APPLICATION OF STATISTICAL QUALITY CONTROL IN HIGHWAY CONSTRUCTION

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Abstract – *In highway construction industry quality control of pavement quality concrete (PQC) is one of the important issue in achieving its desired strength and durability. The main aim of this study was to investigate the existing practices on quality control of highway projects. In order to verify the quality control of pavement quality concrete and dry lean concrete various parameters were studied. In this paper, tools for determining quality control such as X & R charts, Histograms were used for the NH 166 highway. These control charts were developed to investigate pavement quality of the rigid road and witnessed the factual- quality during progress of pavement quality concrete. From this research, it was discovered that some samples lacked uniformity and process went out of control limits for that sample throughout the construction that can distress both the strength and durability further where the material will be utilized and prone to early repairs before the design life is achieved.*

Key Words: Control Charts, Quality control, PQC, Lower Control Limit.

1. INTRODUCTION

Quality control is one of the most significant perspective consider during the manufacturing of the materials. By little variation in water to cement ratio, quality drops without question. The cracking occurs very easily in concrete as a result to shrinkage and creep.

Statistical Quality Control (SQC) is an amazing assortment of critical thinking tool valuable in accomplishing p

Process security through the decrease of inconstancy in various creation and business firms. SQC refers to the use of statistical methods in the monitoring and maintaining of the quality pf products as well as services. Statistical procedure control can help in enhancing a few quality parts of the development procedure and specifically quality control

The legitimate quality acceptance inspecting strategies relies on the attributes of development process and different acceptance testing techniques. To maintain the quality in development of street there ought to be a solid method for observing. For this statistical quality control tools demonstrate an effective tool for maintaining nature of the work. [2].

The application of selected tool of statistical process control, through which we can achieve continuous quality improvement [1].

This paper manages a utilization of measurable quality control devices in the rigid pavement development in Solapur area. There are distinctive factual quality control devices which can be utilized in confirming the nature of the work. Here are two sorts of control graphs,

1) Control diagrams for factors

2) Control outlines for attributes

Control outlines for factors, for example, x̄, R diagram, moving extent graph and so on help to recognize basic sort of the change in the process and likewise characterize as far as possible for the procedure so one can without much of a stretch distinguish when the procedure run wild from the diagram by entering the estimation of factors, for example, crushing strength of cube, flexural strength of beam etc. acceptance sampling which is the one of the main part of the statistical quality control tools help whether to acknowledge or reject work based on their acceptance norms.

2. TYPES OF STATISTICAL QUALITY CONTROL TOOLS

Statistical quality control tools are nothing but a set of statistical tools used for quality control by quality control engineers. There are various statistical tools as follows,

2.1 Descriptive statistics: The Quality characteristics and relationship is defined using descriptive statistic.

2.1.2 Range: - Range is nothing but a difference between maximum and minimum values in the set of data. Mathematically, given as

Range = Largest – Smallest…………………………..(1)

2.1.2 Mean: - Mean is define as average of a data. Mathematically.

$$\mathbf{X}=\frac{\sum_{i=1}^{n} y}{n} \quad \text{……………………………………….(2)}$$

Where,

X= average of samples

$\sum y$ = summation of samples

η = number of samples

2.1.3 Standard deviation: -Standard deviation is define as mount of spared around the mean.

$$\sigma = \sqrt{\frac{\sum_{i=1}^{\eta}(y-\mu)^2}{\eta-1}} \quad \ldots\ldots(3)$$

2.2 Statistical Process Control

- SPC involves inspecting the output from a process and then make decisions is necessary.
- Quality characteristics are measured and charted.
- SPC helps in identifying process variations.

2.3 Acceptance Sampling:

Acceptance sampling helps decide whether desirable quality has been achieved for a batch of products, and whether to accept or reject the items produced. This information is helpful in making the quality acceptance decision after the product has been produced, it does not help detect quality problem during the production process.

3. CASE STUDY

The name of the project is 'Four laning of Mangalvedha - Solapur Section of NH 166 from Design Chainage Km 322+100 to Km 377+200 existing Ch. 315+796 to 377+342 Package III. The project is being carried out under Hybrid Annuity Model (HAM) conducted by National Highway Authority of India (NHAI).

3.1 Data collection

For primary data collection, data related to each material and their specification was collected for month of 'September-October 2019' from site and laboratory. The specification limits for test carried out on materials were extracted from the Ministry Of Road Transportation and Highway (MORTH). The data related to compressive strength, flexural strength, tests on fresh concrete and harden concrete was taken and results were collected for further quality control analysis.

The following tests were carried on materials.

2.4 Aggregate impact value

The test determines the relative measure of the resistance of an aggregate to sudden shock or impact. This test was carried out using Impact testing machine.

Table-1: Observations of aggregate impact value

Description	Notation	Trial-1	Trial-2
Weight of stone places passing is 12.5mm but retained on 10mm	Wa	400	400
Weight of the fraction retained in is sieve 2.36 after impact test	Wb	360	350
Weight of fraction passed in sieve 2.36mm after impact test	Wc	40	50
Aggregate impact value (%)	Wc/Wa	10	12.5
Specified aggregate impact value (%)	30		

As per MORTH guidelines, if the aggregate impact value of the sample falls below 30%, then the sample can be accepted and can be used for further procedure.

3.3 Soundness test on cement

To determine the expansion of the cement, soundness test was carried out using Le- Chateleir's apparatus.

Table-2: Observations of soundness test

Description	Notation	Trial -1	Trial -2
Distance between pointer before boiling (mm)	D1	10	10
Distance between pointer before boiling (mm)	D2	16	14
Expansion of cement (mm)	D2-D1	6	4

According to the guidelines of MORTH, acceptable limit for the soundness of the cement is 10 mm. Hence, sampling can be accepted.

4. ASSESSMENT OF MATERIAL ON THE BASIS OF CONTROL CHARTS AND HISTOGRAM

4.1 Histogram

Histogram is a graphical representation of the distribution of numerical data. It is an estimate of the probability distribution of a continuous variable. It consists of rectangles, where area is proportional to the frequency of a variable and width is equal to class interval.

After computing of the original specification, the hypothesis was formed (H0, H1).

where,

H0 = null hypothesis (All samples fall within the control limits)

H1 = alternative hypothesis (All samples are not fall within the control limits)

The data collected from the tests carried out on the materials were passed through control charts like histograms and x̄ charts. If null hypothesis was found correct then material was accepted for further process. If alternative hypothesis is found correct then a samples which goes out of control limit was rejected. Some histograms were prepared based on the data obtained from the laboratories.

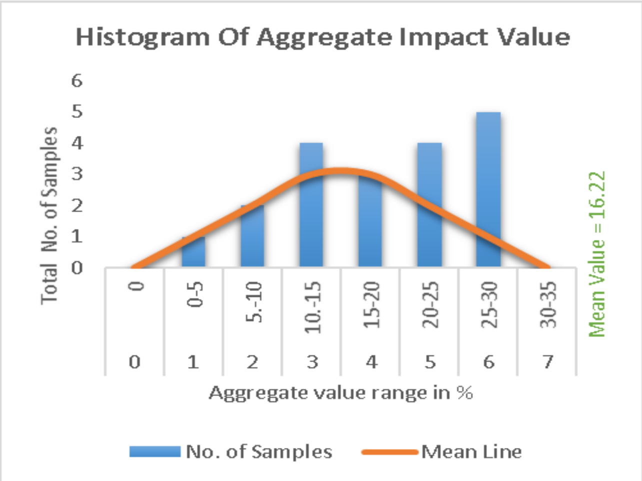

Chart -1: Histogram of Aggregate Impact Value

The aggregate impact value is accepted if and only if the value is below 30%. Here, the samples that were equal to 30% or greater than 30% , the samples were rejected. Thus, the quality of the material was maintained.

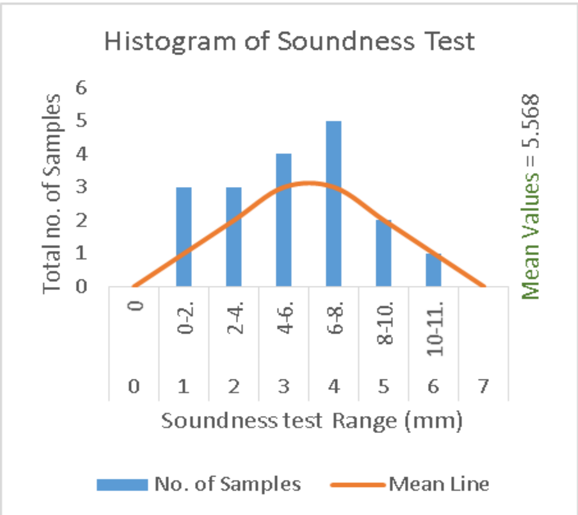

Chart -2: Histogram of Soundness Test

According to the histogram, one sample was beyond the permissible limit. Hence the sample was rejected.

4. CONTROL CHARTS

Control charts is one of the main techniques of statistical quality control. Control Charts are statistical tools that monitor a procedure and give indication to the quality engineer when the process has been troubled. This is a signal to find and correct the cause of the disturbance. Also, this chart often mentioned to as process chart is a graph that shows whether a sample of data drops within the common or normal range of variation. Control chart is a graph used to study how a process changes over time. Data is plotted in time order. It has a central line for the average, an upper line for the upper control limit (UCL) and a lower line for the lower control limit (LCL). These lines are determined from historical data.

In SPC, a process is said to be out of control when a plot of data reveals that one or more samples fall outside the control limits. It indicates that some measures should be taken to remove this unevenness to ensure desired quality. For the data obtained from labs, charts were prepared. Following are X- charts of various tests carried out on materials.

The control limits for the individual chart are calculated as follows: -

Upper Control Limit = $\mu+3\ (\sigma/n^{1/2})$

Lower Control Limit = $\mu-3\ (\sigma/n^{1/2})$

where,

μ = centerline

σ = standard deviation

n = No. of samples

Following are X-charts of tests carried on materials.

Above all material test results was within control limit so material was taken for next process.

4.1 X-Chart For Slump Cone Test

M40 grade of concrete mix was designed. According to MORTH desired slump cone value should lie between 25 cm ± 15 cm. Also the slump value depends type of grade.

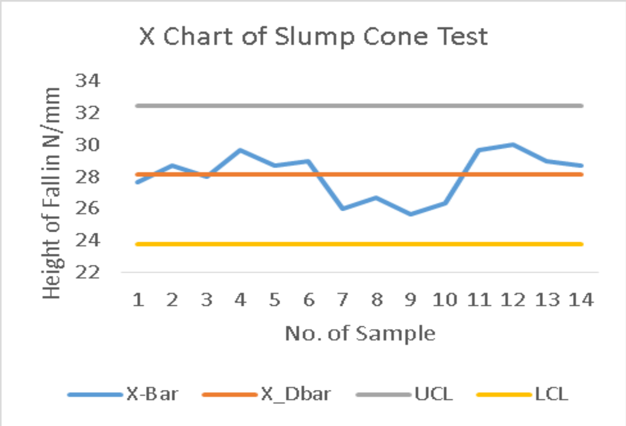

Chart -3: X-chart of slump test

All samples lied within the prescribed limits. Therefore, they were taken for next process.

4.2 X-chart for temperature

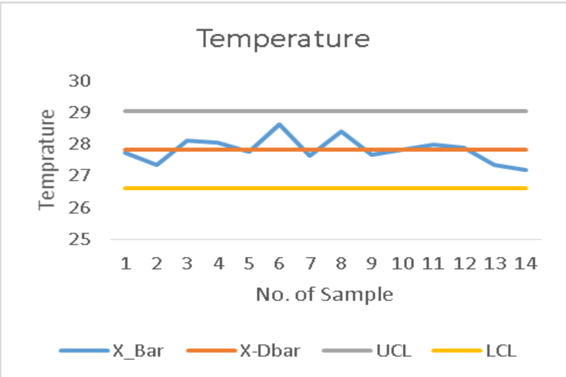

Chart -4: X-chart for temperature

According to the MORTH, the temperature of the concrete while placing should be 27 ± 20C. Thus, the samples obeyed the X-chart as well as MORTH. So the samples were accepted.

4.3 X-chart for Compressive strength

Three concrete cube from every tipper truck was tested throughout the enhancement of the work. These cubes were casted for M40 grade of concrete. Moulds of sizes 150 mm x 150 mm x 150 mm sizes were used. After curing, these cubes were tested for particularly 28 day's compressive strength. 50 samples for respective chainages were tested for monitoring the work. Mean and range chart for the 28 day's compressive strength of cube was developed.

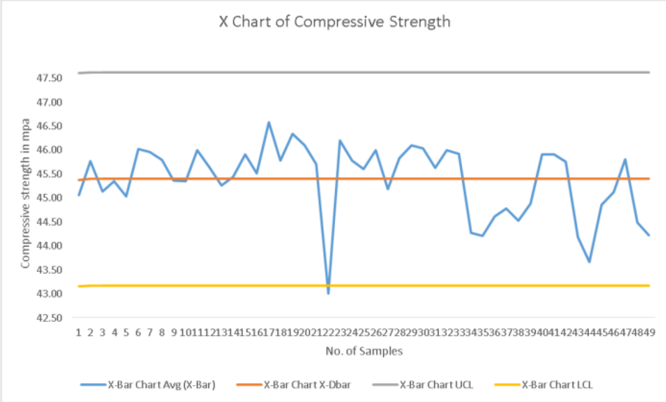

Chart -5: X chart of compressive strength

4.4 X-chart for flexural strength

One beams from every tipper truck was tested during the construction of the highway to achieve flexural strength of the M40 grade concrete. 50 samples for respective chainages are taken during the development of street for the examination. Beams of sizes 700 mm x 150 mm x 150 mm were casted. After 28 days, flexural tests were carried out using two- point loading setup. X-chart was established from the test result obtained.

Fig -1: Free body diagram of two-point loading set up adopted (mm)

Fig -2: Flexural strength testing

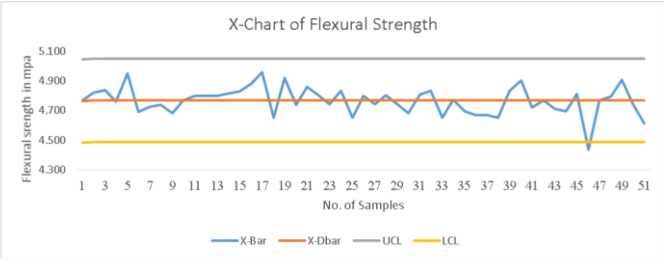

Chart -6: X-chart of flexural strength

According to norms specified by MORTH, the minimum flexural strength of the beam for M40 should be 10% of the characteristic strength of the mix. According to the control charts, estimations of compressive quality should to be close to the mean value. However, in above charts many samples are close to mean value while some are away and a few qualities are beneath the lower control limit. Based on this, a conclusion should be made whether to accept the work or discard, as the value of sample lies beneath the minimum range.

Furthermore, certain samples ran out of control. As these control limits are not detail limit, so the samples which are above or beneath control cutoff might possibly be approved.

5. CONCLUSIONS

From the charts, it was also observed that there are fluctuations in the process of PQC. From the above mentioned investigation, it is discovered that there is absence of consistency in the work while constructing the highway. Sample no. 22 had compressive strength of 43 N/mm2, but according to X-chart it was beneath the lower limit so it may be rejected. But MORTH recommends that the sample can be accepted if the characteristic strength is achieved. According to the X-chart, sample no. 46 should be rejected for the flexural strength as it was beneath the lower limit. But the sample is accepted as the minimum flexural strength criteria was satisfied by the sample.

Quality control of highway is necessary to avoid cracking of pavement quality concrete and abrupt failure. To control the quality in highway there must be a solid strategy for checking the nature of work. For this, statistical quality control tools prove to be an effective tool for maintaining quality of the work.

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