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Total Quality Management & Six Sigma Methodology In Construction Industry

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Abstract: The construction industry in India faces increasing pressure to meet international quality standards and customer expectations. This study explores the application of Total Quality Management (TQM) and Six Sigma methodologies within the sector to enhance construction quality and project performance. It emphasizes TQM as a comprehensive philosophy involving continuous improvement, employee participation, and customer satisfaction across all project stages. Through a detailed case study of a construction project. The paper evaluates the quality of concrete work using Six Sigma performance metrics. The findings reveal disparities in quality perceptions among stakeholders and identify barriers such as inadequate training, communication gaps, and poor quality control practices. By integrating TQM principles with Six Sigma tools, the research advocates for a structured quality management framework, including stakeholder training, establishment of quality circles, and development of national bodies to promote quality awareness. The proposed model offers a practical approach for enhancing competitiveness and achieving defect-free construction outcomes.

***Index Terms* – TQM, SIX Sigma**

1. Introduction

For the Indian construction industry which is aiming for global contracting in the global market and which is wishing to capture sizable international market share in the new millennium, how can the global capacities help these, unless their completed structures match the quality standards of competitors who have embraced total quality management (TQM)?

To stand today in the competition, what construction firms must strive today is not only for customer satisfaction but further for customer delight. Total Quality Management is a philosophy, which can bring about evolutionary change in construction industry by completion of construction projects with trouble free structures and longer life and thus help in becoming global.

Implementation of TQM philosophy can provide a solution, which is all encompassing. It aims at work culture, employee empowerment techniques and finally customer satisfaction. It is not limited to material testing or quality assurance of end product only but it aims at the process of quality planning, quality improvement and quality control at each and every phase. An engineer must understand the application of TQM to technical activities. TQM is the application of the scientific method to business .The complexity of modern business and technology requires a teamwork approach rather than each engineer doing his own thing, thus TQM needs to be applied to the business of the company and to engineering methods.

2 .Total Quality Management

TQM is a management philosophy, a paradigm, a continuous improvement approach to doing business through a new management model. The TQM philosophy evolved from the continuous improvement philosophy with a focus on quality as the main dimension of business. Under TQM, emphasizing the quality of the product or service predominates. TQM expands beyond statistical process control to embrace a wider scope of management activities of how to manage people and organizations by focusing on the entire process, not just simple measurements.

TQM is a comprehensive management system which:

♦ focuses on meeting owners'/customers' needs by providing quality services at a cost that provides value to the owners/customers.

♦ Is driven by the quest for continuous improvement in all operations.

♦ Recognizes that everyone in the organization has owners/customers who are either internal or external

♦ Views an organization as an internal system with a common aim rather than as individual department acting to maximize their own performances

♦ Focuses on the way tasks are accomplished rather than simply what tasks are accomplished

♦ Emphasizes teamwork and a high level of participation by all employees.

Nwabueze9 (2001:659) summaries TQM as having three major requirements, as outlined in the following:

Total: Participation of Everyone, an institution-wide process: "TQM requires continuing improvement and getting things right first time. Since most quality solutions are outside the control of any one individual or function, this needs team work and the maintenance of good relationships."

Quality: Meeting Customer Requirements Exactly: TQM requires customer-agreed

Specifications which allow the supplier to measure performance and customer satisfaction. Individuals and teams need to use quality tools and systems to facilitate measurement and problem solving.

Management: Enabling Conditions for Total Quality: "TQM requires leadership and total commitment from senior management to quality goals. They must ensure that an appropriate infrastructure exists to support a holistic and not a compartmentalized approach to institutional management."

2.1 TQM beliefs

Presented here are universal total quality management beliefs.

♦ Owner/customer satisfaction is the measure of quality

♦ Everyone has owners/customers; everyone is an owner/customer

♦ Quality improvement must be continuous

♦ Analyzing the processes used to create products and services is key to quality improvement

♦ Measurement, a skilled use of analytical tools, and employee involvement are critical sources of quality improvement ideas and innovations.

♦ Sustained total quality management is not possible without active, visible, consistent, and enabling leadership by managers at all levels.

♦ If organization not continuously improve the quality of products and services that organization provide our owners/customers, someone else will.

2.2 Characteristics of Successful TQM Companies

The construction industry has arrived late to TQM, probably due to the tendency to easily brush aside anything in management that is new, or to dismiss TQM as a fad.

Continuous improvement is not a fad but a necessary part of management's obligation to properly run its company. Gone are the boom days when quality did not matter due to the volume of work available and the ease of obtaining work. The attitude of construction managers and contractors was simply to add it to the bill, because the owner will pay for it. In other words, in those boom days Cost plus Profit equaled Price. Now, however, the new attitude is Price minus Cost equals Profit. Owners are now demanding higher quality work, and at a lower cost. In attempting to keep pace with the new attitude, a quality management system that helps keep costs down is well worth implementing.

The characteristics that are common to companies that successfully implement TQM in their daily operations are listed here.
♦ Strive for owner/customer satisfaction and employee satisfaction
♦ Strive for accident-free jobsites
♦ Recognize that the owner/customer provides the revenue while the employees are responsible for the profit
♦ Recognize the need for measurement and fact-based decision making
♦ Arrange for employees to become involved in helping the company improve
♦ Train extensively
♦ Work hard at improving communication inside and outside the company
♦ Use teams of employees to improve processes
♦ Place a strong emphasis on the right kind of leadership, and provide supervisors with a significant amount of leadership training
♦ Involve subcontractors and suppliers, requiring them to adopt TQM
♦ Strive for continuous improvement.
Quality principles that successful TQM companies recognize The quality principles that successful TQM companies recognize and attempt to continually incorporate into their actions are the following:
♦ People will produce quality goods and services when the meaning of quality is expressed daily in their relations with their work, colleagues, and organization.
♦ Inspection of the process is as important as inspection of the product. Quality improvement can be achieved by the workers closest to the process.
♦ Each system with a certain degree of complexity has a probability of variation, which can be understood by scientific methods.
♦ Workers work in the system to improve the system; managers work on the system to improve the system.
♦ Total quality management is a strategic choice made by top management, and must be consistently translated into guidelines provided to the whole organization.
♦ Envision what you desire to be as an organization, but start working from where you actually are.
♦ Studies have indicated that people like working on a quality-managed jobsite especially due to the cleaner site and safer place to work.
♦ Accept the responsibility for quality. Establish datum's for measurement.
♦ Use the principle of get it right, the first time, every time.
♦ Understand that quality is a journey, not a destination. It consists of steps that form a process that is continuous.
The goal of management is to create a culture of quality across the entire project site get the job done right, the first time, every time. As in the airline industry where 99% quality is not good enough, the construction industry also needs to strive for 100-percent quality. Today, the number of contractors being considered for projects by some owners is growing smaller, and only those contractors who can produce quality work are being asked to bid by these owners. Every effort to incorporate the above principles into the company's actions will further quality production.

2.3 Steps in implementing TQM

- Obtain CEO Commitment
- Educate Upper-Level Management
- Create Steering Committee
- Outline the Vision Statement, Mission Statement, & Guiding Principles
- Prepare a Flow Diagram of Company Processes
- Focus on the Owner/Customer (External) & Surveys
- Consider the Employee as an Internal Owner/customer
- Provide a Quality Training Program
- Establish Quality Improvement Teams
- Implement Process Improvements
- Use the Tools of TQM
- Know the Benefits of TQM

2.4 Barriers of TQM implementation

These include the following;

- Lack of faith in and support to TQM activities among management personnel.
- Lack of management commitment.
- Failure to appreciate TQM as a culture revolution. In other words, inability to change organizational structure.
- Misunderstanding about the concept of TQM
- Improper planning
- Lack of employee commitment.
- Lack of effective communication
- Lack of continues training and education
- Lack of interest or incompetence of leader.
- Ineffective measurement techniques and lack of access to data and result.
- Non-application of proper tools and techniques.
- Inadequate use of empowerment and teamwork.
- Inadequate attention to internal and external customers.
- Delay or no implementation of quality improvement teams recommendation.

3. Purpose of Research

The constituent parts of the concept of TQM have been part of human endeavor for a very long time, and have been contemplated throughout history. Its currency as a topic of immense interest lies in the combination of these parts into the concept of TQM, a philosophy and approach that has been widely used internationally in different sectors of the economy. However, the concept is not always well understood and is often ineffectively used. The major reason for this is the lack of both a universally accepted definition and a clear-cut understanding of the concept and what it entails. There is widespread ambiguity about what is exactly meant by the concept. This is clear in literature where researchers and managers have attributed various meanings to the concept. The failure to find a definition that could apply universally and the lack of understanding of TQM terminology may well explain many of the problems experienced by managers in its implementation. Understanding the meaning of TQM is vital as TQM is a long-term cost and effort-intensive initiative.
The purpose of this study is to explore the variety of definitions provided by several researchers worldwide in literature available in the public domain for the concept of quality and that of TQM in order to arrive at an understanding of theory on TQM, which forms the foundation for the implementation of TQM by organizations and institutions.. After studying this chapter, one should get convinced about the utility of TQM in the construction sector.

4. Literature Review

According to Djerdjour & Patel 2 (2000:26), quality is no longer an optional extra; it is an essential strategy to survive. TQM is therefore a solution for improving the quality of products and services. Before one can discuss the concept of TQM, one first needs to discuss, understand and analyze the concept of 'quality' itself.

Pycraft, Singh & Phihlela12 (2000:616) argue that there are four actions required to ensure high quality, namely:

• Ensure that there is consistency between the internal quality specification of the product or service and the expectations of customers.

• Ensure that the internal specification of the product or service meets its intended concept or design.

• Ensure that the actual product or service conforms to its internally specified quality level.

• Ensure that the promises made to customers concerning the product or service can be delivered by the institution.

According to Pun11 (2001:324), the following is necessary to achieve an intense understanding and transformation toward TQM: (1) a historical review of TQM based on the prescriptions of the quality gurus, (2) a historical evolution from quality to total quality, (3) the principles of TQM, (4) a definition of TQM, and (5) the importance of TQM.

According to Evans & Dean3 (2003:12), the roots of quality definitions can be divided into four categories, namely:

- Quality is excellence.
- Quality is value.
- Quality is conformance to specifications.
- Quality is meeting and /or exceeding customer expectations.

Stamatis15 (2003) developed a generic model for the implementation of customer service, for the very reason of complying with the expectations of the customer. The generic model of Stamatis follows a six-step approach:

- Step 1: Identify the added value of service that is to be rendered to the customer.
- Step 2: Identify the customer and clearly determine his or her expectations.
- Step 3: Identify the institution's critical needs that are required for customer satisfaction.
- Step 4: Define the process required to perform the work in order to ensure quality customer service.
- Step 5: Zero-defect the process and eliminate wasted efforts.
- Step 6: Ensure continuous improvement by obtaining continuous feedback from the customer, in order to produce continuous total quality results as output.

McIntyre7 (2000) highlights six basic concepts that are required for TQM as suggested by Bester field(1998), viz:-

- A commitment by management to provide long-term top-to-bottom organizational support
- An unwavering focus on the customer, both internally and externally
- Effective involvement and utilization of the entire work force.
- Continuous improvement of the business and production process.
- Treating supplier as partners
- Establishing performance measures for the processes.

The overall response to a questionnaire mailed to 1500 construction organization was approximately 14% (208 companies. One hundred and fifty-one (151) indicated that, their companies were actively participating in some form of TQM, to better understand the concepts of TQM and the associated economic benefits of integrating TQM into their business operations.

Pheng10 (2004) finds that in a survey carried out by the National Productivity Board in Singapore, by Quazi and Padibjo(1997), out of the 300 firms surveyed; only one-third of the manufacturing companies and one-fourth of the services and construction companies had implemented TQM programs. Of these companies that had implemented TQM, most were of foreign origin. This appears that local companies were lagging behind their foreign competitors.

The factors, which may cause resistance in the implementation of TQM in construction, are mentioned below.

- Product diversity
- Organizational Stability
- Misconception of the cost of quality. The costs incurred from not achieving quality can cost owners up to 12% of the total project cost.

Kazag5 (2005) confirms that since each phase of construction project can be accomplished by different companies and/or different departments of a firm, which makes the integration and coordination, become very difficult in most cases. for the solution of this bottleneck, the concept of total quality management has been proposed. According to Rosen field(1992) ,construction firms are interested in activities with the aim of getting outputs. The composition of product and service mostly differs from the other, and every project continues in a different place or environment. On the other hand, construction firms generally employ temporary unskilled labor within constantly changing geographic locations that finally leads to some deficiencies in achieving stability in quality related issues.

Ashford(1992) stated that major unsuitable products observed on construction sites resulted from labor faults. He asserted that 45% of 200 faulty products examined on 50 sites in England were from negligence; about one-half of them originating from a lack of knowledge or experience. Seasonal or periodic decreasing and increasing of the construction works, continuous change of construction sites, together with the inability of making exact future plans are the other disadvantages of the construction industry besides the lack of education of workers.

Dawwod1 (2006) finds a number of deficiencies associated with the site construction management and planning. These are: separation of execution and planning, unreliable plans and schedules, unorganized supply chain, unreliable site logistics and very poor coordination of vertical and horizontal communication. To introduce and discuss a major initiative that is currently running at the University of Teesside, Center for Construction Innovation Research (CCIR) dubbed the agile construction site. The concept is to develop site processes, techniques and tools that can improve supply chain management, construction site planning, scheduling and control. The paper presents methodologies and tools that have been developed from three research projects: Vircon,(Virtual Construction Site),LEWIS(Lean Enterprise Web Based Information System) and PECASO (Pattern Execution and Critical Assessment of Site Organization).Integrated database, visualization technologies, lean process and optimization technologies are techniques used to develop tools and processes for the agile construction site. The paper introduces briefly the concept of the initiative and details some of the tools that have been developed using real life case studies.

Seraphim13 (2006) observed that road construction projects are characterized by the use of heavy and expensive equipment and machinery. They are highly influenced by weather and geological risk factors, change in working condition, environmental regulations and other risk factors. Accuracy of construction planning in road projects is highly dependent on the experience of construction planners to understand and incorporate risk factors. The prime objective of the paper is to discuss the creation of a knowledge-based/simulation system that assist project managers to generate sound construction schedules using knowledge and information which were developed by extracting construction and resources behavior knowledge from 124 current and previous road projects.

Matt6 (2001) feels that quality control in construction involves sticking with minimum standards of material and workmanship in order to ensure the performance of the facility according to the design. For the purpose of ensuring compliance, samples and statistical methods are used for accepting or rejecting work completed and batches of materials.
Total quality control is a commitment to quality expressed in all parts of an organization and involves many elements. Design reviews to ensure safe and effective construction procedures are a major element. Other elements include extensive training for personnel, shifting the responsibilities for detecting defects from quality control inspectors to workers, and continually maintaining equipment. Worker involvement in improved quality control is often formed in quality circles in which workers meet regularly to make suggestions for quality improvement.

Singla14 (2006) mentioned that if it is ensured that 100% material has been used in a particular stretch of the road, then it also controls the quality of the work. At present, the quality control exercise is made at three levels as below. The contractor sets up a field laboratory as approved by the Engineer-in-Charge with all the quality controls equipments and provides adequately trained personnel to carry out all the required tests and quality control work as per specifications. The contractor is also supposed to carry out all the quality control tests on all materials and works to the stipulated frequency as prescribed in the specifications. At the second stage, the quality control tests are being conducted by the field staff deployed for the execution of the work. The tests are conducted for all the materials and works from time to time and discrepancies, if any, are rectified from the contractual agency.
At the third stage, quality control tests are being conducted by the quality control wing has been specially, created for this work.

Following are the drawbacks of the existing system of quality control:

- The numbers of tests prescribed in the codes are more
- The contractor does not engage requisite staff for the quality control tests.
- The staff engaged on contract does not take interest in the quality control tests
- The tests are not conducted at site and only bogus entries are made in the prescribed registers.
- There is no foolproof method to check that 100% material has been used at site as it directly affects the quality of the work.

Rowlinson and Walker (1995) point out that the construction industry is also characterized by its non-standardization. Production processes are to some extent different from one another. Hence, no universal standard or specification can be applied to the product, which leads to difficulties in quality assurance. Furthermore there are excessive changes to the details of the design of a project are typical throughout the construction process. They may be attributed to the lack of build ability of the design produced or variations by the contractors for the sake of speed and cost of production. Quality is often at risk because of the excessive changes (Kanji and Wong, 1998).

Studies have indicated that TQM is likely to fail within 18-24 months of its the endeavour irrespective of the approach used (Smith et al., 1993). One of the common reasons for the failure of TQM is the cultural position of the company. If the TQM effort is inconsistent with the organizational culture, the effort will be undermined (Dean and Evans,1994 in Adebanjo and Kehoe, 1998). The Egan Report on Rethinking Construction (Egan, 1998) stresses the need for the industry to make substantial changes in its culture and structure, as a driver for improvement in efficiency, quality and safety. However, addressing culture change has not been easy since most people are unclear about exactly what this means and how it should be approached (Smith et al, 1993). Williams et al. (1993) in Adebanjo and Kehoe (1999) addressed that, despite the growing awareness of cultural issues, comparatively little attention has been paid to the practical, day-to-day processes involved in creating, managing and changing organizational culture.

Ahire et al. (1996) believe that employee empowerment and involvement framework is not effective unless employees have received formal, systematic training in quality management. Ishikawa (1985) states that quality begins and ends with training. For McAdam et al., (2002) training and development are key components of all TQM initiatives.

Firms that establish workplace education programmes report noticeable improvements in their workers' abilities and the quality of their products (Cebeci and Beskese, 2002). Feigenbaum (1961) points out that the importance of training is to ensure that the skills of the workforce do not become obsolete in an environment of change and an understanding and attitude of quality is developed and maintained.

According to Rao et al.,8 (1996) TQM training should be directed at all levels of the organization since senior managers who understand the TQM process are not only able to break down barriers within their own organizations, but they can also serve as role models for others who may resist to change. In his empirical research of developing a TQM instrument, Zhang et al., (2000) reports that organizations have realized that education and training is an integral part of the TQM initiative. Several recent empirical studies revealed that training and education are critical to successful TQM implementation (Rao et al., 1999; Zhang et al., 2000; Ahire et al., 1996).

Gufreda and Maynard12 (1992) described employee involvement as the process of transforming an organization's culture to utilize the creative energies of all employees for problem solving and for making improvements. Mak (2000) summarizes the critical ideas in Japanese management and derives several principles related to people management. He states that management should pursue the Tao "road" of people-based management so that it recognizes the importance of daily interaction with all employees and a shared identity with them in solving work problems.

Crosby takes a very pragmatic approach in making each of these points of value for the institutions that practice them.

Management commitment – Top management must be convinced of the need for quality and must clearly communicate this to the entire institution by written policy.

- Quality improvement teams – Form a team composed of department heads to oversee improvements in their departments and in the institution as a whole.
- Quality measurement – Establish measurements appropriate to every activity in order to identify areas in need of improvement.
- Cost of quality – Estimate the costs of quality in order to identify areas where improvements would be profitable.
- Quality awareness – Raise quality awareness among employees.
- Corrective action – Take corrective action because of steps 3 and 4.
- Zero defect planning and zero defects day (error-free work days) – Form a committee to plan a programme appropriate to the institution and its culture.
- Supervisor training – All levels of management must be trained in how to implement their part of the quality improvement plan.

Fayek,Manjula and Oswaldo4 (2003) and along with the COAA Field Rework Committee decided to develop industry Best Practices for reducing and preventing construction field rework. As a first step, a methodology was required to measure and quantify field rework, and identify the most significant causes of rework. A pilot study was commissioned with the University of Alberta to develop and test such a methodology.
The specific goals of the pilot study were as follows:
- To develop a definition for construction field rework.
- To develop a standard rework index for quantifying the amount of field rework on a project.
- To develop a standard methodology for identifying rework in the field and measuring or quantifying the amount of rework on the basis of cost, schedule, and other impacts.
- To develop a realistic classification of the major factors and sub-factors causing rework, and to develop a standard definition of each factor.
- To develop a standard methodology for quantifying the impact of each cause on the rework amount.
- To develop a methodology for assessing the impact of rework from a given activity on other affected activities in the project.
- To develop a standard methodology of tracing the cause(s) that led to rework, from the original source.

CII Defines the Rework as "Activities in the field that have to be done more than once in the field or activities which remove work previously installed as part of the project"
According to Wyper & Harrison (2000:721), Six Sigma is a logical and methodical approach to achieving disciplined quality improvements in areas critical to the success
of any service-oriented institution or manufacturing business. Because this quality improvement is a prime ingredient of TQM, many institutions find that adding a Six Sigma programme to their current business system, such as the ISO 9000:2000, gives them all or almost all the elements of TQM: (current business system) + (Six Sigma) = (TQM).

5. Various Definitions of Six Sigma
Harry and Schroeder (2000) ,who are the key developers and proponents of the Six Sigma programme at Motorola ,defined Six Sigma as " a disciplined method of using extremely rigorous s data gathering and statistical analysis to pinpoint sources of errors and ways of eliminating them"
Snee(2000) indicated that "Six Sigma should be a strategic approach that works across all processes ,products ,company functions and industries."
Pande (2000) defined Six Sigma as (1) a way of measuring processes ,a goal of near perfection represented by 3.4 defects per million opportunities (DPMO); and more accurately,(2) a comprehensive and flexible system for achieving, sustaining, and maximizing business.
According to Nave (2002:73), Six Sigma includes five steps: define, measure, analyse, improve and control (commonly known as DMAIC):

Define – First begin by defining the process and ask who the customers are and what are their problems to identify the key characteristics important to the customer.

Measure – Measuring the process by first categorizing the key characteristics of the process, then measurement systems are verified and data collected

Analyze – Once the data are collected, it must be analyzed. The intent is to convert the raw data into information that provides insights into the process. These insights include identifying the fundamental and most important causes of the defects or problems.

Improve – The fourth step is to improve the process. Solutions to the problem must then be developed, and changes are made to the process.

Control – If the process is performing at a desired and predictable level, it is put under control. This part is the sustaining portion of the Six Sigma methodology. Six Sigma starts with the application of statistical methods for translating information from customers into specifications for products or services being developed or produced. Six Sigma is a business strategy and a philosophy of one working smarter not harder. It promotes and requires different behavior and a new way of thinking facts based, statistical thinking. Six Sigma is named after the process that has six standard deviations on each side of the specification window.

Motorola started the six sigma concept of measuring defects in the early 1980s as a way to develop a universal metric as indicated below in Table 5.1

Table 5.1 Simplified Sigma Conversion Table

Yield = % percentage of items without defects	Defects per million opportunities(DPMO)	Sigma level
30.9	690,000	1
69.2	308,000	2
93.3	66,800	3
99.4	6,210	4
99.98	320	5
99.9997	3.4	6

Higher sigma value indicates better products or processes with fewer numbers of defects per unit of product or service. Products produced at a Six Sigma level of quality operate virtually defect-free by definition, with only 3.4 defects per million opportunities (DPMO) as shown in above Table. Through Six Sigma, every measurable can be compared on the same platform, no matter how different they may be. All the organization needs to do is to set out guidelines in determining measurable targets during implementation.

6. Objectives of Study

- To understand the basic fundamentals of the TQM philosophy.
- To study the six sigma application in construction industry.
- To evaluate objectively the quality grading of concrete.
- To prepare the Quality Grading sheets for various construction items

In order to achieve the objectives set, data was collected from the field practices which are being followed in the construction industry. Data has been collected from ongoing major construction project, which is a construction of commerical building.

7. Data Collection

- The data related to the following aspects has been collected. These include
- Contract document.
- Monthly & Quarterly progress reports.
- Bar chart.
- Factual data from site based on daily activities, recorded by the observer Photos of actual site condition of construction project.
- Minutes of meetings held between various agencies.
- IRC 57 format to rate the quality of concrete work.

- Discussion with the Project Coordinator, Contractor, Architect, Site Engg, Site supervisor, quality assurance cell.

Factual qualitative data from site based on observation of daily activities by independent observations:-

- Delay in issue of drawings to customer.
- Inadequate control of time management which results in delaying project
- A particular activity description not clear.
- A few details missing in working drawing plan.
- Improper implementation of order given by supervisors, due to tremendous work pressure and multiple responsibilities on field engineers.
- Improper concreting (major construction work was carried out during night hours during which temp was observed in the range of 15^0C to 25^0 C.)
- Rework was frequently observed related to concreting.
- Use of unskilled labor for pump concreting at slab construction.
- An important aspect like curing was not up to the expectation due to poor monitoring.
- A particular category of skilled labor was assigned other task to keep them engaged.
- Daily targets set for work completion were seledomly achieved.
- Project co-coordinator not appointed
- Reporting system not established.
- Role & Responsibility of key personnel not defined
- Testing laboratory on site not established.
- Improper Dewatering system at foundation.
- Delay in from structural design to issue foundation drawings.
- Site meeting schedule with various agencies not decided
- Lack of Communication & Coordination between various agencies.

7.1 Project Information

- Total Built-Up Area 27,434 Sqmtr.
- Type of building Commercial
- Location of site Pune
- Foundation strata Fully Saturated BC soil
- Depth Of foundation 6 m below GL
- RCC foundation Stepped (Water Proofed)
- No of floors B+G+4
- Bed lifts 8 No.(Speed 3m/sec)
- Capsule lifts 2 No.
- Mini RMC Plant $0.5m^3$/batch
- Parking capacity 600 Cars + 2000 Two Wheelers
- Helipad On Top floor
- Concrete Foundation- M35 ,Column:M50
- Project duration 24 Month

7.2 Data Analysis

Analysis of data is evaluated in the following ways.

- Calculations of six sigma level (quality grading) for concreting work by circulating questionnaire to various personnel associated with the project work (Project Coordinator, Architect, Site Engg. Independent observer.)

8. Calculation of Six sigma level (quality grading) for concreting

- In the present study format of IRC were given to the following personnel associated with the construction project and were asked to rate the performance of the above works. This was done, with a view to find out, how different personnel judge the same type of works and to further find if major variations exist in their judgment. Also, in order to get an independent evaluation, the observer himself observed the above work continuously, when they were being performed.
- Project Coordinator

- Architect
- Site engineer
- Independent observer

8.1 Quality grading for concrete construction

Sr.No	Item	Rating by Project Coordinator	Rating by Architect	Rating by Site Engg.	Rating by Independent observer
1	QA/QC System/Service available	4	4	4	4/5
2	Storage of cement	4	3	5	4/5
3	Type and Storage of Aggregates	2	3	3	2/3
4	Water used (quality)	4	4	4	4/5
5	Use of Admixtures	2	2	3	2/3
6	Type and use of machinery	2	2	3	2/3
7	Training of Personnel	4	2	4	3/5
8	Client supervision QTY + QLTY	3	2	2	2/3
9	Workability of concrete	4	3	4	4/5
10	Controls and checks on W/C ratio	4	3	4	4/5
11	Formwork Design Accuracy	4	3	3	4/5
12	Formwork-Water tightness	2	2	2	2/3
13	Formwork-release agent	1	2	2	2/3
14	Formwork-Sequence of release	NA	NA	NA	NA
15	Reinforcement: Type & Testing	2	3	2	2/3
16	Reinforcement storage ,Fabrication	2	2	2	3/3
17	Reinforcement placing and cover blocks	4	5	4	5/5
18	Sequence of loading in mixer	3	2	3	2/3
19	Transport and placing tools ,equipment	3	3	4	3/5
20	Reinforcement Congestion(Detailing)	4	3	4	4/5
21	Construction joints	4	3	4	4/5

22	Testing of concrete(Frequency)	4	3	4	5/5
23	Finishing of concrete tools	1	1	2	2/3
24	Finishing of concrete materials	4	3	4	4/5
25	Curing method	4	3	5	5/5
26	Curing Time	2	2	3	2/3
27	Surface finish	4	3	4	3/5
28	Dimension & profile of finished concrete	2	1	2	2/3
29	Hot weather concrete precaution	3	2	4	3/5
30	Provision for maintenance of concrete surface	1	2	2	1/3
	Total	97 /122	75/122	98/122	89/122

Total Maximum: 98

Acceptable concrete to score 80 to 90 points out of 122

Non Acceptable concrete to score < 80 points

Good concrete-91 to 100

Excellent Concrete -101 to 115

Best Concrete – 115 to 122

Concrete with zero defects 122.

Discussion: concrete work

- As per the rating by Project Coordinator and Site Engineer, as is evidence from total score the grading for construction concrete is good.
- As per the rating by architect concrete, it is not acceptable concrete.
- As Per the independent observer, it is acceptable concrete.
- Infact, rating by Project Coordinator is matching with as that of site engineer.
- Considering logic for that of Zero defect, the score obtain by concrete would have been 122/122.we are able to say that a score of 89/ /122 as given by independent rater is equivalent to 122 – 89 = 33 defect no in 122 no, therefore in million ratings, % of item without defect = (89/122) x 100 = 72.95 %
  This is very close to the sigma 2 level

9. Conclusion

This study emphasizes that TQM & Six Sigma methodology must be adopted in planning and execution of the construction projects. The methodology is suggested for finding the six sigma performance level by developing quality assessment sheets for various construction activities which will help in assessment of quality. A concept of rating any particular activity, by the various stake holders associated with it will help in getting the realistic picture of the status of the activity being performed. Similarly this rating it to the six-sigma level, for evaluating the performance. The first step towards the TQM is reflected through the commitment of top management. The author recommends that part of this commitment can be realized

through creation of quality circle team in the organization by appointing quality manager, quality defect data collector.
Quality level of various construction activities must be accessed through above team by developing quality assessment manual by applying six-sigma concept.
Various agencies, staff personnel associated with the project must be trained towards TQM..
National level organization must be formed which is completely dedicated to TQM .the role of this organization would be to create awareness about the need for implementing the TQM in construction industry and to increase the quality level within the construction sector.
Every construction organization in its own interest of becoming globally competitive should adopt the tqm approach.

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