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Implementing Six Sigma Approach for Quality Evaluation of a RMC Plant at Mumbai, India

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Abstract: *There has been a 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. It has become a great challenge for the RMC manufacturers to supply consistent level of quality of concrete to the customers. In this study, the quality performance of an RMC plant at Mumbai, India, using the Six Sigma philosophy has been evaluated by using various quality tools. The existing sigma level of the process has been found to be 1.23, which is very less than the manufacturing industry and RMC production process has been found neither stable nor capable. Some recommendations for process improvement and conclusions based on the observations of the present study are also presented at the end.*
Keywords: *DMAIC, DFSS, RMC, 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. This has lead to a steep rise in the production of Ready-Mix Concrete (RMC) in order to cope with the continuously increasing demand from the construction industry. Keeping in view the variables such as variation in raw materials, transportation delays etc., one of the biggest challenge faced by the RMC manufacturers is to consistently supply the desired quality of concrete to the customers. Hence there is a need to apply “six sigma” approach to the RMC production.

Six-Sigma is a quality management philosophy which aims at process improvement by applying statistical process control to reduce variations in product and minimize the defects. It was first evolved, developed and applied by Motorola in the year 1986 followed by General Electric in 1995. Due to Six Sigma, Motorola managed to reduce their costs and variations in many processes and won the Malcolm Baldrige National Quality Award in 1988 [1]. The use of Six-Sigma approach for quality management is common in the manufacturing industry but it is still in the developing stage in the construction industry due to its reliance on statistical data and rigidity. The conventional approach of quality-control in construction industry is a reactive approach and is based on taking actions after the quality failure. The Six-Sigma approach on the other hand is a pro-active approach which rings the bell before the quality failure so that the quality control team can act to avoid the quality failure of the product.

The statistical background of Six-Sigma philosophy is based on the normal distribution of data in a bell curve. It is observed that most manufacturing processes follow the nature of bell curve. An important property of normal distribution is that 99.99999998 % of the area lies under $\pm 6\sigma$ (standard deviation), which implies that if the Lower Specification Limit (LSL) of a product is 6σ bellow the mean value and Upper Specification limit (USL) is 6σ above the mean value, then the defects can be reduced to 0.002 parts/million [2]. Motorola observed the temporal variations of the processes and stated that mean of the processes can shift up to $\pm 1.5\sigma$ from its original value. In that case, still the defects (points lying beyond $\pm 6\sigma$) in the process would be 3.4 ppm and conformance level would be 99.9996 %.

There are two methodologies for applying Six-Sigma approach for any process, namely DMAIC and DFSS. The DMAIC (Define-Measure-Analyze-Improve-Control) is applied for process improvement of an existing process. The DFSS (Designed For Six Sigma) methodology is applied for a new process. In the present study, the DMAIC methodology has been applied to an existing RMC plant in Mumbai, India to analyze the compressive strength of the concrete. Various six sigma tools such as histogram, control charts fishbone diagram etc to analyze the process sigma level, process stability and process capability of the RMC production.

II. Research Objectives

The objective of the present research is to apply DMAIC methodology for quality evaluation of a RMC plant located at Mumbai, India. The steps involved in the methodology are as follows:

1. Conducting the VOC (Voice of eternal customers) survey for knowing the quality requirements of RMC to the customers and the level of quality which they are served with presently.
2. Studying the RMC production process and collecting the compressive strength data of previous production.

3. Evaluation of sigma level of the plant for different grades of concrete on the basis of histograms.
4. Analyzing the correlation of compressive strength data using the scatter plots and also verifying the stability and capability of the RMC production process using the control charts ($\overline{X}$ and $\overline{R}$).

III. Six Sigma DMAIC Methodology

The DMAIC methodology is applied on the existing RMC production process to evaluate the quality performance of the plant in various phases such as Define, Measure, Analyze, Improve and Control. The DMAIC is a systematic approach for measuring the quality problem in a process, assessing the variation in the process, determining the events of defects and their causes as well as improving the process.

1) Define Phase

This is the first phase of DMAIC methodology which is used to identify the critical quality parameters of a particular product in consideration and defining the quality problem for that product. In this study, the quality parameters of RMC have been considered and their requirements by the customers are assessed by conducting the Voice Of Customers (VOC) survey.

For this study, a number of customers of RMC from the infrastructure as well as the Real Estate sector were surveyed to understand their quality requirements. The following observations which reveled from the VOC

- The workability at site, homogeneity and compressive strength are the critical quality parameters of RMC.
- Many customers from the construction industry are going for Non-Destructive Testing of RMC within 28 days of casting which revel the lack of confidence in consistency of quality of RMC suppliers. Based on the observations of VOC, compressive strength parameter was selected as critical for the process of RMC production.

2) Measure and Analyze Phase

The next step is to measure the current performance of the process. For this phase, the plant layout and the production process of Supreme Infra. RMC plant, India was closely studied. Also, the compressive strength data of various grades such as M25, M30 and M40, of previous time were collected from the quality control department. Details of various suppliers of raw materials such as aggregates, natural and artificial sand, fly ash etc. as well as their test reports were also studied.

In the Analyze phase, understand and analyze the data collected by using simple statistical tools as well as the process to determine the root causes of the problem that need improvement [3]. In this phase, quality tools such as histograms, control charts, fishbone charts etc. are used to analyze the process.

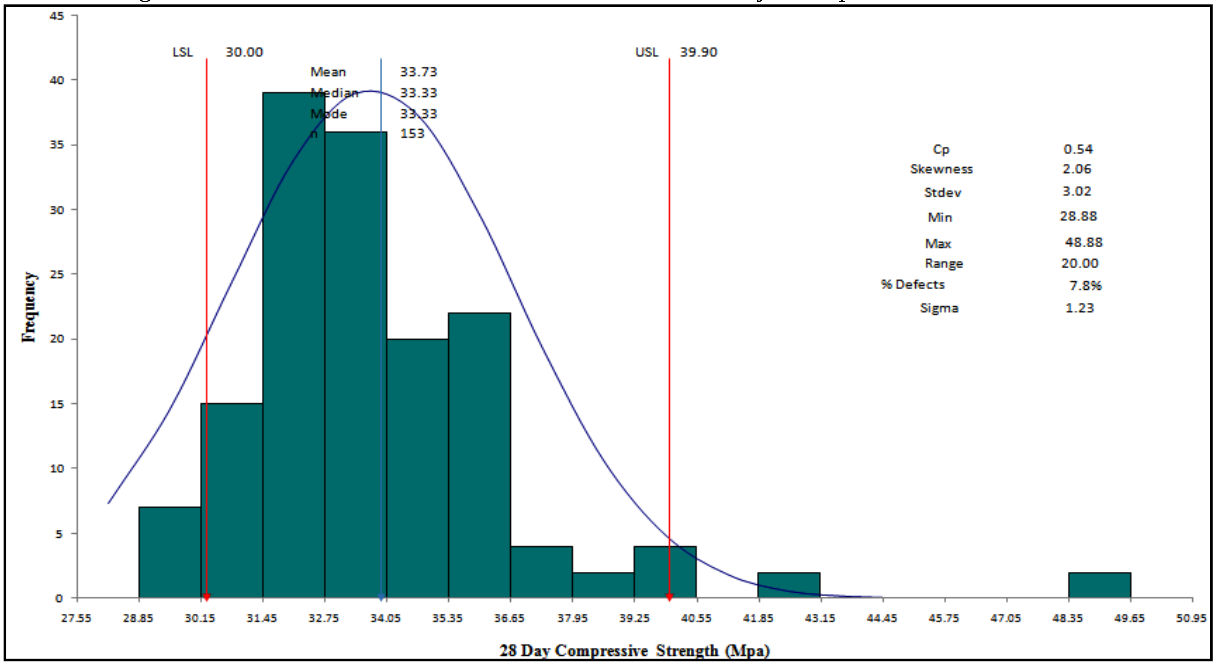

Figure 1. Histogram and process capability analysis of M30 Grade Concrete

The initial task is to determine the "Sigma level" of the process. The sigma level indicates the number of standard deviations of the data which are included in the Upper Specification Limit (USL) and the Lower Specification Limits (LSL). Higher the sigma level, lesser the number of defects. The sigma level of the current process is determined by histogram for M30 grade of concrete drawn using QI-Macros module as shown in fig. 1. The sigma level of the process is found to be 1.23 which indicates that there is a substantial variation in the performance of the process. Sigma level is the minimum of either {(USL - Mean)/ σ} or {(Mean – LSL)/ σ}.

Using the process capability, we can measure whether performance of the process is centered [1]. Process capability can be calculated by the expression {(USL-LSL)/6σ}. The process capability (C_P) for the process is found out as 0.54 which is less than 1 and hence the performance is undesirable.

Control charts ($\overline{X}$ and $\overline{R}$ charts) are used to monitor the process to find out whether a process is in control or not. A $\overline{X}$ chart is a chart used to record the variation in the average value of samples [2]. The $\overline{X}$ chart and $\overline{R}$ chart for M30 grade concrete are shown in Fig.2 and Fig.3 respectively. The subgroup size for these control charts is 3 i.e. the three samples collected out of the same transit mixer belong to one subgroup. Careful examination of $\overline{X}$ chart shows that many points (in the month of August, September and October) are beyond the Upper Control Limit (UCL) and Lower Control Limit (LCL). Thus the production process can be treated as "Out Of Control". The out of control points on the chart represent the event of a special cause of variation in process which can be due to special factors such as change in raw materials such as fine aggregates, coarse aggregates, improper calibration of load cells of the plant etc.

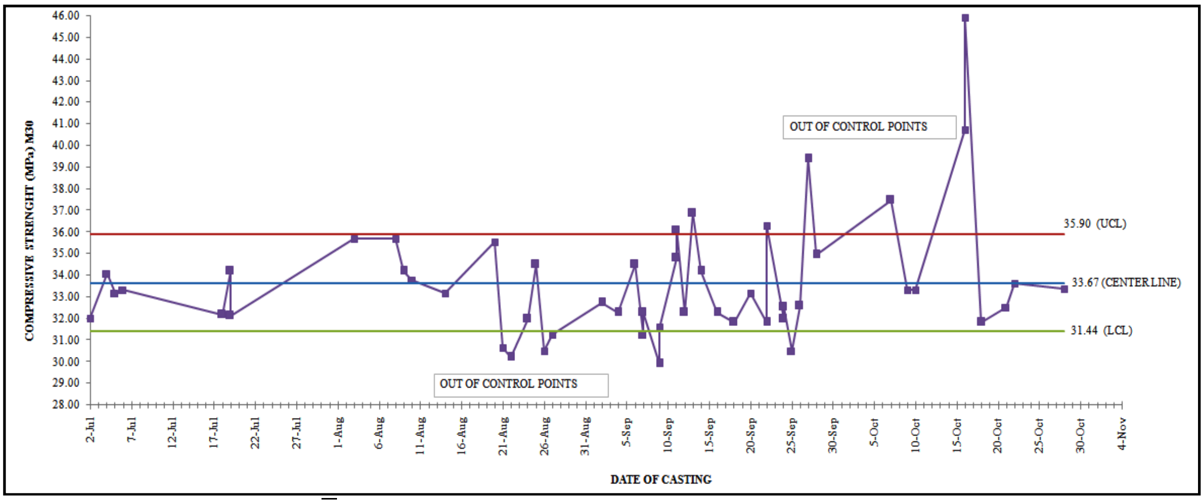

Figure 2. $\overline{X}$ Chart for M30 Grade of Concrete (02/07/2014 - 04/11/2014).

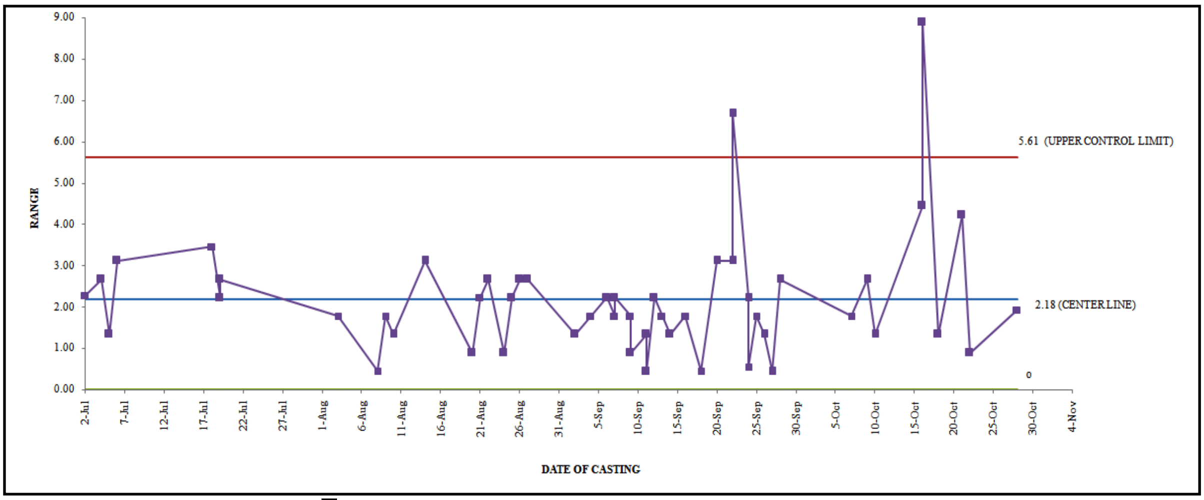

Figure 3. $\overline{R}$ Chart for M30 Grade of Concrete (02/07/2014 - 04/11/2014).

Scatter diagram is one of the most powerful tools used to determine the correlation (relationship) between two variables. Correlations may be positive (rising), negative (falling) or null (uncorrelated) [4]. The scatter plot of M30 grade of concrete is shown in Fig. 4 with date of casting on X axis and compressive strength on Y axis. It is clear from the scatter diagram that correlation of compressive strength with date of casting is very weak as the coefficient of correlation is (R^2) = 0.044 which is extremely less than 1.

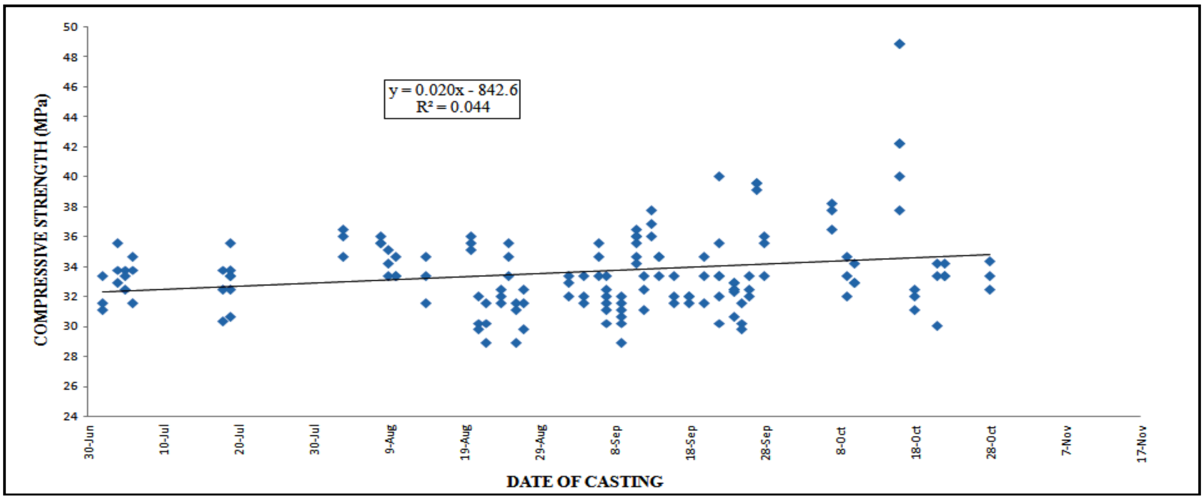

Figure 4. Scatter Plot for M30 Grade of Concrete (02/07/2014 - 04/11/2014).

3) Improve and Control Phase

The statistical analysis of the process clearly indicates that the process is neither capable nor stable. The main task in Improve and Control phase is eliminating the root causes of variations and developing process requirements that minimize the likelihood of failures based on the knowledge and information obtained in previous phase [5]. Major causes which contribute to the variation in quality of concrete are to be assessed using the Pareto chart. Also the improvements made in the process should be implemented and monitored accordingly.

IV. Conclusions

In the present study, the quality requirements of RMC by the construction industry are assessed and DMAIC methodology which is based on Six Sigma Philosophy has been applied for the quality evaluation of an RMC plant in Mumbai, India. The conclusions drawn from the observations and results of the present study are as follows:-

1. The sigma level of RMC plant under study is found to be 1.23, which is very low as compared to the manufacturing industry. Also the percentage defects in the process are found to be 7.8 %.

2. Production process capability (C_P) is 0.54 which is less than 1 as well as the process is out of statistical control. This reflects that current process is neither stable nor capable.

3. The Six Sigma DMAIC methodology can be applied to the RMC production in order to find the root causes of variations, eliminating the causes of variations and achieving the process improvements by applying the quality tools.

4. The control charts ($\overline{X}$ and $\overline{R}$ charts) should be used for RMC production process as they reflect the temporal occurrences of variations of process out of the control limits due to assignable causes. Hence the causes can be eliminated and the entering of process out of the specification limits can be avoided in the future.

4. There is a need to change the perspective of quality management in RMC industry and a more pro-active and robust approach is required for improving the quality performance. In the present scenario where quality has gained a strategic importance, Six Sigma philosophy has the potential to replace the earlier quality management systems and hence it should be encouraged and inculcated in the organizational structure itself.

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