Implementing Six Sigma Approach for Quality Evaluation of a RMC Plant

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ABSTRACT

Today, the consumption of Ready Mix Concrete (RMC) is rapidly increasing in India owing to the rapid growth in Infrastructural and Real Estate sectors. Supplying concrete with desired quality consistently has become a great challenge for the RMC suppliers. Hence, the evaluation as well as monitoring the quality of RMC production is critical. this paper is an attempt to a apply the Six Sigma DMAIC approach to a RMC Plant in Chakhan, Pune. The sigma level of the existing plant has been evaluated. Also the production is Statistically analyzed using various tools such as X bar chart and R charts and the process capability index has also been reported.

Introduction

Concrete is one of the largest construction materials used today. Although majority of the concrete used is hand mixed, but there has been a substantial increase in the use of ready mix concrete for good quality concrete. Keeping in view the variation in raw materials, transportation delays etc., one of the biggest challenges 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 philosophy used to identify the root cause of a problem causing variation in the process. 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.

Sigma is based on the critical quality that customers concerned, that can help enterprises to pursue high level quality, promote efficiency and reduce costs. Hence the advantages of the Six Sigma should also be taken for construction management. Therefore, a better understanding of this improvement approach would have significant profit for establishing better management model of the construction industry.[5]

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.

Research Objectives

The objective of the present research is to apply DMAIC methodology for quality evaluation of a RMC plant located at Pune, 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 that 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. Analysis of the data, using Six Sigma tools.
5. Study of the process to suggest various improvements.

The DMAIC Six Sigma Methodology

DMAIC is an approach of applying Six Sigma for improving quality. DMAIC is one of the Six Sigma methodologies which focuses on improving the quality of an existing process. The various phases of DMAIC are Define,

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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.

Define

This is the first as well as a crucial stage, wherein the improvement opportunities are identified. In the study of the RMC plant mentioned here, the customers were identified and their quality requirements were understood by using Voice Of Customers (VOC).

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 perform Non-Destructive Testing of RMC within 28 days of casting which reveal the lack of confidence in consistency of quality of RMC suppliers. Based on the understanding of VOC, compressive strength and slump value were identified as critical parameters on which the quality of the concrete relied.

One way to understand overall operation is by developing a process map. The first step of the model is to perform strategic analysis, which needs to be market/customer driven.[3]

A Flow chart of the RMC process was prepared for an overlook of the entire process.

SIPOC (Supplier Input Process Output Customer) is another important tool at the define stage to identify all relevant elements of a process improvement project. SIPOC diagram also clears the boundaries of the project
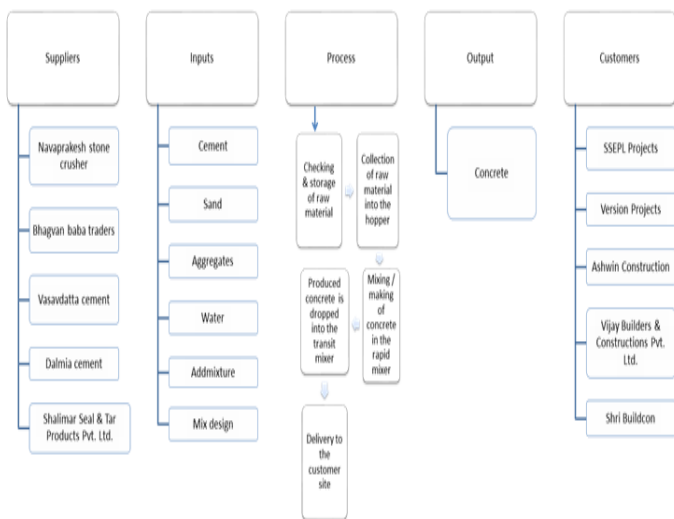

Fig 1. SIPOC Diagram

Measure

This phase forms the measurement systems for the inputs and outputs of the selected project. What to measure and how to measure? Data regarding the measurable parameters, those which characterize the problems of inputs and output of the RMC plant was collected. One year data of the compressive strength of concrete is collected from the QC lab for further analysis. It was noticed that they did not keep proper records of the slump value of concrete, which is a quality defining parameter. The compilation of compressive strength of concrete grades ranging from M15 to M30 was done. Regarding the inputs to the process, details of various suppliers of raw

materials such as aggregates, natural and artificial sand, fly ash etc. as well as their test reports were studied.

Analyze

Analyze stage includes analysis of the data collected in the previous stage using Six sigma tools. Some of the six sigma tools are statistical tools, which are useful in identifying the quality problem. Tools used of analysis in this study are histograms, control charts, fishbone diagram, process map and scatter diagram. The initial task was to find the Sigma level of the current 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 are the number of defects produced. The sigma level of the current process is determined by histogram for different grades of concrete drawn using QI-Macros module as shown in figures below. Sigma level is the minimum of either $\{(USL - Mean)/ \sigma\}$ or $\{(Mean – LSL)/ \sigma\}$.

Using the process capability, we can measure weather performance of the process is centered. The capability index can be calculated by the expression $\{(USL-LSL)/6\sigma\}$. Capability index (CP) for the process is found out to be more than 1 which states the process is in statistical control.
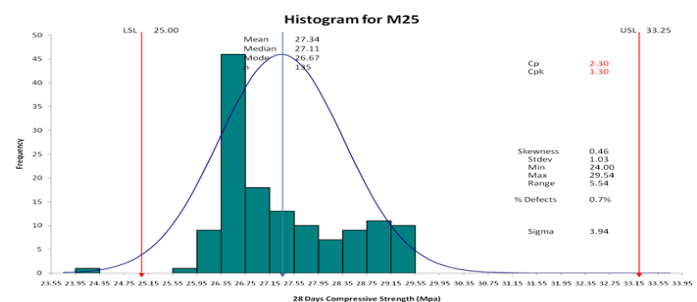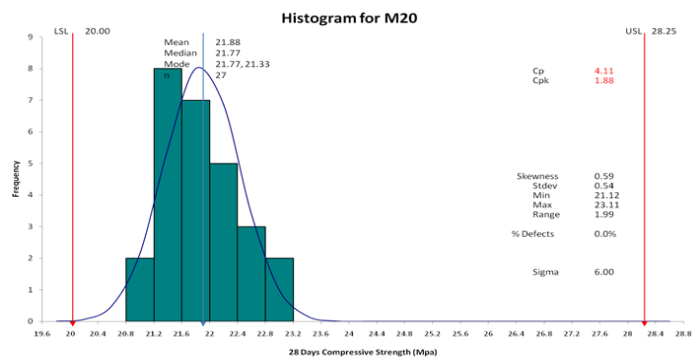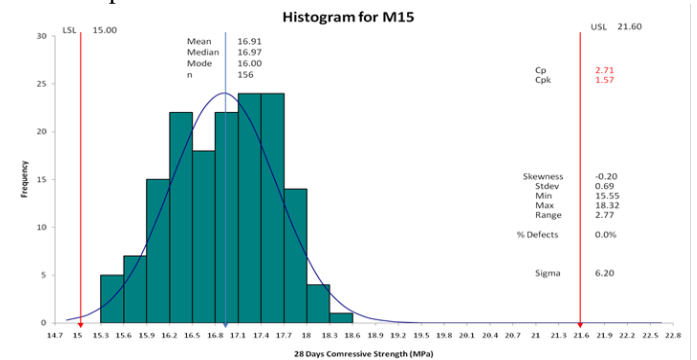

Fig 2.Histograms of compressive strength for M15, M20 and M25 grade concretes

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. An $\overline{X}$

chart is a chart used to record the variation in the average value of samples [2].

Statistical process control assumes that variation in a product or service comes from either a combination of natural (random) causes or assignable causes. Natural or random causes are uncontrollable. However, assignable causes can be related to a specific event and hence can be controllable. The problem that arises is the need to determine whether variation that is occurring is natural (uncontrollable) or assignable (controllable). These include points that are outside the control limits, trends, sudden shifts, and cyclic behavior of points. For a process to be in control, all points on the control charts must be within specified control limits and exhibit random behavior. Plots outside the limits indicate points where control must be exercise.[4]

The $\bar{X}$ chart and $\bar{R}$ chart for M15 grade concrete are shown in Figures below. The subgroup size for these control charts is 3 i.e. the three samples were collected from the same transit mixer comprising of to one subgroup. Careful examination of $\bar{X}$ chart shows that many points (in the month of) are beyond the Upper Control Limit (UCL) and Lower Control Limit (LCL).The out of control points on the chart represent the event of a special cause (assignable causes) 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..It is also important to identify the cause of a particular out of specification value of the output, at that particular time to avoid such problems in future.

Fig 2. X bar chart and R chart for M15 grade concrete

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 M grade of concrete is shown in Fig. 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 (R2) = 0.044 which is extremely less than 1.
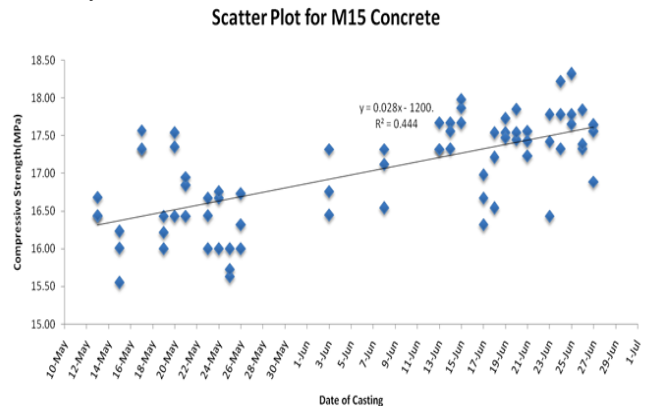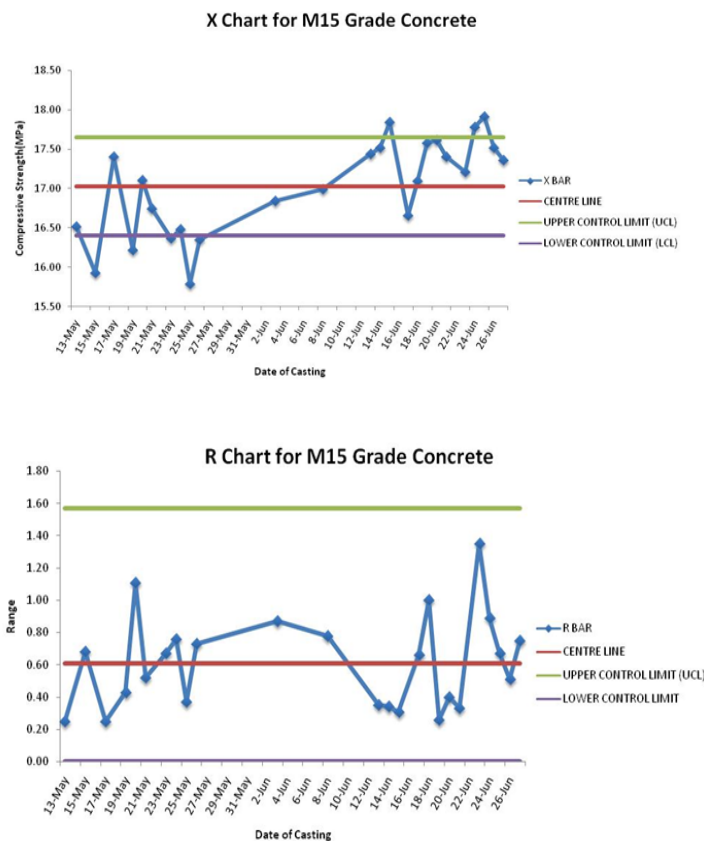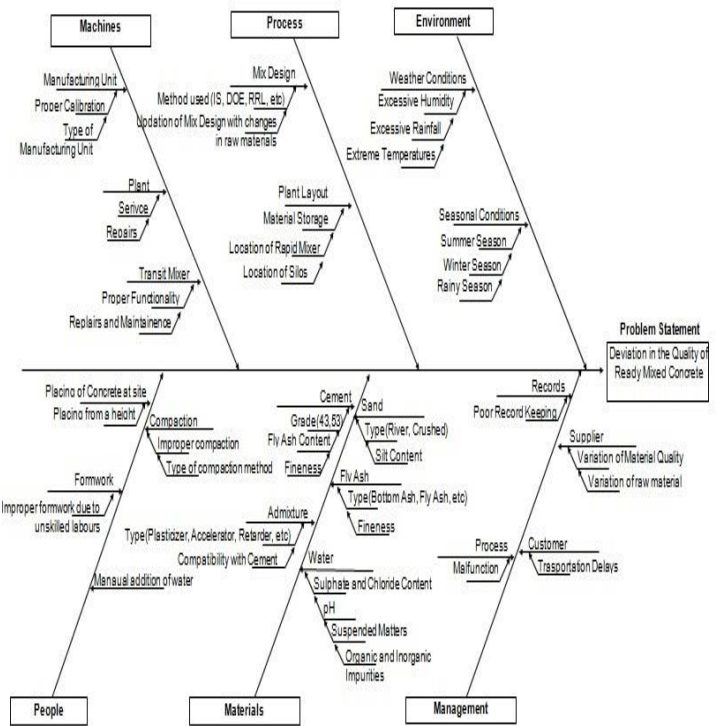

Fig 3. Scatter Plot for M15 grade

Cause and effect diagram also known as fishbone diagram is a diagram that shows the possible causes that can result in non-conformities.

Fig 4. Cause and effect Diagram of RMC Production Improve

The main task in Improve 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. The RMC plant should keep proper records of the data, importantly slump value. Control charts should be used to keep track of the process. All cements do not have the same compatibility with a certain admixture. The RMC plant made use of two types of cement and one admixture, without proper study of their compatibility. It is important to test their compatibility before use. Also the raw materials used for concrete production should be from a single supplier i.e minimal variation in the quality of the materials.
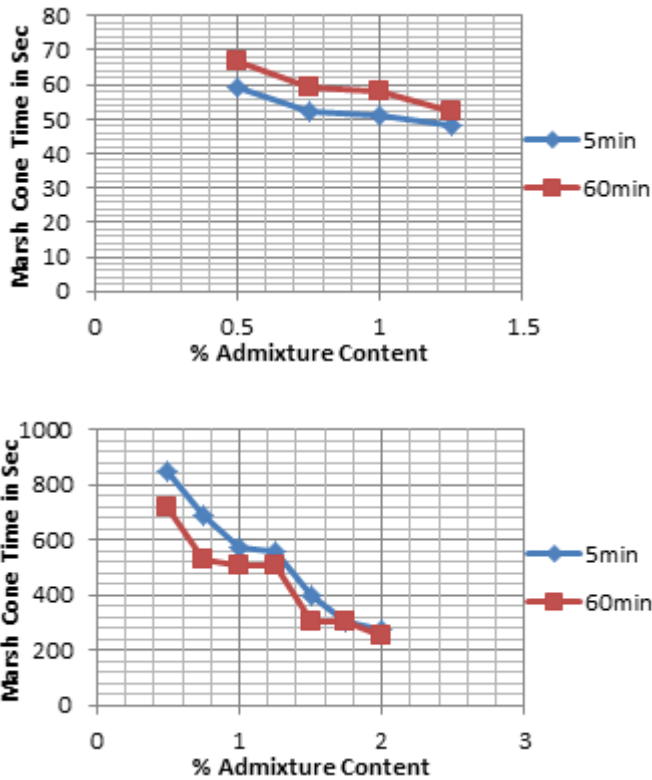
Fig 5.Graph of Cement Admixture Compatibility

Control

The control stage is to make sure that the improvements proposed are implemented and monitored to achieve the target intended.

Conclusion

1. The sigma level of RMC plant under study is as good as the manufacturing industry. Also the percentage defects in the process are found to be very low.

2. Production process capability index ((CP) >1), which means the process is in statistical control. This reflects that current process is stable and 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 ((X)‾ and (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 mostly assignable causes. These causes can be eliminated to further improve the process.

5. 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 practiced in the organizational structure itself.

6. Every cement does not have the same compatibility with a particular admixture. Therefore a proper study of the cement admixture compatibility should be made before the design is made. The dosage of admixture changes the workability of concrete and indirectly the quality of concrete.

Acknowledgment

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