A Study of Risk Evaluation of Ready Mix Concrete Production and To Propose effective model for incorporating precautionary measures

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Abstract — *Ready mix concrete is continuously growing industry in India. Quality control charts is effective and can be used to monitor quality of ready mixed concrete (RMC) during its production process. Statistical Quality Control charts helps in monitoring the concrete quality at the RMC plant during its production process. The systematic identification and evaluation of major failure mode and effectively dealing with the result is significant to success of ready mix concrete production for different grades of concrete (M20, M25, M30, M40). In this work, an attempt is made to find out the various failure modes in RMC production process with the help of Failure Mode and Effective Analysis (FMEA) technique. This technique helps to identify failure factors in production process of concrete and give corrective actions for improvement. The various factors in production process like mix design of various grade, material grading, process and equipments used for testing will helps in indicating risk priority number to monitor quality control of concrete.*

Keywords- *Risk Evaluation, RMC plants, Quality control, Failure mode and Effective analysis (FMEA), SQC, Risk Priority Number (RPN).*

I.   INTRODUCTION

Concrete is the most universal of all the construction material and is frequently considered as the most economical one 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. RMC is specialized material in which the cement, aggregate and other ingredients are weigh-batched at a plant and mixed in a central mixer or truck mixer, before delivery to the construction site in a condition ready for placing. Thus, fresh concrete is manufactured in a plant away from the construction site and transported within estimated journey time. Ready mix concrete is produced under factory conditions and permits close control of all operations of manufacturing and transportation of fresh concrete. Due to its durability, low cost and its ability to be customized for different applications, RMC is now one of the most popular building materials. 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.

Managing o f risk is an integral part of industrial management system. There is an awareness and understanding about importance of risks and its management techniques in European countries. Operations managers on RMC plants in the Europeans 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, Pune, Bangalore, 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. Hence, there is need for a proper and most efficient technique for risk evaluation in RMC industry.

In this work, a study is made with help of using Statistical quality control applications which an important tool which can be used effectively for quality and productivity improvement for various projects. With that, an traditional method is used to identify the various failure mode which take place in production process that is the Failure Mode and Effective Analysis(FMEA). With this technique various potential failure can be identified and with that various corrective actions for improvement can be implemented. Reputed RMC plants in Pune region were selected for the study and the results developed are analyzed to know the effectiveness of traditional and SQC technique. Also remedial measure for identified potential failures are suggested. And this model will be valuable information to engineers for identifying failures in production process.

II.   LITERATURE SURVEY

In this section, we discuss the research work done by various eminent researchers over last few years , on Statistical tools and various methods related to production process.

Goutam Dutta et.al [1] were conducted a study on design and applications of Risk Adjusted Cumulative Sum (RACUSUM) for online strength monitoring of Ready Mixed Concrete. In this paper, an attempt is made to design and apply a new CUSUM procedure for RMC industry which takes care of the risks involved and associated with the production of RMC. This procedure is termed as Risk Adjusted CUSUM (RACUSUM). Mohamed A 2 et.al [2] were conducted a study on the use of basic quality tools for yhr improvement of the construction industry. 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.

Gupta D. Y et.al [3] were conducted study on a revolution in production of concrete. 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. Ready mix concrete is an industrial product which is delivered to consumer in fresh condition after the production process of RMC plant. The process of Ready mixed concrete (RMC) flows from (design, production, transportation, pouring, placement and maintenance). Agnieszka Dziadosz et.al [4] conducted a study on risk analysis in construction projects. This article presents three different methods of the risk analysis as well as highlighting their advantages, disadvantage and primary areas of applications.

Mehrzad et.al [5] were studied about assessment and risk management of potential hazards by Failure Modes and Effect Analysis (FMEA) methos in Yazd Steel Complex. In his work, the risks in different parts of the complex were evaluated by using FMEA method. Jyoti Trivedi et.al [6] were studied about the FMEA risk management technique for quality control of RMC production. The risk priority number results indicated 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. Gunjun joshi et.al [7] were studied about FMEA and Alternatives v/s Enhanced Risk Assessment Mechanism. In this work, the advantage of using six sigma in Risk Assessment are also pointed out and proposed a novel technique which would overcome the restrictions of existing Risk Management tools.

III.   RESEARCH OBJECTIVE

This research paper has aimed to (1) To identify and synthesis the factors affecting the production of concrete. (2) To quantify relative importance of the potential failure factors and to demonstrate the ranking of factors and categories according to their importance level on occur of the failures. (3) To categorize the factors due to failure in production and to address the major of failure factors and make recommendations in order to overcome the concrete production process.

IV.   QUANTITATIVE RISK EVAULATION

The different methods of quantitative risk evaluation is done with following:
- Fault tree Analysis (FTA)
- Cost of exposure quality risk analysis
- Failure Mode and Effect Analysis (FMEA)
- Cause-consequence Analysis
- Event tree analysis(ETA)

Failure Mode and Effective Analysis (FMEA) Technique

FMEA 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 tp calculate risk in FMEA, risk has three components which are multiplied to produce RPN (risk priority number). By doing this calculation one will be able to decide the priority to select the most severe factor. There is no threshold value for RPNs. The most common rating for severity, occurrence and detection in order to calculate risk priority number can be seen. It can be seen from results that risk priority number of the process factor with highest number, thus it needs to be corrected immediately for improvement.

Rating scale for occurrence, severity and detection

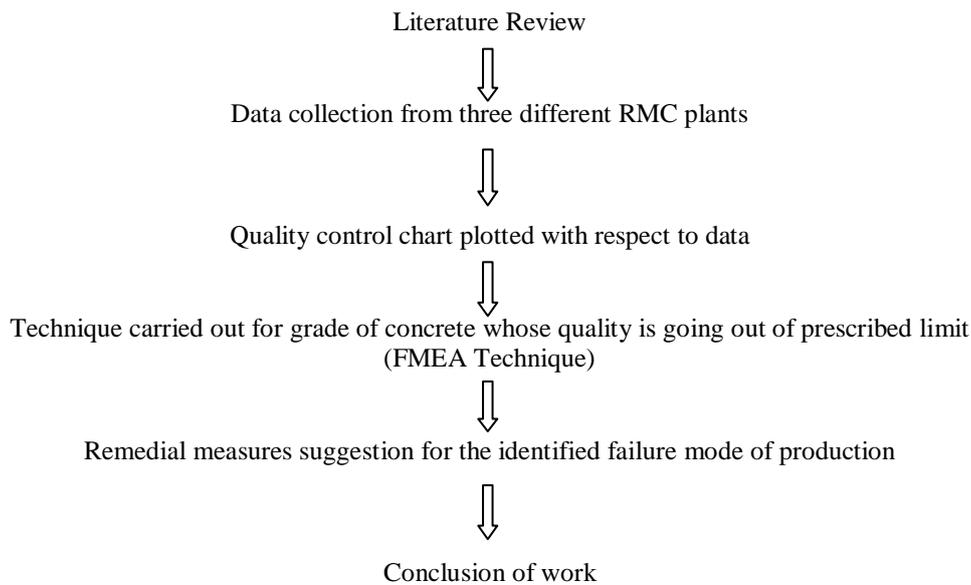|	1	2	3	4	5
Occurrence	Remote	Low	Moderate	High	Very high
Severity	None	Low	Moderate	High	Extreme
detection	Very high	High	Moderate	Low	Very low

Table 1: Rating scale of FMEA

After obtaining the rating for severity, occurrence and detection , the risk priority number (rpn) is calculated for each failure mode as per equation,

$$RPN = SEVERITY*OCCURRENCE*DETECTION$$
$$= S*O*D$$

The factor with maximum value of RPN is considered as the most critical risk and factor with minimum RPN is the least critical risk. Here the major consideration is given to the most critical risk, since it governs the overall performance of the plants.

V.   METHODOLOGY OF WORK

Literature Review

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Data collection from three different RMC plants

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Quality control chart plotted with respect to data

⇓

Technique carried out for grade of concrete whose quality is going out of prescribed limit
(FMEA Technique)

⇓

Remedial measures suggestion for the identified failure mode of production

⇓

Conclusion of work

VI.   DATA ANLAYSIS

The data collected three different RMC plants in pune for different grade of concrete based on data analysis framework. The control charts are prepared with help of Microsoft excel. Four statistical parameters were calculated from the data collected i.e, mean, standard deviation, upper control limit (UCL) and Lower control limit (LWL).

For plant 1: M25 & M30 grade of concrete for plant 1 and their control charts
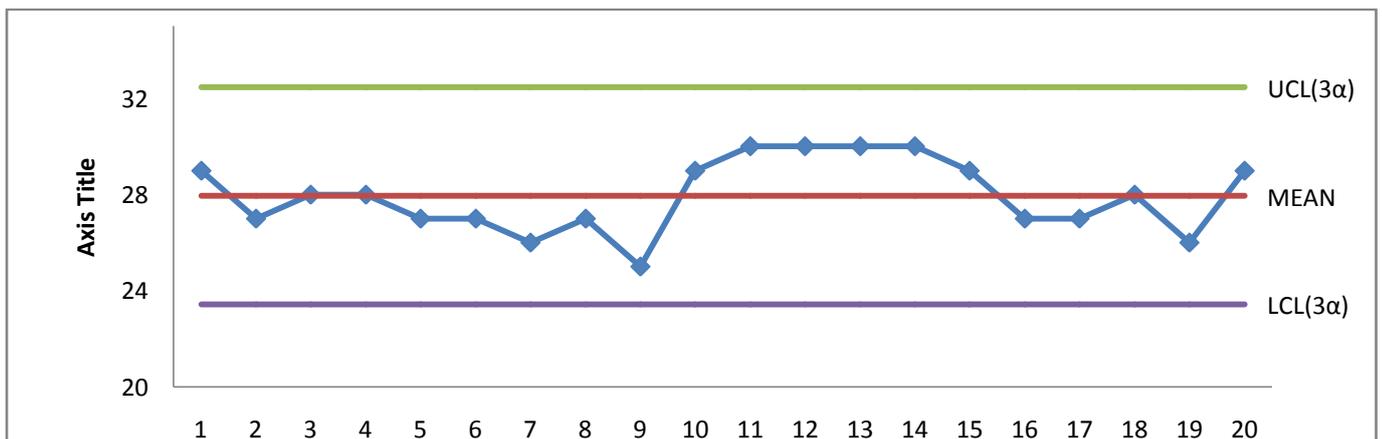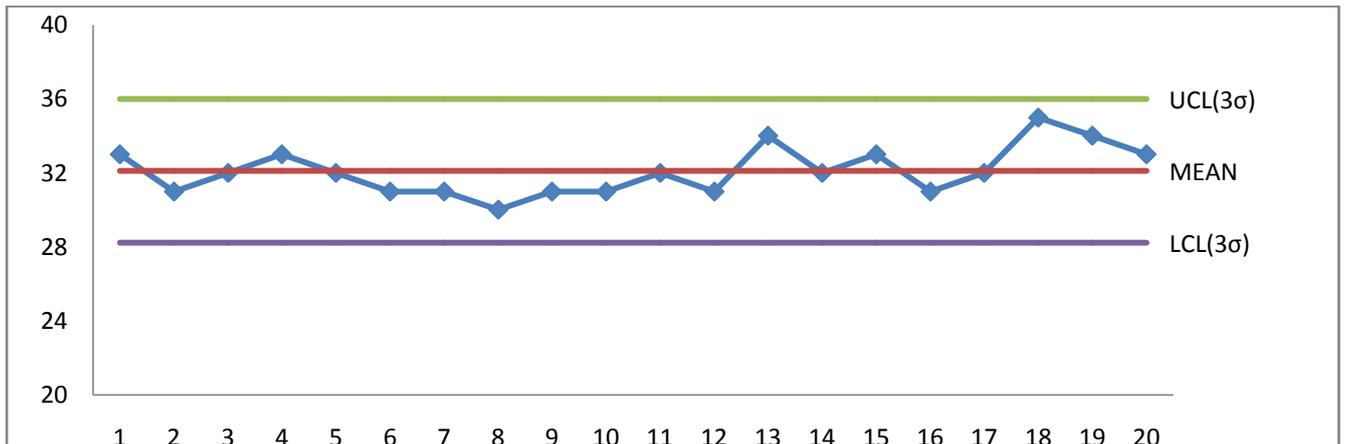

Fig 1: Control chart for M25 grade of concrete

Fig 2: Control chart for M30 grade of concrete

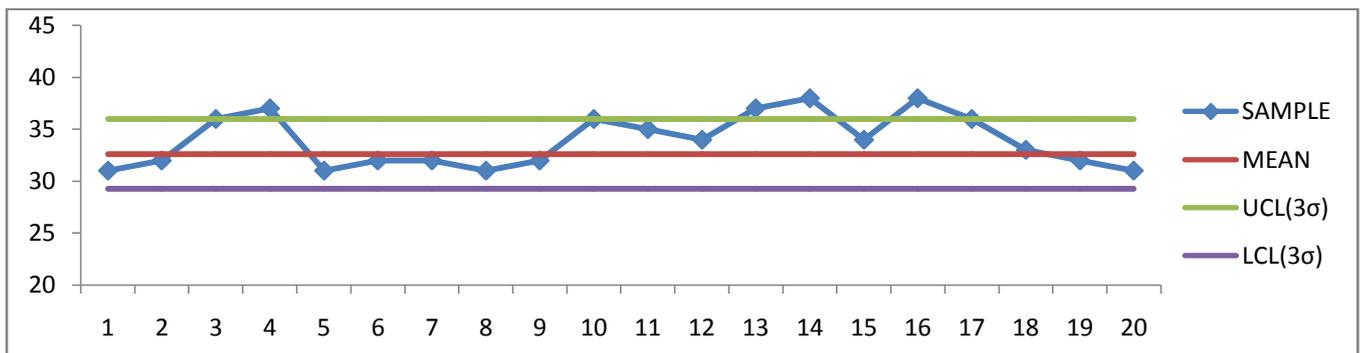**For plant 2: M25 grade of concrete for plant 2 and their control charts**

Fig 3: Control chart for M25 grade of concrete

For plant 3: M25 grade of concrete for plant 2 and their control charts
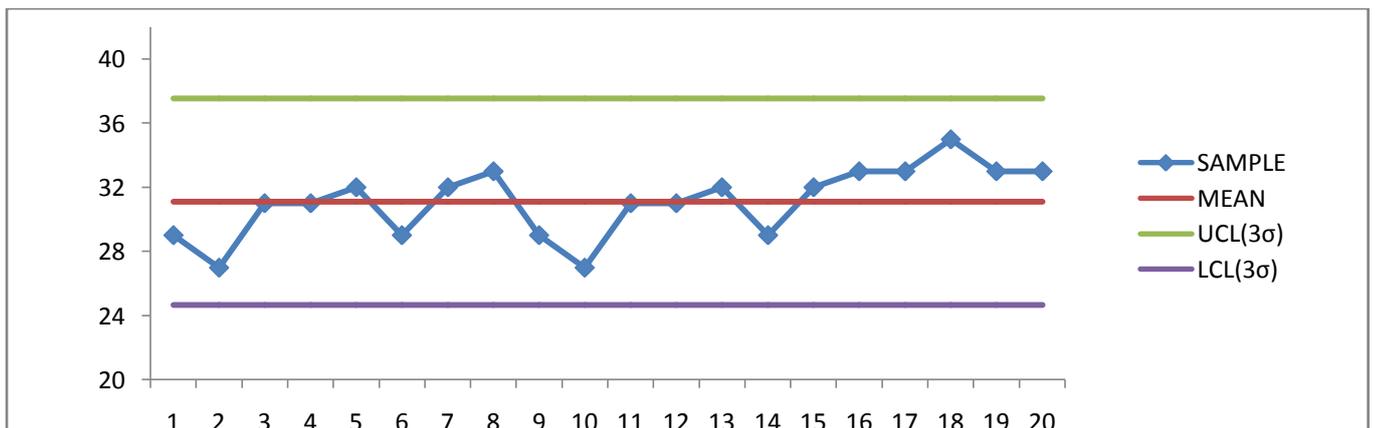

Fig 4: Control chart for M25 grade of concrete

It can be seen that from figure 3 (control chart for data collected in RMC plant 2), out of 20 samples of concrete cubes there is failure in 7 samples from control chart which means that it is necessary to modify mix design of that corresponding sample. Due to this, FMEA is applied to plant 2 to assess the failure mode. Control chart for data collected from both plant 1 and plant 3 in figure 1 2 and 4 that the quality of that RMC production is under prescribed limit.

FMEA Application
For the plant selected for the application of FMEA, the factor which Affect the production of concrete considered are as following;
- Material
- Process

- Quality
- Equipments

After obtaining the rating for severity, occurrence and detection, the risk priority number (RPN) is calculated for each factors as per the equation. The table shows the failure mode of concrete production and they are as follows:

MAJOR FACTORS	FAILURE MODE	S	O	D	RPN
MATERIAL	Raw materials scarcity	2	2	3	12
	Delayed arrival of raw materials at plant	2	2	4	16
	Materials to be checked when arrival	3	4	3	36
	Testing for materials to be done	3	3	3	27
	Error in testing & inspection of materials	4	3	3	36
	Improper storage system	4	4	2	32
PROCESS	Lack of technical expertise/ personnel	4	4	3	**48**
	Incorrect Mix design	4	4	3	**48**
	Frequent breakdown of M/Cs, plants etc	3	4	3	36
	Internal system failure	3	4	3	36
	Wrongly designed layout	3	2	2	12
	No flow through pipes during discharge of concrete at site	2	3	2	12
QUALITY	Varying degree of moisture in sand	3	3	2	18
	Non availability of advanced testing facilities	3	4	2	24
	Poor maintanance of materials	2	3	2	12
	Not keeping proper checklist	3	4	2	24
EQUPIMENT	Improper maintenance of machinery	4	4	3	**48**
	Breakdown of Machinery	4	4	2	32
	Not maintaining maintenance check sheet & repair records	3	3	3	27
	Foundation of the CTM machine not placed correctly	4	4	3	**48**
	Calibrations & weighing on scale done periodically	3	4	2	24
	Misalignment of cube	4	4	3	**48**
	Improper Seal of the hydraulic oil from CTM machine	4	4	2	32
	Grade of oil of CTM machine	4	4	2	32
	Gap between piston and its housing from CTM machine	3	4	2	24

Table 2: FMEA worksheet

The task of determining the most critical failure mode in production of concrete which was carried out using FMEA Technique and it resulted with five failure mode with equal priority number (RPN=48). The five failure mode in production process of concrete are as follows;

- Incorrect mix design
- Lack of technical expertise/personnel
- Improper maintenance of machinery
- Foundation of CTM machine not placed correctly.
- Misalignment of cube

VII.   RESULTS AND CONCLUSION

Based on experimental testing conducted for plotting control charts the following conclusions can be drawn:

- The quality control chart proves to be most effective tool for quality control of RMC production.
- The quality pattern predicted from control charts from plant-1and plant-3 was under prescribed control limits. But the quality pattern of plant -2 was going out of prescribed limits. Thus, FMEA technique is applied for plant-2.

In this work, the FMEA technique resulted in five critical failure mode with RPN=48 (incorrect mix design, lack of technical expertise/personnel, improper maintenance of machinery, foundation of CTM machine not placed correctly, Misalignment of cube). From this study, the most potential failure mode obtained should recommend some remedial measures.

- ❖ In order to improve the quality of RMC production, grading of material should be done properly including proper sieve analysis and also material to be tested before taken into mix design.
- ❖ The expertise or technical engineer should have knowledge of each process going in RMC production so that

error can be eliminated.
- ❖ Adequate machinery guarding and proper guarding on transit mixer and concrete pump is necessary.
- ❖ The machine should be kept on solid foundation else the load being applied to the test block is dissipated in some amount to the uneven or weak foundation as well.
- ❖ It is necessary to place the cube at the exact centre of the platen and it is already marked on it by the manufacturer by a set of concentric circles.

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