# Concreting For Construction- Quality Control by Six Sigma Approach

**Nishaant Ha, Swethaa.B, Chris Anto.L**

***Abstract*** *A quality intensive approach towards construction concreting for the commercial industry is gaining immense importance and it has become the prime duty of every engineer to contribute towards ensuring durability and serviceability of the offered concrete. In this paper, a discussion is presented on a possible way of assuring quality of concrete by implementing six sigma principle to reduce the variability in characteristics among various batches. The methodology of DMAIC (Define-Measure-Analyse-Improve-Control) is applied to the concreting process, considering the Compressive Strength as the Critical to Quality (CTQ) factor. The concrete samples obtained from an RMC were tested for compressive strength at 3, 7 and 28 days, tabulated and analysed for variations. Also, different types of cements used are considered. Sigma levels are identified and suggestions for improving the levels are recommended, which in turn tend to reduce variations and thus streamline the strength values within narrow limits. Control charts as guidelines for further concreting are established.*

***Keywords: CTQ, DMAIC, DPMO, Sigma Level***

## I. INTRODUCTION

In the vast field of construction, customer satisfaction and maximizing success have become key goals for any establishment or firm. Hence, greater focus is being offered in maintaining a strict quality control to ensure minimization of defective outputs. Six sigma principle aids the management team to effect control on various construction processes and to set a baseline of quality standards. The objective of applying six sigma strategy is to reduce the number of defects to 3.4 per million outputs, thereby leading to better quality. Design. Measure, Analyse, Improve and Control (DMAIC) are the basic keys of six sigma that will be used in this research.

## II. SIX SIGMA APPROACH IN CONCRETING

The motive of Six Sigma is to improve the quality to near perfection which runs down to 3.4 defects per million opportunities (DPMO), to maximize the customer satisfaction and business benefits. This goal will be achieved when the sigma level is 6.When it comes to concreting, Critical to Quality factors are analysed andthe most evident is the Compressive Strength which is taken as the prime CTQ The defects here are considered as those compressive strength values that fall outside the control boundaries of 1N/mm2. Once the number of defective outputs have been identified, they are converted to a macro scale, i.e., Defects Per Million Opportunities (DPMO) which depicts the total number of defects per ten lakh or one million outputs produced. This will be useful in calculating the sigma level of each operation and therefore its efficiency. From the view point of enhancing the process success percentage, control charts are prepared and can be used as a reference for future processes.

## III. DESIGN OF EXPERIMENT

The framework for the study is devised based on the conceptual structure of six sigma approach namely DMAIC-Define Measure Analyse Improve and Control whereby the process at hand and its goals are clearly identified in the very first step. This aids us in understanding the nature of the process and the issues associated with it. Subsequently, the parameters that would be observed in the due course of the study are listed. From the scrutiny, the parameters that would be Critical To the Quality of the process are chosen. The parameters are measured in the actual sense and analysed so as to suggest means of betterment and maintenance. For the study under consideration, the process namely construction concreting has a clearly defined goal of customer satisfaction. Thus, the define phase comprises of steps that focus on the process operations and means by which the CTQ namely Compressive Strength at 3,7 and 28 days of concreting, which would be done with the use of Compression Testing Machine. In addition, the different types of cement are used viz Chettinad, Mahagold, and Jaypee The measure phase begins as soon as the concrete is cast and cured for 3 days. Totally 140 samples under each criteria (i.e. days) are tested for strength. The values are tabulated against units of N/mm2 and the mean, standard deviation and the percentage variations are estimated. The test values are analysed for defects or deviations from the mean, along with the percentage difference of variation from the average. Tabulations for the overall strength values, and for the individual cements for 3, 7, and 28days respectively are computed. The percentage difference and the sigma levels for each category are listed. The sigma level is calculated by converting the actual number of defects into DPMO (Defects Per Million Opportunities), using the following formula (1,000,000 x No. of Defects)

$$DPMO = \frac{}{((\text{No. of Defect Opportunities/Unit}) \times \text{No. of Units})}$$

The sigma level is interpolated from table 1, using the calculated DPMO values for each type of cement and test period. With a varying sample size for each type of cement,

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| Sigma Level | DPMO |
|---|---|
| 1 | 690,000 |
| 2 | 308,000 |
| 3 | 66,800 |
| 4 | 6,210 |
| 5 | 320 |
| 6 | 3.4 |

**Table 1: Sigma levels and their corresponding DPMOs**

the sigma levels are also seen to vary considerably.The overall sigma level of the population was found to be 1.7, 2.7 and 2.2 for 3, 7 and 28 days respectively. Amongst the different types of cement used , the highest as well as the lowest levels were recorded with Jaypee Cement, with almost zero defects for the latter stage whereas maximum deviations at the early days. This indicates lesser gain of strength during the early days and a faster build up later on. It is also observed that more the defects, greater the deviation and thus reduced sigma levels.

When it comes to the percentage of variation from the mean among the various samples, the overall variation comes up to 2.6% on an average at 3 days of concreting and consequently drops down to 1.3% at the end of curing period, i.e., 28 days. With Chettinad and jaypee cements, the variability can be almost considered constant and equal with an average of around 0.96% over the three test periods. A higher degree of variance is seen with Mahagold Cement, which is found to be almost similar to the population variance but for the 7 day test results.

| Cement/Day | Population | Chettinad | Jaypee | Mahagold |
|---|---|---|---|---|
| 3 day | 1.7 | 2.07 | 0.81 | 1.75 |
| 7 day | 2.7 | 3.13 | 6 | 2.78 |
| 28 day | 2.2 | 2.06 | 6 | 2.31 |

**Table 2: Calculated Sigma Levels**

| Cement/Day | Population | Chettinad | Jaypee | Mahagold |
|---|---|---|---|---|
| 3 day | 2.559 | 0.967 | 1.365 | 2.57 |
| 7 day | 0.442 | 0.957 | 0.991 | 1.498 |
| 28 days | 1.289 | 0.966 | 0.876 | 1.213 |

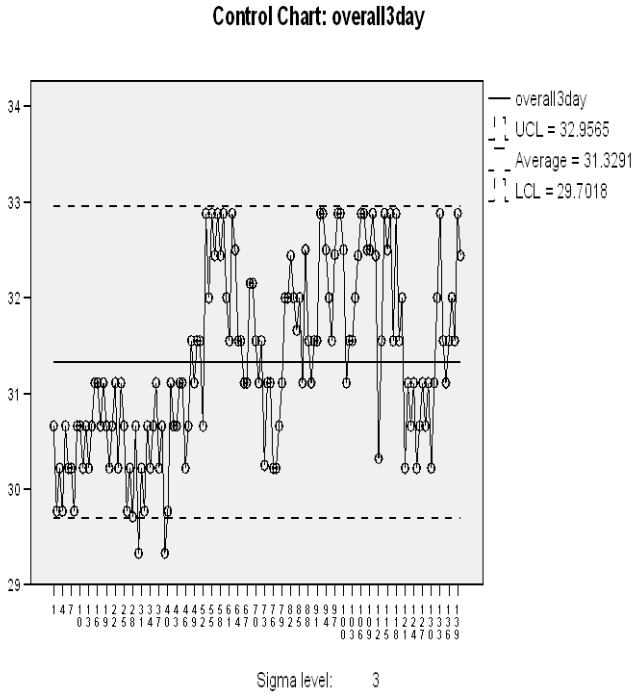
**Table 3: Percentage Variations**

In addition, from field records and routine observations, it has been found that different batches of aggregates have been used for preparing these samples. It has further been identified that the atmospheric temperatures and the climatic conditions has varied over time. Modes of curing were also found to play a part in producing varied results. Involvement of unskilled labour, inevitable losses, lack of knowledge about the process could also have contributed to the ill effects.

To improve the consistency and hence the sigma levels of the above discussed concrete process, a few recommendations are suggested

- Using the same type of ingredients over a period of time
- Conduct initial material tests to assess the nature of the raw materials and prepare the design mix accordingly
- Maintain a standard method of curing for each lot
- Educate labours on the necessity of quality and steps to enhance it.
- Establish standards that could act as references for comparing the outputs then and there.

The suggested improvements should be implemented in the process and the four steps of define, measure, analyse and improve are to be carried out periodically to achieve and maintain apt quality standards. At this juncture comes the need to control the process in order to confirm to the quality standards established. This can be inculcated into the system by means of 'Control Charts', an essential tool of six sigma approach, that can efficiently be used as a check against future outputs. The control charts are a horizontal plot of the test values with limits of three times the standard deviation on either side. Test values that fall within the specified range are considered acceptable and vice versa.



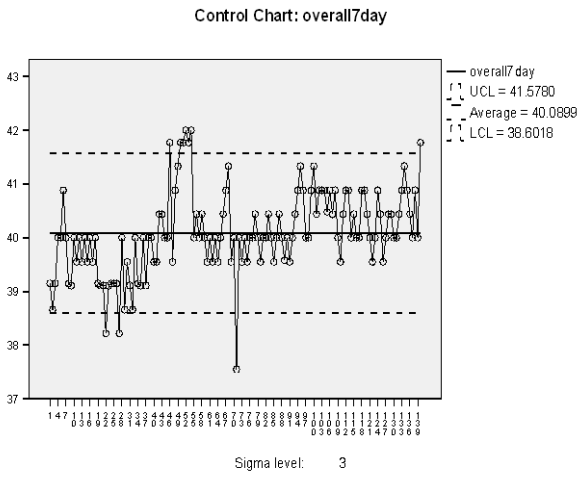



**Fig. 2 Control Chart for Population (7 days)**

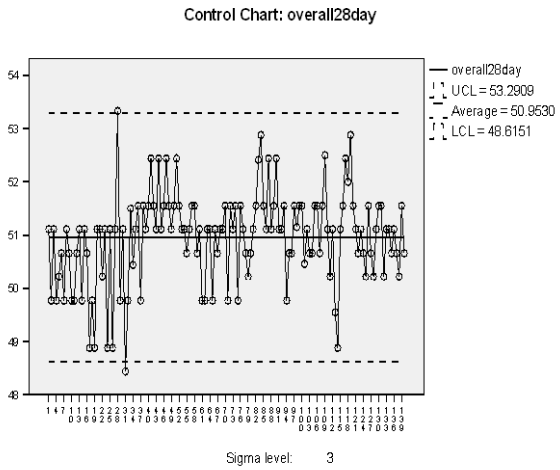



**Fig. 3 Control chart for Population (28 days)**

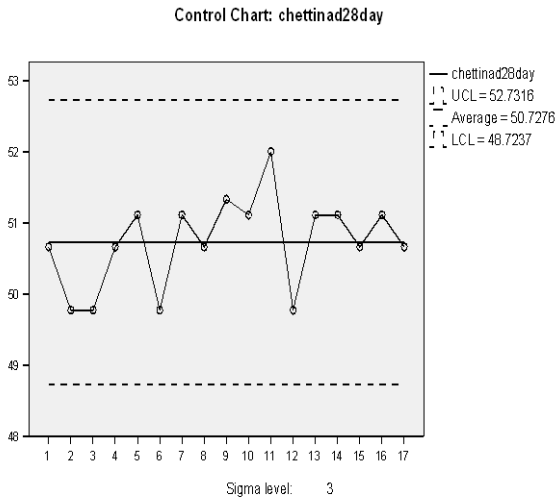



**Fig. 4 Chettinad cement control chart (28 days strength)**

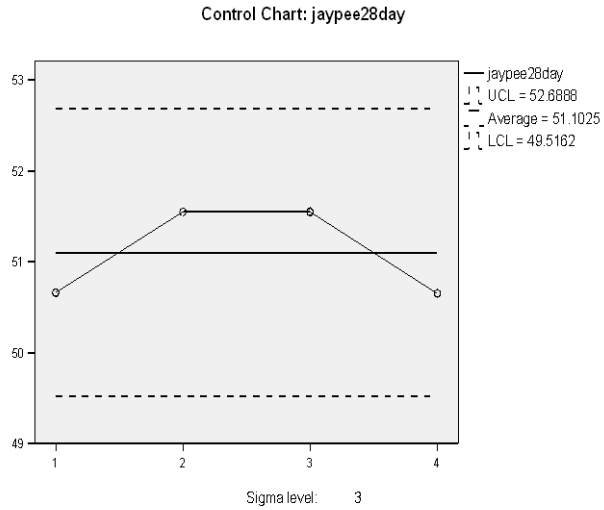



**Fig. 5 Jaypee cement control chart (28 days strength)**

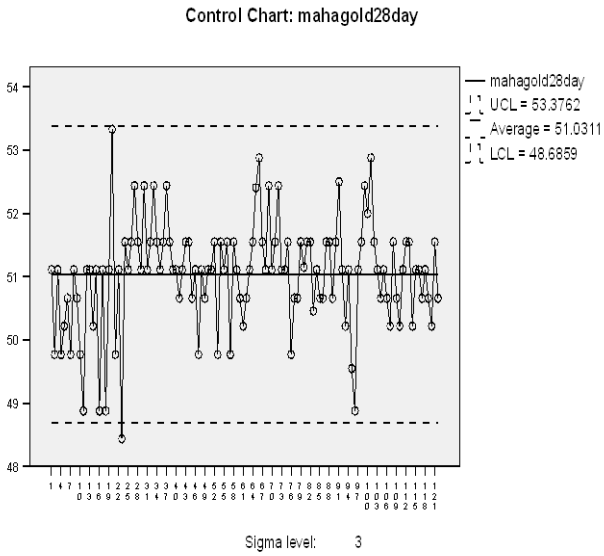



**Fig 6 Mahagold cement control chart (28 days strength)**

## IV. CONCLUSION

Though the application of the six sigma approach in the construction industry may not have been popularized because of the inherent versatile nature of the field, quality control and assurance by this method definitely provides a structured approach- a framework that is systematically stable and reliable. Also, it needs to be noted that the maintenance of quality cannot be achieved in one step but in a number of repeated cycles of DMAIC, until the six sigma level is reached. It is to be understood and agreed upon that the scope of this research is limited not only to the process of concreting but also to every single sphere of the construction industry.

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