IMPLEMENTATION OF SIX SIGMA FOR QUALITY EVALUATION AT READY MIX CONCRETE (RMC) PLANT

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Abstract - *Due to technological advancement, huge sky scrapers and mega projects are possible. This results in increasing demand of concrete. The demand of concrete is also increasing as there is a rise in infrastructure projects in developing nations as India. Due to this huge demand, maintaining the quality at a standard level is a tedious task. Hence, six sigma can be used to improve the sigma level and maintain the level of standards related to quality of concrete. The main aim of this research works is to determine and rank the customers requirement regarding quality of concrete. To fulfil this aim, Quality Function Deployment (QFD) is used to convert voice of customers into engineering standards. The research also aims to determine the existing sigma level of RMC plant and to develop a control measure to eliminate the uncertainties and improve the sigma level. After completing the research, it is concluded that the existing sigma level of the RMC plant is 1.83 which is very low than the value 6 which represents that the is a need for standardization in RMC industry for concrete production. The research also concludes that high strength, high workability and low segregation and bleeding are topmost customers requirements.*

Key Words: *RMC plant, Six Sigma, DMAIC, DMADV, Quality Function Deployment (QFD), House of Quality (HoQ).*

1.INTRODUCTION

As per Indian Standard code of practice (IS 4926-2003) Ready Mixed Concrete plant (RMC) is defined as "concrete mixed in a stationary mixer in a central batching and mixing plant or in a truck-mixer and supplied in the fresh condition to the purchaser either at the site or into the purchaser's vehicles" [1]. This results in a more accurate design, allowing specialist to be developed and implemented on construction sites. Ready mix Concrete (RMC) is preferred over in-situ concrete because it is environmental friendly. Its manufacturing is not messy and it is nor time consuming. It offers solution to exact problem of customer and ensures customer satisfaction and provides concrete of preferred quality. It also eliminates the stocking of materials at site for manufacturing concrete required at project sites. The quality of concrete has a direct effect on the strength and stability of the structure. There are things which found fewer advantages to produce concrete on a worksite than RMC. Quality of concrete is under the threat which resulting in poor product due to some reasons. RMC is produced under the plant conditions and permits a close control of all operations of manufacture and transportation of concrete at site. Due to its stability, low cost and its ability to be modified for different applications, RMC is now one of the most popular building materials.

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 [2]. 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 ± 6σ (standard deviation), which implies that if the Lower Specification Limit (LSL) of a product is 6σ below 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 [3]. Motorola observed the temporal variations of the processes and stated that mean of the processes can shift up to ± 1.5σ from its original value. In that case, still the defects (points lying beyond ± 6σ) 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-Analyse-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 analyse the compressive strength of the concrete. Various six sigma tools such as histogram, control charts fishbone diagram etc to analyse the process sigma level, process stability and process capability of the RMC production.

Quality Function Deployment (QFD) supports design teams to develop products on a structured way that relates customer demand via engineering specifications to parts specifications and to production process variables and thus to production operations planning [4]. The emphasis on "voice of the customer" is the key to QFD [5]. QFD in the construction industry has gained a whole new meaning and importance with the increasing trend to adopt project procurement using the design/build (D/B) method [6]. For the need to understand the critical design issues prior to production quality control process charts were widely used to ensure that the design criteria were met during manufacturing, but there was no formal system to translate the customer's needs into the initial design and subsequent process control points. Thus, an opportunity was created for QFD to come to fruition as a method to check the design itself for adequacy in meeting customer requirements and to translate those requirements to production [7]. The QFD method includes building one or more matrices known as quality tables. The matrix is named as the "house of quality" (HoQ). It exhibits the customer's needs or voice of customer (VoC) on the left-hand side, and the technical response to meeting those needs along the top. Ready mixed concrete (RMC) is a product which also should satisfy the requirements of the customer or consumer. The quality monitoring of RMC should have a major focus towards customer satisfaction. Thus, this paper is an attempt to explore the application of QFD and particularly HoQ in monitoring the quality of RMC produced by commercial batching plants with special focus on customer satisfaction.

2. LITERATURE REVIEW

All the papers in the literature review helped us to obtain the following inputs for our project:

1. The Six-Sigma principle is a managerial tool for productivity and quality improvement and a systemized tool for quality and process control.
2. The methodology of DMAIC (Define-Measure-Analyze-Improve-Control) is applied to the concreting process, considering the Compressive Strength as the Critical to Quality (CTQ) factor.
3. It is 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.
4. At present, none of the RMC batching plants use this technique for continuous quality improvement and incur a significant amount of material and production cost.
5. Seven quality tools are available to help organizations to better understand and improve their processes. They are 1. Check Sheets 2. Cause-and-Effect Diagram 3. Flow Charts 4. Pareto Charts 5. Scatter Diagram 6. Histogram 7. Control Charts
6. The sigma level was found out as 1.77 which shows that a lot of improvement is required in the process of manufacturing of concrete.
7. It has been observed that many RMC batching plants have a very high design buffer and design the concrete for one grade higher strength to ensure security of the minimum strength leading to increase in initial cost.

3. QUALITY FUNCTION DEPLOYMENT (QFD)

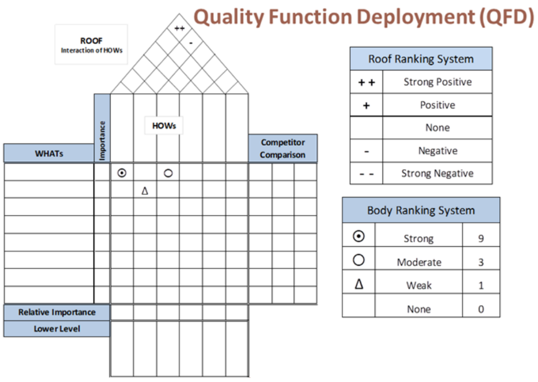
Quality Function Deployment (QFD) is a structured approach to defining customer needs or requirements and translating them into specific plans to produce products to meet those needs. The "voice of the customer" is the term to describe these stated and unstated customer needs or requirements. The voice of the customer is captured in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, etc. This understanding of the customer needs is then summarized in a product planning matrix or "house of quality". These matrices are used to translate higher level "what's" or needs into lower level "how's" - product requirements or technical characteristics to satisfy these needs.

While the Quality Function Deployment matrices are a good communication tool at each step in the process, the matrices are the means and not the end. The real value is in the process of communicating and decision-making with QFD. QFD is oriented toward involving a team of people representing the various functional departments that have involvement in product development: Marketing, Design Engineering, Quality Assurance, Manufacturing/ Manufacturing Engineering, Test Engineering, Finance, Product Support, etc.

The active involvement of these departments can lead to balanced consideration of the requirements or "what's" at each stage of this translation process and provide a mechanism to communicate hidden knowledge - knowledge that is known by one individual or department but may not otherwise be communicated through the organization. The structure of this methodology helps development personnel understand essential requirements, internal capabilities, and constraints and design the product so that everything is in place to achieve the desired outcome - a satisfied customer. Quality Function Deployment helps development personnel maintain a correct focus on true requirements and minimizes misinterpreting customer needs. As a result, QFD is an effective communication and a quality planning tool. House of Quality (HoQ) is developed for the process of QFD. Google from is created and distributed containing questioner from Annexure-A to collect primary data for creating HoQ and rank engineering parameters.

3.1 HOUSE OF QUALITY (HOQ)

The House of Quality (HOQ) is defined as a product planning matrix that is built to show how customer requirements relate directly to the ways and methods companies can use to achieve those requirements. House of Quality diagrams use a design that resembles the outline of a house and can be created using technical and competitive benchmarking data. HOQ is considered the primary tool used during quality function deployment to help facilitate group decision making.



(Figure 1. Framework of House of Quality and QFD)

The main feature represented in the structure of HoQ as represented in figure 1 is "What" and "How". Where, "What" represents the engineering parameters and "How" represents engineering parameters related to the customer requirements. The rating scale consists of only 4 options to represent the association of customers requirement with engineering parameters such as strong, moderate, weak and none. Formulation of House of Quality (HoQ) for Quality Function Deployment (QFD) is mainly done in two phases. In first phase customer survey is carried out to collect data regarding customers requirements related to quality of concrete needed at site. In second phase, survey is carried out between concrete experts to determine relation between customers requirement and engineering parameters.

By brain-storming and secondary data survey, it was found that w/c ratio, aggregate content, fineness modulus, admixture, fly ash content and type of cement are the major engineering parameters related to quality of concrete and customers requirement. Primary survery is done to determine the association of engineering requirements with customers requirements. The average value of the ranking is used to form HoQ. Figure 2 represents House of Quality for quality of concrete at RMC plant. Relative importance weight is formed to determine the ranking of engineering parameters and engineer should give top priority to eleminate risks form those technical requirements.

Customer Requirement	Technical Requirement	W/C Ratio	Aggregate Content	Fineness Modulus	Admixture	Flyash content	Type of cement
High Strength	5	9	3	9	9	3	3
High Durability	3	9	3	3	3	9	1
High Workabality	5	3	9	1	3	9	3
Low Curing Period	1	9	1	1	3	3	9
Low Segregation and Bleeding	3	3	3	9	3	3	9
Impact Resistance	1	9	9	3	3	9	3
	Importance weight	114	88	90	84	108	72
	Relative importance weight	20.50	15.83	16.19	15.11	19.42	12.95

(Figure 2. House of Quality for Quality of concrete)

4. SIX SIGMA

Six Sigma (6σ) is a set of techniques and tools for process improvement. It was introduced by American engineer Bill Smith while working at Motorola in 1986 [7][9]. A six sigma process is one in which 99.99966% of all opportunities to produce some feature of a part are statistically expected to be free of defects. Six Sigma strategies seek to improve manufacturing quality by identifying and removing the causes of defects and minimizing variability in manufacturing and business processes. It does this by using empirical and statistical quality management methods and by hiring people who serve as Six Sigma experts. Each Six Sigma project follows a defined methodology and has specific value targets, such as reducing pollution or increasing customer satisfaction. The term Six Sigma originates from statistical modeling of manufacturing processes. The maturity of a manufacturing process can be described by a sigma rating indicating its yield or the percentage of defect-free products it creates—specifically, to within how many standard deviations of a normal distribution the fraction of defect-free outcomes corresponds.

(Figure 3. Steps involved in DMAIC)

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. Figure 3 represents different stages used in DMAIC methodology and also represents methods to be used at various stages. But, the process of DMAIC is to be used in a closed loop as improvement cannot be achieved in a single cycle. The process should pe repeated until the production process system reaches 6 level of sigma value.

4.1 DEFINE

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. 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.

An SIPOC (Supply- Input- Process- Output- Control) chart is prepared to define the process at RMC plant which if used to measure and evaluate quality at RMC plant. Table 1 represents SIPOC chart to define RMC production process.

(Table 1. SIPOC chart for RMC production process)

Supply	Input	Process	Output	Customer
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 Owner

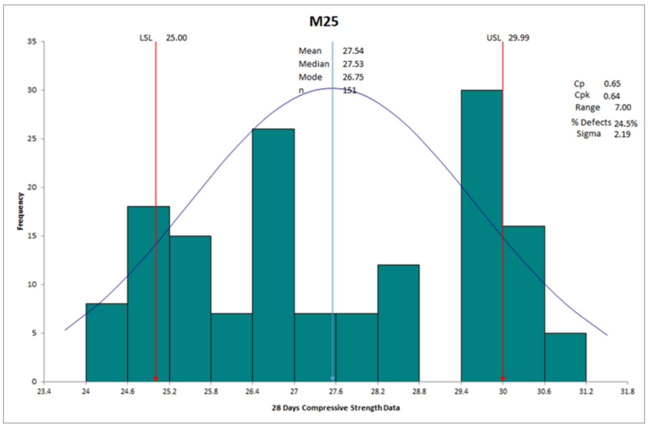
4.2 MEASURE

This is the second step in six sigma implementation which deals with defining the measurement system related to the quality. Compressive strength of concrete produced by RMC plant is used as a measurement system for quality of concrete. Data of compressive strength for various grades of concrete such as M25, M30 and M40 are collect from 01/01/2021 to 31/05/2021.

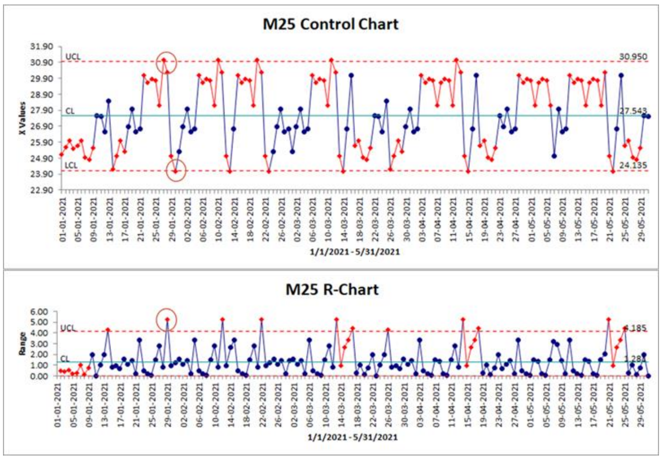
4.3 ANALYSE

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. Sigma level is the minimum of either {(USL - Mean)/ σ} or {(Mean – LSL)/ σ}. 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)/6σ}. Capability index (CP) for the process is found out to be more than 1 which states the process is in statistical control.

4.3.1 M25

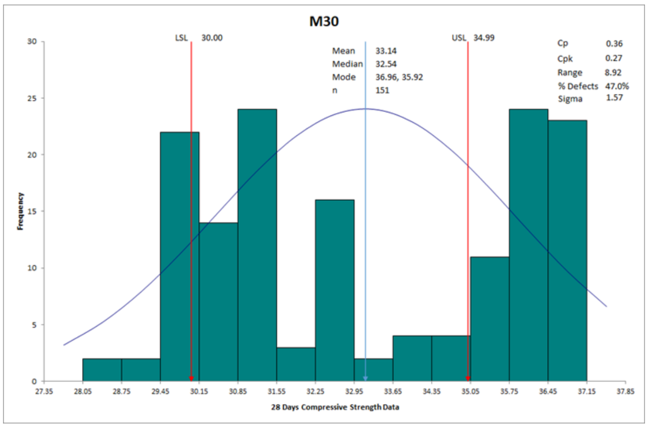


(Figure 4. Histogram for M25 grade concrete)

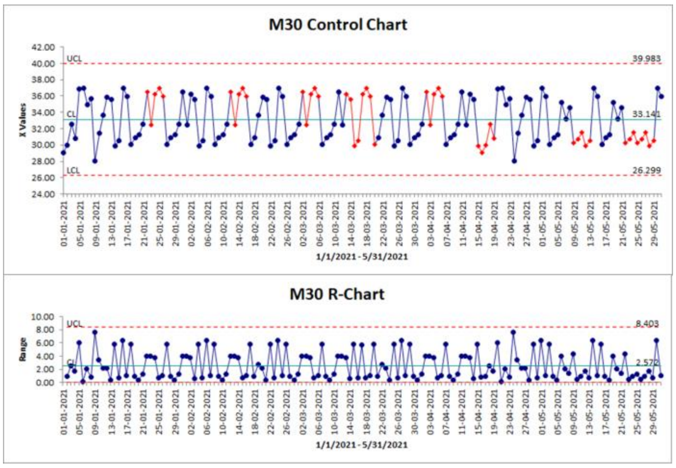


(Figure 5. Control and R-chart for M25 grade concrete)

4.3.2 M30

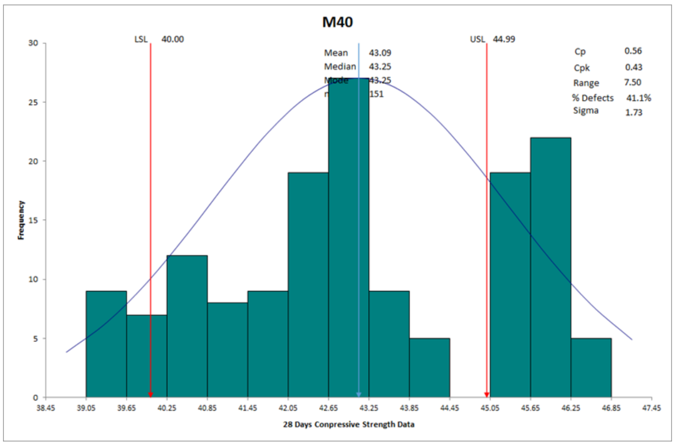


(Figure 6. Histogram for M30 grade concrete)

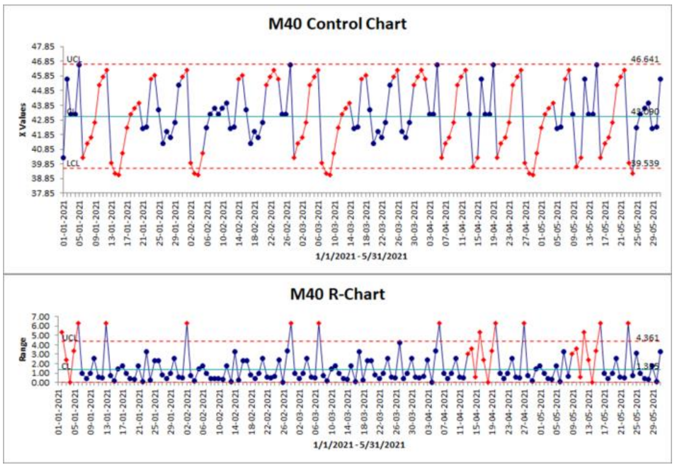


(Figure 7 Control and R-chart for M30 grade concrete)

4.3.2 M40



(Figure 8. Histogram for M40 grade concrete)

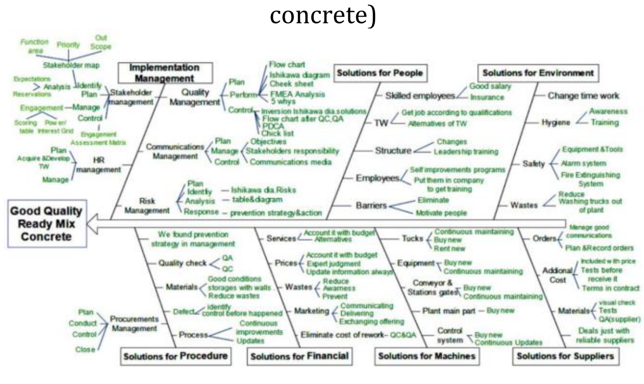


(Figure 9. Control and R-chart for M40 grade concrete)

4.4 IMPROVE

The main task in Improve phase is eliminating the root causes of variations and developing process requirements that minimize the likelihood of failures. A fishbone diagram is created to determine the root causes for the variation in compressive strength data of the concrete and is represented by figure 10. A question is use to collected data from primary data survey to determine solutions for the problem. A reverse fish bone diagram is created to determine effective measures to eliminate the root causes and is represented by figure 11. The reverse fishbone diagram is also known as solution effect diagram as it represents solutions to solve root cause which is poor quality of concrete.

(Figure 10. Fish-bone diagram for poor quality of concrete)



(Figure 10. Solution effect diagram for good quality of concrete)

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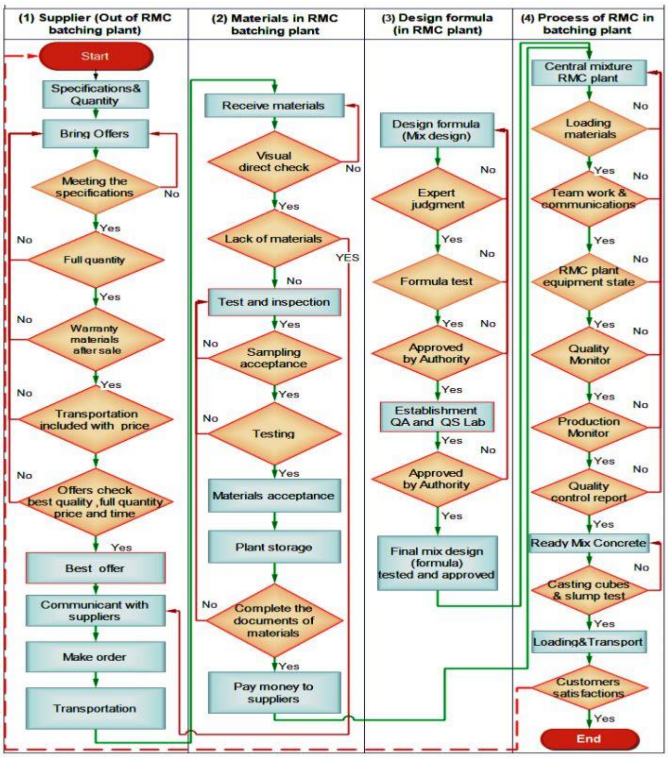
4.5 CONTROL

Control is the last step in DMAIC methodology which deals with formulating a process which provides continuous process improvement. The solution effect diagram developed in the previous stage is used to improve existing concrete production process. Quality Control (QC) is monitoring and inspection the process outcomes to evaluate if it is meeting with associable principles of quality which defines means to remove reasons of non-conformance standards. In addition, it is the company unit, which allotted responsibility for good quality. Figure 11 represents flow chart for continuous monitoring of the production process from selection of supplier for the concrete material till the concrete mixing and transportation process.



(Figure 11. Control Chart for RMC production process)

5. RESULT

Voice of Customer survey was done to determine the customers requirement related to the quality of concrete needed at construction sites. The sample size for the data collection were 20 civil site engineers who perform the concreting operations at the site.

5.1 CUSTOMER REQUIREMENTS

Table 2 and figure 12 shows the % selection of various customers quality requirements. From the graph, it can be concluded that the top four customers requirement for the quality of concrete is High workability, high strength, low segregation and bleeding and high durability.

(Table 2. Customer Requirements)

Sr. No.	Customer Requirements	Percentage Votes
1	High Strength	22.37
2	High Durability	15.79
3	High Workability	23.68
4	Low Curing Period	6.58
5	Low Segregation and bleeding	18.42
6	Impact Resistant	6.58
7	Economical	6.58

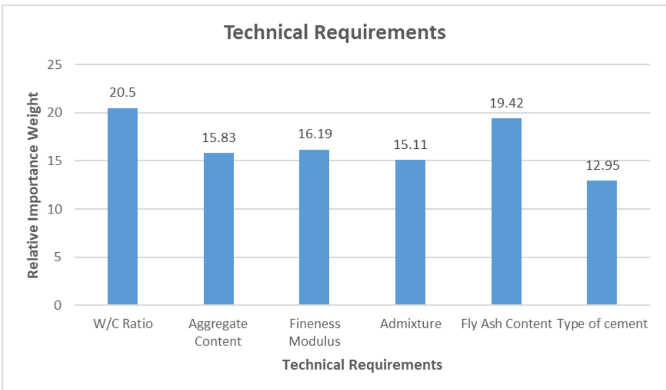
(Figure 12. Graph of Customer requirements vs % votes)

5.2 TECHNICAL REQUIREMENTS

Table 3 and figure 13 shows technical requirements and their relative importance weights calculated in formulation of House of Quality (HoQ). It can be concluded from the graph that, W/C ratio and fly ash content should be closely monitored to reduce defects in concrete quality and increase sigma value of production process.

(Table 3. Technical Requirements)

Sr. No.	Technical Requirements	Relative Importance
1	W/C Ratio	20.5
2	Aggregate Content	15.83
3	Fineness Modulus	16.19
4	Admixture	15.11
5	Fly Ash Content	19.42
6	Type of cement	12.95



(Figure 13. Graph of Technical requirements vs Relative importance weight)

6. CONCLUSIONS

After doing rigorous study on implementation of six sigma for quality improvement at RMC plant in Pune region it can be concluded that,

1. High workability, high strength, and low segregation and bleeding are the three top customers requirement determined by primary data collection.
2. The HoQ technical requirements are ranked as follows:
    a) W/C ratio
    b) Fly-ash content
    c) Fineness Modulus
    d) Aggregate content
    e) Admixture
    f) Type of cement
3. The production process is neither stable nor capable to produce concrete of stable quality as Cp value of M25, M30 and M40 is 0.65, 0.36 and 0.56 respectively which is less than 1.
4. The average sigma level of RMC production process is 1.83 which is very low than 6. Hence, more pro-active and robust approach is required to improve existing production process.
5. Environment, people, management, suppliers, machines, finance and plant procedures are the seven important parameters contributing towards poor quality of RMC concrete.
6. Feedback network at all four stages (Supplies, Material, Design and Process) can help in designing a continuous improving RMC concrete production system.

REFERENCES

1) BUREAU OF INDIAN STANDARDS, "READY-MIXED CONCRETE — CODE OF PRACTICE," Indian Standards, 2003.
2) K. R. Motta and P. A. Domingo, "The implementation of six sigma in Manufacturing Organizations: Motivations and Results Achieved," Brazilian Journal for Business and Management,, vol. 4, no. 2, pp. 11-20, 2005.
3) D. H. Besterfield, Quality Control, Prentice-Hall, 2012.
4) Govers, "What and how about quality function deployment," International Journal of Production Economics, Vols. 46-47, pp. 575-585, 1996.
5) J. M. Kamara, C. J.Anumba and N. F. Evbuomwan, "Client requirements processing in construction: A new approach using QFD," J. Arch. Engrg. ASCE, vol. 5, no. 1, pp. 8-15, 1999.
6) L. S. Pheng and L. Yeap, "Quality Function Deployment in Design/Build Projects," Journal of Architecture Engineering, ASCE, vol. 7, no. 12, pp. 30-39, 2001.
7) E. S. Jaiswal, "A case study on Quality Function Deployment," Journal of Mechanical and Civil Engineering, vol. 3, no. 6, pp. 27-36, 2012.
8) MOLLY THOMAS and L. PORCIA, "Effectiveness of implementation of lean six sigma techniques in construction", International Journal of Advances in Science Engineering and Technology, 5(3), July-2017, ISSN: 2321-9009, (pp. 1-10).
9) Kuo-Liang Lee and Yang Su , "Applying Six Sigma to Quality Improvement in Construction", JOURNAL OF MANAGEMENT IN ENGINEERING © ASCE, OCTOBER 2013, ISSN : 1943-5479, (pp. 464-470).
10) Nishaant Ha, Swethaa.B, Chris Anto.L, "Concreting For Construction- Quality Control by Six Sigma Approach", International Journal of Innovative Technology and Exploring Engineering (IJITEE), 8(2), December 2018, ISSN: 2278-3075, (pp. 332-335).
11) E.Poovaragavan and K.Chandra Sekar, "Continuous Process Improvement In Ready Mix Concrete Plants", International Journal of Scientific & Engineering Research, 7(4), April-2016, ISSN 2229-5518, (pp. 154-159).
12) Jishnu Gohel, Dr. Debasis Sarkar and Dr. H. B. Raghavendra, "Process monitoring of RMC by application of EWMA control charts ", International Journal of Application or Innovation in Engineering & Management (IJAIEM), 6(8), August 2017, ISSN 2319 – 4847, (pp. 44-50).
13) Viraj Parekh, Sagar Jotani, and Jay Patel, "Application of Six Sigma on RMC Plant", Springer Nature Singapore Pte Ltd. 2021, Advances in Civil Engineering and Infrastructural Development, Lecture Notes in Civil Engineering 87, ISSN: 2366-2557, (pp. 295-301).
14) Debasis Sarkar and Riki Panchal, "Quality Function Deployment (QFD): A Six Sigma Tool for Performance Monitoring of Ready Mixed Concrete ", International Advanced Research Journal in Science, Engineering and Technology, 4(2), February 2017, ISSN: 2394-1588, (pp. 14-18).
15) Jishnu Gohel, Dr. Debasis Sarkar and Dr. H. B. Raghavendra, "Process monitoring of RMC by application of EWMA control charts ", International Journal of Application or Innovation in Engineering & Management (IJAIEM), 6(8), August 2017, ISSN 2319 – 4847, (pp. 44-50).
16) Viraj Parekh, Sagar Jotani, and Jay Patel, "Application of Six Sigma on RMC Plant", Springer Nature Singapore Pte Ltd. 2021, Advances in Civil Engineering and Infrastructural Development, Lecture Notes in Civil Engineering 87, ISSN: 2366-2557, (pp. 295-301).
17) Debasis Sarkar and Riki Panchal, "Quality Function Deployment (QFD): A Six Sigma Tool for Performance Monitoring of Ready Mixed Concrete", International Advanced Research Journal in Science, Engineering and Technology, 4(2), February 2017, ISSN: 2394-1588, (pp. 14-18).