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FMEA RISK MANAGEMENT TECHNIQUE FOR QUALITY CONTROL OF RMC PRODUCTION

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ABSTRACT

Concrete is the most extensively used among all the construction material and is frequently considered as the most economical and durable material. For effective quality and productivity improvement of infrastructure projects, statistical quality control (SQC) application proves to be an important tool which can be used in order to ensure that concrete produced is of desired quality. In order to identify the major failure mode in production of Ready Mixed Concrete (RMC) of different grades (M20,M25,M30) FMEA is used. The Failure Mode Effect Analysis (FMEA) technique is to identify risk factors for the potential failure mode in the production process of concrete and to take the appropriate corrective actions for improvement.The risk priority number results indicate's process failure in terms of irregular grading process, material testing prior use in mixing process which were the important factor to be monitored for quality control.

Keywords: Statistical quality control(SQC), Ready mix concrete (RMC), Quality Control, Quality Tools,risk priority number(RPN),failure mode effect analysis(FMEA)

I. INTRODUCTION

Concrete is the most universal of all the construction material and is frequently considered as the most economical one and is strong and durable material. As per Indian Standard code of practice (IS 4926 - 2003) Ready Mixed Concrete (RMC) is defined as the concrete delivered in plastic condition and requiring no further treatment before being placed in position in which it is to set and harden. (Naiknavare P; Naiknavare, Deshpande, & Padhye, 2010). In the era of competitive markets and globalization, quality concepts and philosophies have emerged as strategic issues at all organizational levels and in all industries and services including the RMC industry which is the major asset of national economies. The seven basic quality tools have been used by quality professionals to identify procedures, ideas, statistics, cause and effect concerns and other issues relevant to RMC industry.(Mohamed A. 2., 2012)

There is an awareness and understanding about importance of risks and its management techniques in European countries. Operation managers on RMC plants in the European countries are likely to work on risk management at production plant and delivery sites. In India, Risk Management at RMC plant is not given enough importance. Information gathered from different RMC plants in India in places like Mumbai, Navi Mumbai, Pune, Bangalore, and Noida, reveals that a regular and proper risk management approach is not practiced in Indian RMC Industry. Unless the risks are addressed properly, the RMC industry in India shall not gain reliability, confidence of customers and will also cause reduction in profit margins.(Valke & Kabiraj, 2010)

Thus, the aim of the study is to identify the effective risk factors for the concrete production process for quality control using failure mode effect analysis(FMEA) tool, and to propose quality control model for ready mix concrete(RMC). This model will be a valuable information to engineers for identifying failures of on process concrete production.

II. LITERATURE REVIEW

The most realistic and effective tool for monitoring the quality of ready mix concrete was brought into existence which is known as risk adjusted cumulative sum(RACUSUM). RACUSUM model is based on the likelihood ratio scoring method, the quantification of which involves parameters such as estimated risk, odds ratio under null hypothesis odds ratio under alternate hypothesis, and actual outcome of the sample strength. The log-likelihood score thus obtained, when added to the conventional cumulative summation(CUSUM) values and the corresponding graphical plot, is termed as the RACUSUM plot.(Datta & Sarkar, 2010).

Quality Control of Ready Mixed Concrete can be divided into three convenient areas like forward control, immediate control and retrospective control. Statistical Quality Control(SQC) application proves to be an important tool which can be used effectively for quality and productivity improvement for infrastructure projects. Statistical Quality Control can be effectively applied to RMC industry for online (during production) and also offline (before and after production) quality monitoring and control.(Mohamed A. 2., 2012)

A production of ready mix concrete includes mix design of RMC, IS codes, mixing process, carrying of concrete, handling process, quality assurance and site preparation.(Gupta D. Y., 2008). Ready mix concrete is an industrial product which is delivered to consumer in fresh condition after the production process in RMC plant. The process of Ready mix concrete(RMC) flows from (design, production, transportation, pouring, placement and maintenance).

Failure Mode and Effect Analysis (FMEA) is one of the risk analysis techniques recommended by international standards such as MIL-STD-1629A (U.S. Department of Defense 1980). FMEA is a technique that is based on identifying potential failures, analyzing root causes, and examining failure impacts so that these impacts can be reduced.

The most common tool used for quality process improvement in RMC is PDCA cycle (Plan Do Check Act cycle) is shown in figure 1.

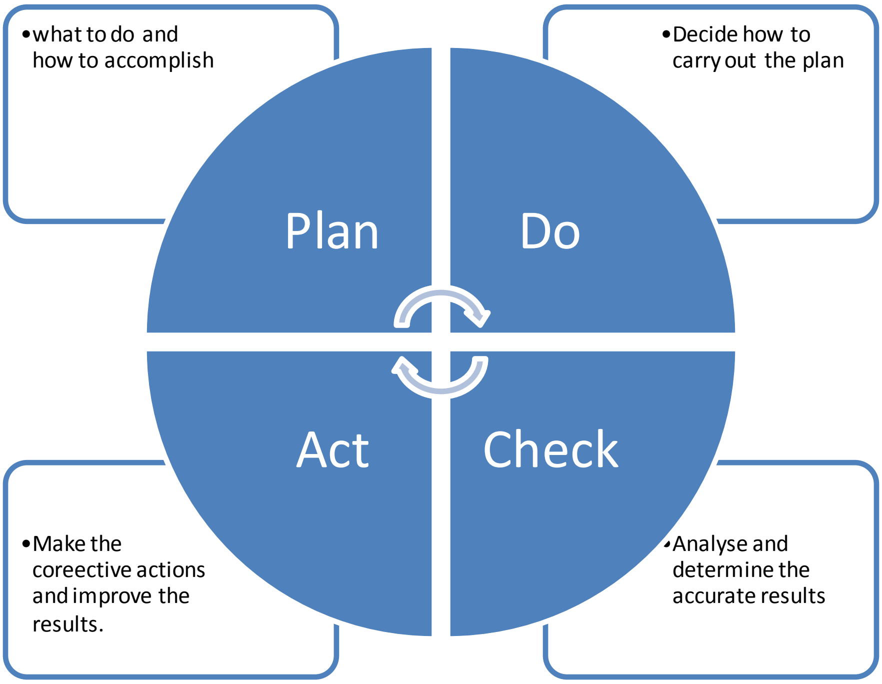

Fig 1: PDCA Cycle

PDCA cycle for process improvement is documented under seven phases i.e. Identify the opportunities for improvement, investigate the current process, expand the optimal solution, apply the changes, study the results, standardize the solution and plan for future.

Within the context of traditional FMEA, the degree of criticality of an event is measured by calculating Risk Priority Number (RPN). Risk Priority Number (RPN) is an index score calculated as the product of the three input terms, Severity (S), Occurrence (O), and Detection (D). The severity rating (S) is used to represent the potential effects associated with the occurrence of failure mode. The occurrence rating (O) is the probability of occurrence of a failure (Ayyub, 2003)

Researcher's has introduced an application of FMEA to the context of project risk management by calculating the RPN to find out the most critical events that require immediate response.(Tippet, 2004),this calculation is straight-forward and easy to understand. But, shortcomings within this RPN calculation have been noted(palaez, 203-213). For instance, a failure mode with Severity (S), Occurrence (O), and Detection (D) values as 9, 5, and 5 respectively results RPN as 225. Whereas, a failure mode with Severity (S), Occurrence (O), and Detection (D) values 7, 7, and 5 respectively results RPN as 245.So, the latter failure mode shall be considered to establish the response. But, from Management perspective, the Severity(S) rating for the former mode is higher, which cannot be neglected.

So, Ayyub (2003) stated that without linking the value of RPN to linguistic terms describing the priority to take corrective actions, the project team will not be able to recognize the difference between the closer values of RPN.(Ayyub, 2003)

Failure mode and effect analysis is the technique which is used to identify the potential failure modes for the product or a process before the problem occurs to consider the risk. It might also rank each failure according to the criticality of a failure effect and its likelihood of taking place. FMEA is an analytical technique which explores the effect of failure of individual components in a system. (Quantified risk assesment techniques part-1 Failure mode and effect analysis FMEA, 2012). (Lipol & Haq, 2011)

For calculating the risk using FMEA, RPN (Risk Priority Number) is calculated based on severity, occurrence and detection. RPN=S*O*D. The scale of severity(S), occurrence(O) and detection(D) is range from 1-10 where 1 is lowest and 10 is highest. (Quantified risk assesment techniques part-1 Failure mode and effect analysis FMEA, 2012) (Lipol & Haq, 2011)

A. Benefits of FMEA

Improve the design of product or process after identifying the risk i.e. better quality, upper reliability and enlarged safety.

Improve customer satisfaction i.e. cost saving, decrease warranty cost and decrease waste.

Development of control plans, testing requirements and reliability plans.

B. Limitation of FMEA

FMEA is not used to identify the complex failure mode in product or process (deals with only single point failure and cannot deal with multiple failure mode).

III. RESEARCH SIGNIFICANCE

There is a tremendous growth in use of ready mix concrete for the construction in developed countries. In today's world, the ready mix concrete is used by almost every construction industries, but they are lagging behind in considering the quality of concrete. The quality of concrete is still ignored or not taken into consider by RMC producers hence in order to improve the performance of RMC, proper monitoring and control is required. Hence there is a need of risk identification. In order to identify the major failure mode in production of RMC, FMEA technique is required to study.

IV. DATA COLLECTION AND ANALYSIS

Data collected from RMC plants located in ahmedabad.The grade of concrete produced from the plant-1 is of grade M25. The ingredients considered for concrete mix of M25 grade is 382kg of cement, 748 kg of sand, 528 kg of 10mm aggregate, 656 kg of 20mm aggregate, 172 kg of water and 3.06 of admixture. The compressive strength test results were obtained for 7 days and 28 days along with slump of concrete. The 28 days compressive strength was taken into consideration for risk monitoring and control factor for the study.The basic capacity details of RMC plant was total capacity of - 60m^3,number of transit mixer- 2 ,capacity of transit mixer- 6m^3,capacity of cement silos- 120 tons ,Plant model- Automatic horizontal hoppercement grade-53 used,concrete produced in each batch-2.25 m^3.The mix design for M25 grade concrete is shown in figure 2.

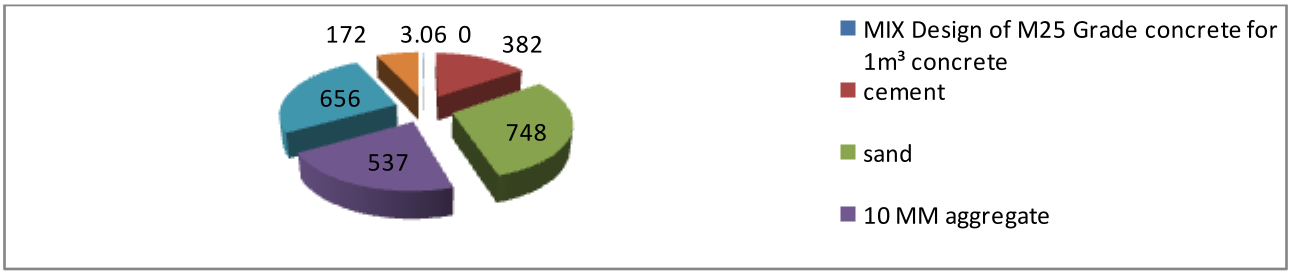

Fig 2: Mix design of M25 grade concrete

The test results for M25 grade concrete is shown in table 1.

Table 1: Test results for M25 grade

Sr. Name	Grade of concrete	Date of Casting	7 days compressive Strength N/mm²	28 days compressive Strength N/mm²	Slump Value (mm)
1	M25	02-09-2014	22.28	29.13	91
2	M25	02-09-2014	23.32	27.8	102

V. DATA ANALYSIS

The data analysis is carried out with the help of data collected from three different RMC plants from Ahmedabad. In data analysis, firstly the basic statistical calculations are carried out from the test results obtained i.e. mean, standard deviation, upper control limit (UCL) and lower control limit (LCL).The mean of 28 days compressive strength was calculated for the collected number of samples which was plotted as a center line of control chart. Before calculating standard deviation, variance is to be calculated and variance is average of the square of the distance between each point in a total population (N) and the mean (μ). Standard deviation is obtained by taking root of variance.

A. Frame-work for Data analysis

The frame work for data analysis is shown in figure 3.

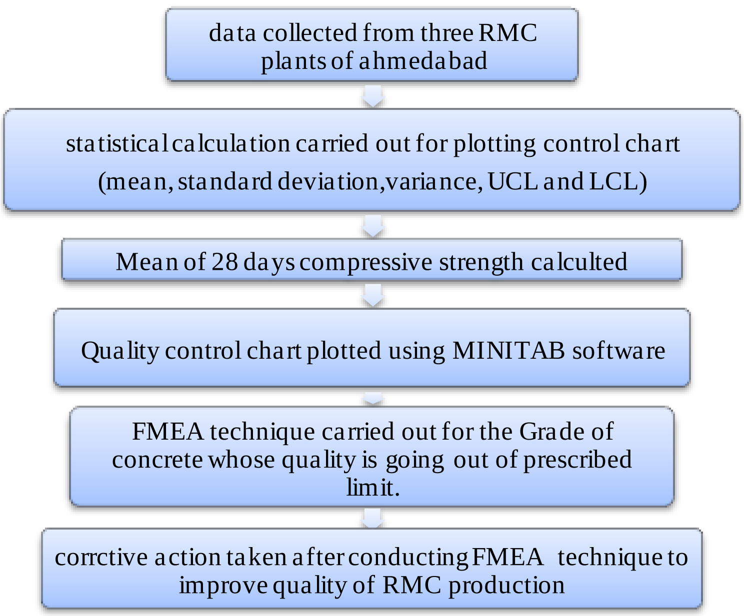

Fig 3: Analysis frame-work

B. Salient features of functioning of Minitab Software

Minitab software is statistical software which is used for generating the schewart control charts to determine the quality of concrete under the calculated control limits. Schewart control chart is the one of the important tool out of seven basic quality tools to determine the quality of ready mix concrete from which failure mode and effect analysis is carried out.

It can be used for learning about statistics as well as statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand. Minitab is relatively easy to use once you know a few fundamentals.

Minitab starts with two basic windows, i.e. session window and worksheet window, session window shows the statistical results and worksheet window shows the input data. Minitab will accept only numeric data.Minitab can change data types within limits. It cannot make a simple switch of people's names to numeric values, but if you have a column of numbers that was accidentally entered as text, then you can change those numbers to numeric values.

There are various other graphs like histogram, box plot graph and scatter plot can also be plotted using Minitab software.

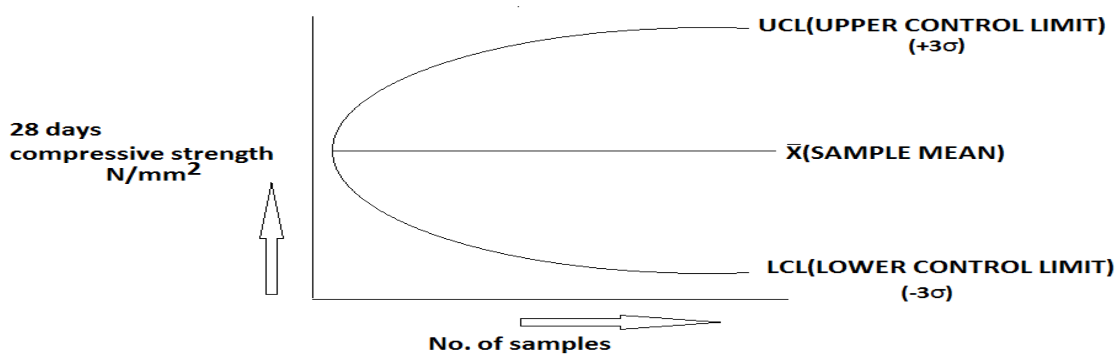

Fig 4: sample quality control chart

Figure 4.shows the schewart control chart with number of sample on x-axis and 28 days compressive strength is mentioned on y axis respectively. There are two sigma limits in the chart i.e. upper control limit which is the maximum value of compressive strength and another is lower control limit i.e. minimum value of compressive strength. The sigma limit consider for this study is 3. This will become the prescribed control limit of the quality control chart under which chart is plotted. If it goes beyond this limit, it is considered as failure.

C. Data calculations

The data is collected from three different RMC plants in Ahmedabad for the different grades of concrete based on data analysis frame work. Four statistical parameters were calculated from the data collected i.e. mean, standard deviation, upper control limit (UCL) and lower control limit (LCL) is shown in table 2.

Table 2: Statistical Parameters

SR.NO	RMC PLANT	GRADE OF CONCRETE	MEAN	STANDARD DEVIATION	UCL	LCL
1	RMCplant-1	M25	32.6	2.35	39.71	25.61
2	RMCplant-2	M20	24.54	1.16	28.02	21.06
		M25	30.18	1.81	35.61	24.75
		M30	34.7	2.09	40.97	28.43
3	RMCplant-3	M20	32.2	1.95	38.05	26.35

D. ResultsFrom Minitab

Minitab software is used to plot the quality control charts in order to predict the production process. In the present research, Minitab software is used to plot the control charts for 28 days compressive strength of ready mix concrete.

Minitab software includes the stepwise procedure by inputting the data which is shown in the following snapshots below. The data for control chart is to be input in the form of sheet as shown in figure 5 i.e. 28 days compressive strength and M25 grade of concrete.

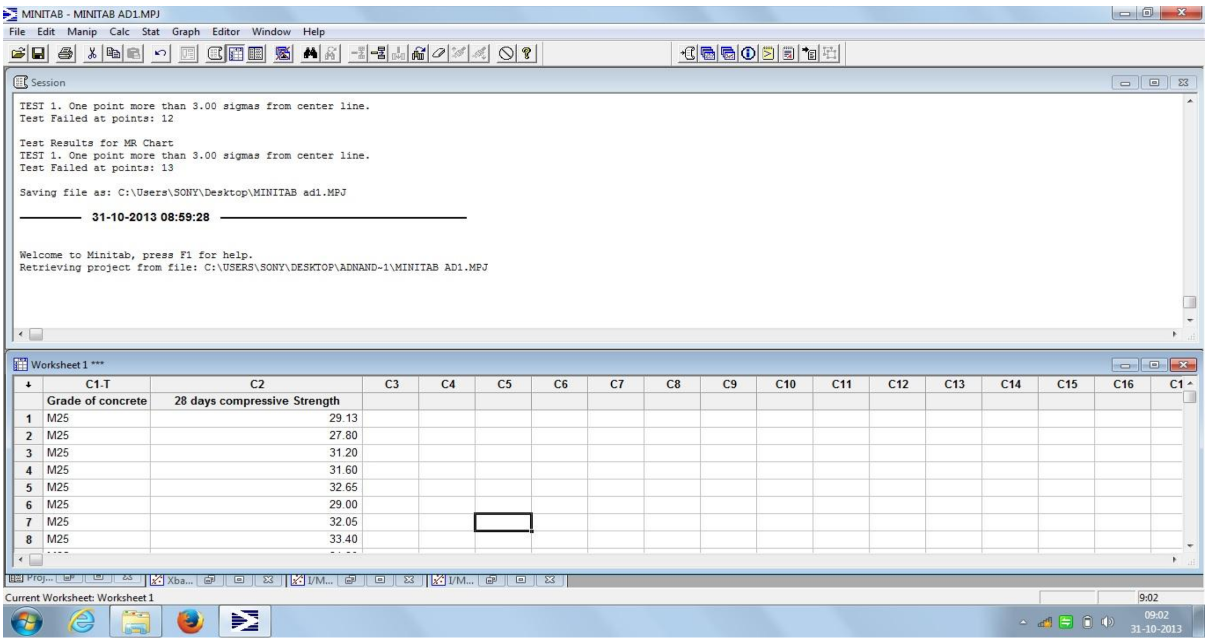

Fig 5: Minitab Input data sheet

After inputting the compressive strength data, the calculated value of mean and standard deviation is to be entered in the minitab as shown in figure 6.8

Fig 6: Input data for mean and Standard Deviation

Control chart has its control limit up to the three times the standard deviation on both the limit i.e. upper control limit and lower control limit which is to be set into Minitab as shown in figure 7.

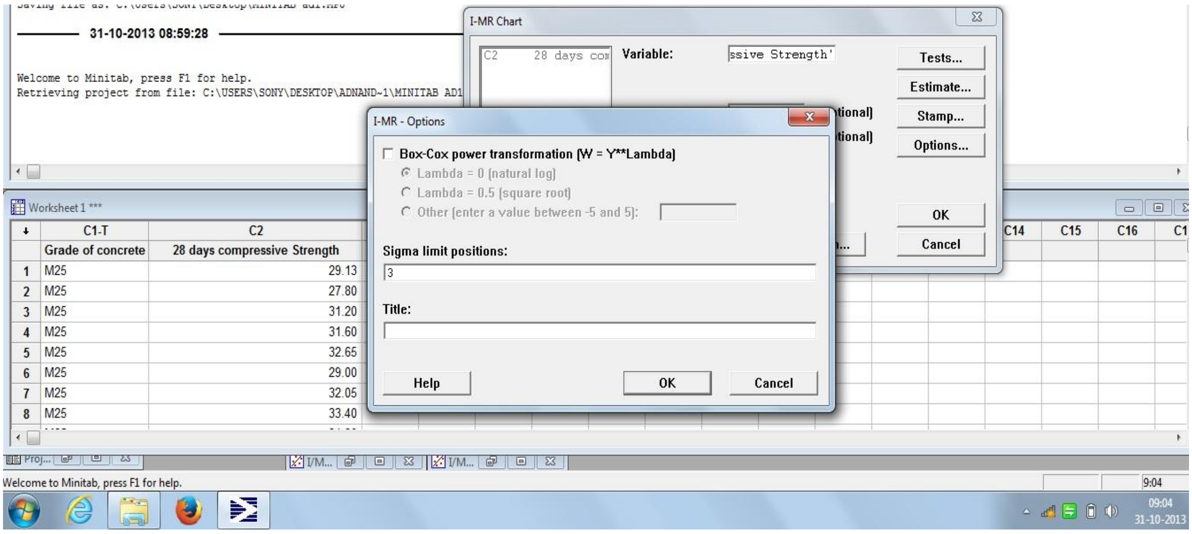

Fig 7: sigma limit position

Once the sigma limit is fixed for UCL and LCL the control charts is plotted for different grades of concrete of the three RMC plant data.

Fig 8: control chart for M25 grade

It can be seen that from figure 8 (control chart for data collected for RMC plant-1), out of 39 samples of concrete cubes there is a failure in 12th sample from control chart which means that it is necessary to modify the mix design of that corresponding sample.Thus, FMEA technique is applied on plant-3 to assess the failure mode.

Control chart for the data collected from (RMC plant-3)is shown in figure 8.control charts for the data collected from (RMC plant-2) is shown in figure 9, 10 and 11 respectively.

It can be seen from the figure 9, 10, 11 and 12 that the quality of the RMC produced is under the prescribed control limit.

Fig 9: control chart for M20 grade

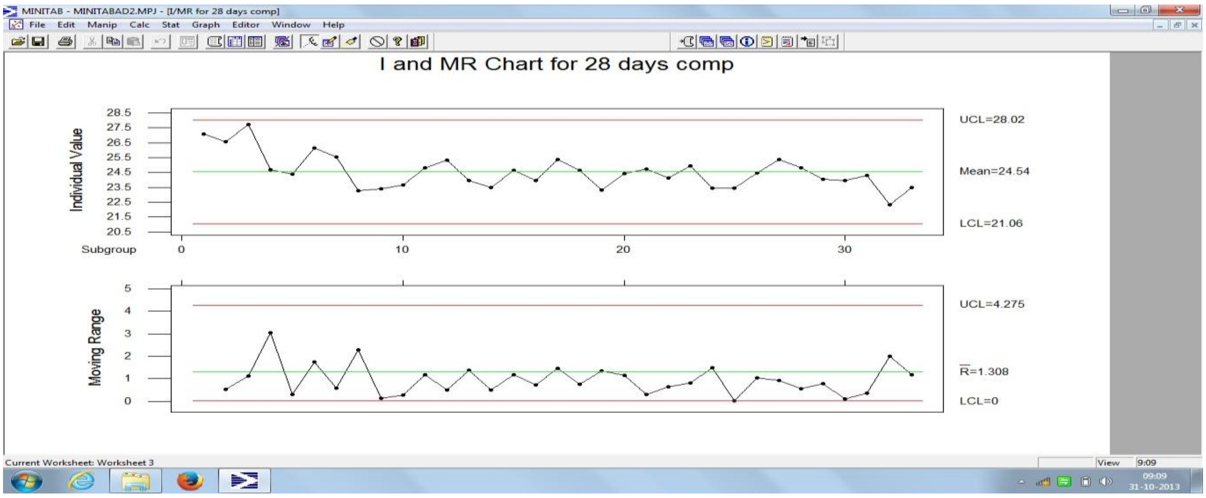

Fig 10: control chart for M20 grade

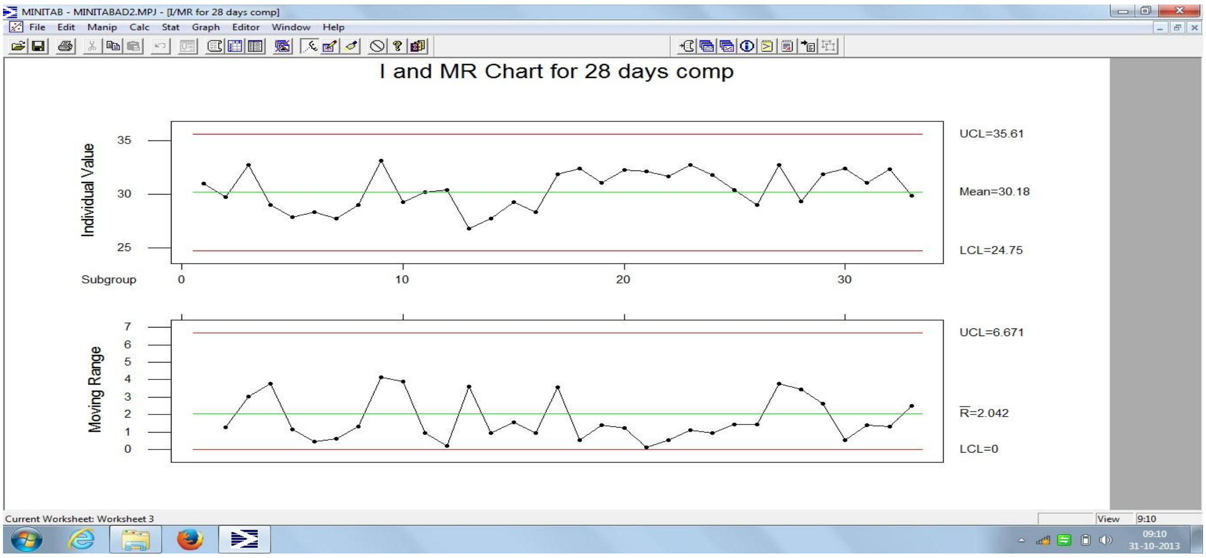

Fig 11: control chart for M25 grade

Fig 12: control chart for M30 grade

E. Major issues in RMC plants

The major issues found in the production of Ready mix concrete through survey during the study were selection of improper source of material i.e. (cement, sand, aggregate), non systematic process of conducting mix design of ready mix concrete and improper grading and also using equipments without any maintenance this all factors influence the quality of ready mix concrete and thus the compressive strength get decreases.

F. FMEA (Failure mode and effect analysis)

Failure mode and effect analysis is the technique which is used to identify the potential failure modes for the product or a process before the problem occurs to consider the risk. It might also rank each failure according to the criticality of a failure effect and its likelihood of taking place. FMEA is an analytical technique which explores the effect of failure of individual components in a system.

In order to calculate risk in FMEA, risk has three components which are multiplied to produce RPN (risk priority number). By calculating RPN, one will be able to decide the priority to select the most severe factor. There is no threshold value for RPNs. In other words, there is no value above which it is mandatory to take a recommended action or below which the team is automatically excused from an action .The most common rating scale for severity, occurrence and detection in order to calculate Risk priority number is shown in table 3. The Failure mode and effect analysis is a technique which is carried out for the failed sample in order to identify the potential failure mode in the RMC production process. It can be seen from table 4. of FMEA sheet that the Risk priority number of the process factor is highest i.e. 48, thus it needs to be corrected immediately for improvement.

Table 3: Rating scale for occurrence, severity and detection

	1	**2**	**3**	**4**	**5**
Occurrence	remote	low	moderate	high	very high
Severity	none	low	moderate	high	extreme
Detection	very high	high	moderate	low	very low

Table 4: FMEA sheet

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mode of Failure	Cause of Failure	Effect of Failure	Frequency of Occurrence (1-5)	Degree of Severity (1-5)	Chance of Detection (1-5)	Risk Priority (1-125) [4] x [5] x [6]	Design Action
Material	Cement, Aggregate, Sand	Compressive strength	3	3	2	18	Test certificate should be properly checked, material should be checked on arrival at site and properly stored
Process	Process of Mix Design and Grading	Compressive strength	3	4	4	**48**	Grading should be done properly (Sieve analysis), material testing before use in mix.

Equipment	Weighing on scale and Calibration	Compressive strength	3	4	2	24	Calibration at every 5000 m^3 of concrete production or every month

G. FUTURE RESEARCH

The present research was restricted to RMC plants located in and around ahmedabad city but further research can be carried out for some other RMC plants located in Gujarat. It can be continued with considering durability,density as quality parameter along with compressive strength to ensure the quality of ready mix concrete and to improve the RMC production.

VI. CONCLUSIONS

Based on experimental testing conducted for plotting control charts and FMEA technique used, following conclusions are drawn:

The quality control chart was proved to be the most effective tool for quality control of RMC production.

The quality pattern predicted from control chart from plant-3 and plant-2 was under prescribed control limits. But the quality pattern of plant-1 was going out of prescribed control limits.Thus, FMEA technique was applied on plant-3.

The Minitab software was used to generate schewart control charts for different grades of concrete from three different RMC plants and the 12th sample out of 39 samples crossed the upper control limit (UCL) –39.71. for M25 grade concrete for RMC-plant-1.

Failure mode assessment was carried out as shown in table-4 for M25 grade mix design for plant-1. The results show that the Risk Priority Number-48 of the process factor was highest out of all other failure modes and was critical which is to be immediately corrected for process improvement.

In order to improve the quality of RMC production, grading of material should be done properly including proper sieve analysis and also material should be tested before taken into mix design.

Depending upon the RPN calculated in FMEA'S sheet as shown in table-4, next priority will be given to equipment as RPN for "equipment factor" was 24, calibration of equipment after every 5000 cu.m production should be carried out and last priority should be given to "source of material" as RPN of "material factor" was obtained as 18 which is least severe from all other factors.

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