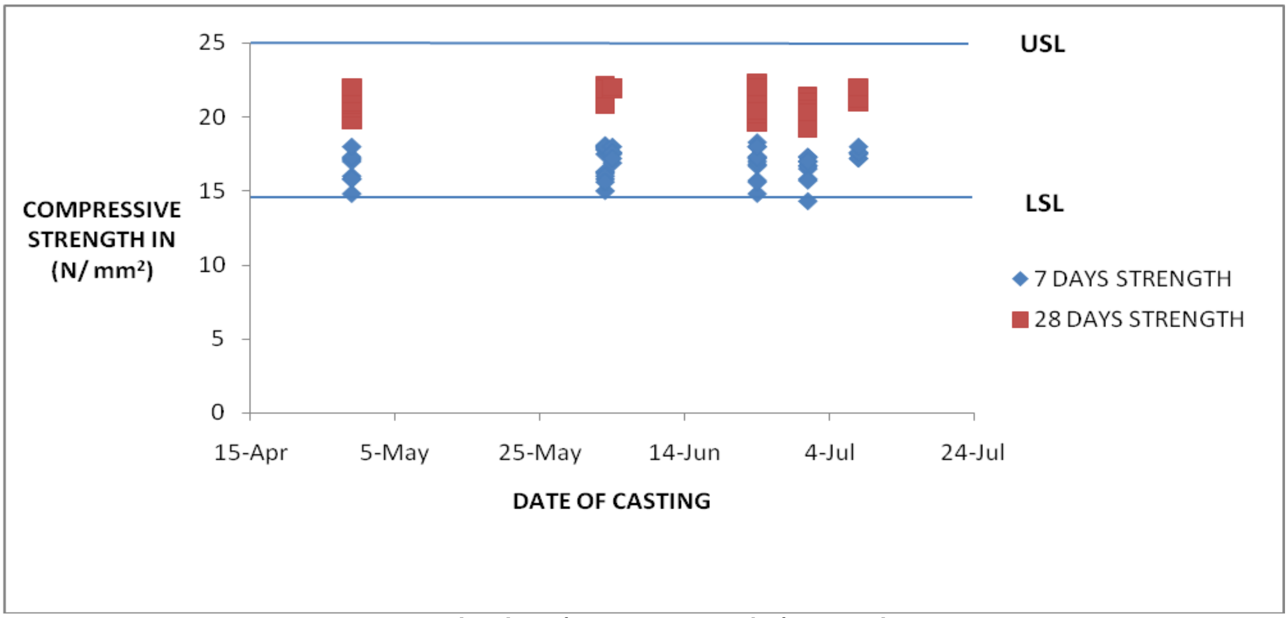

Fig 1.2: Statistical Analysis of Compressive Strength of M-20 Grade Concrete

Upper specific limit (USL) = 25 N/ mm^2
Lower specific limit (LSL) = 14.8 N/mm^2

V. CONCLUSION

Based on above analysis following conclusion were derived.

- Based on the literature survey the main causes of poor quality are root of raw material, unskilled labor's, poor technique of manufacturing, irregular supervision in the manufacturing and construction industry. The main factors more time of manufacturing were identified as less utilization of machine, material-related problems, owner's financial constraints, poor delivery system, unqualified/inadequate experienced labor, shortage of labor, and low productivity of labor.
- Factor affecting quality was ranked according to RII the most important factor affecting on company level is quality at site and punctuality. This is flowed by poor quality of raw material, improper compaction and poor delivery system followed by company.
- A detailed analysis of RMC plant at Indore is carried out to validate the survey findings. The six sigma DMAIC method noticed after arranging defects in ascending order are fineness modulus of aggregate, compaction of concrete, water absorption of aggregate, impact value, crushing value and dimension of cube respectively.
- Process is not under control in quality as well as manufacturing time and improvement suggestions are given to improve the process.
- Checklist is created and implemented to control the process. Suggestions for improvement are considered and welcomed by company.

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