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Statistical Quality Assessment of M60A20 Grade Concrete: A Case Study

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Abstract: Concrete is one of the thing that comes into mind whenever we think about construction of anything, be it buildings, dams, airports, ports, roads etc. It is the most produced and used construction material in world and demand for it will increase day by day. Quality Control during production of concrete therefore becomes an important tool for achieving the highest quality concrete and at a lower cost. The compressive strength is considered to be the most important property and it is used as an indicator to check the quality of concrete and to judge compliance with the specifications. Variability in compressive strength of concrete produced in batches is inevitable in practice. Numerous studies have been carried out and statistical approaches have been devised in the field of quality control to analyse the statistics of strength results in order to draw conclusions about quality level in concrete plants and ways to improve it. In the present research the quality of concrete is examined using well established quality control tools and techniques. The main objective of the study is to assess the compressive strength of M60A20 grade concrete produced at site and evaluate the variance for strength deviation and evaluate opportunities for improvement in concrete production processes and in pouring methods of concrete.
Keywords: Quality assessment, quality control, variability, compressive strength, statistical analysis, standard deviation

I. INTRODUCTION

Concrete is one of the most widely used construction material in the world. It is important to understand and find engineering approaches and ways to improve the quality of this product at production plants and construction sites as well as to reduce cost. In typical construction projects, compressive strength is the most important criterion in assessing the acceptability of a concrete batch supplied by any given plant. Variability in compressive strength of the concrete batches from any plant is inevitable. Sources of such variability range from errors in proportion measurement of the batch ingredients to the variation in the properties of these ingredients [1]. Concrete mix proportions have a large influence on the quality of concrete. The water-cement ratio controls the 28-day compressive strength of concrete. The strength of concrete is also dependent on the quality of the constituent materials. Quality of concrete is also affected by other factors, such as mixing, transporting, placing, compaction, relative humidity, temperature and curing of concrete [2].

A. Variation in Strength

Concrete is a mixture of several constituents such as cement, water, aggregate (Coarse and fine), air and ad-mixtures. For Batch to Batch, variations in the characteristics and proportioning of ingredients, changes in w/c ratio as well as variations in transporting, placing, and compaction of the concrete, lead to variations in the strength of the finished product. For within batch, variations due to improper sampling, fabrication techniques, curing, testing lead to variations in the strength[1, 3].

Variation in measured characteristics may be random or assignable depending on the cause. Random variation is normal for any process; a stable process will show only random variation. Assignable causes represent systematic changes typically associated with a shift in a fundamental statistical characteristic, such as mean, standard deviation, coefficient of variation, or other statistical measure.

The standard deviation is the most commonly used indicator of data scatter around the mean. However, it is often more informative to use the coefficient of variation when comparing variability in data between two sets of results with markedly different mean strengths[3].

To improve the quality control, standard deviation should be reduced and that can be achieved by reducing the variability in ingredients, their production, manufacturing of concrete, curing and testing. Thorough assessment of compressive strength results, control charts, histograms and Shewhart chart and other advance statistical tools leads to finding of variance.

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II. PRESENT STUDY

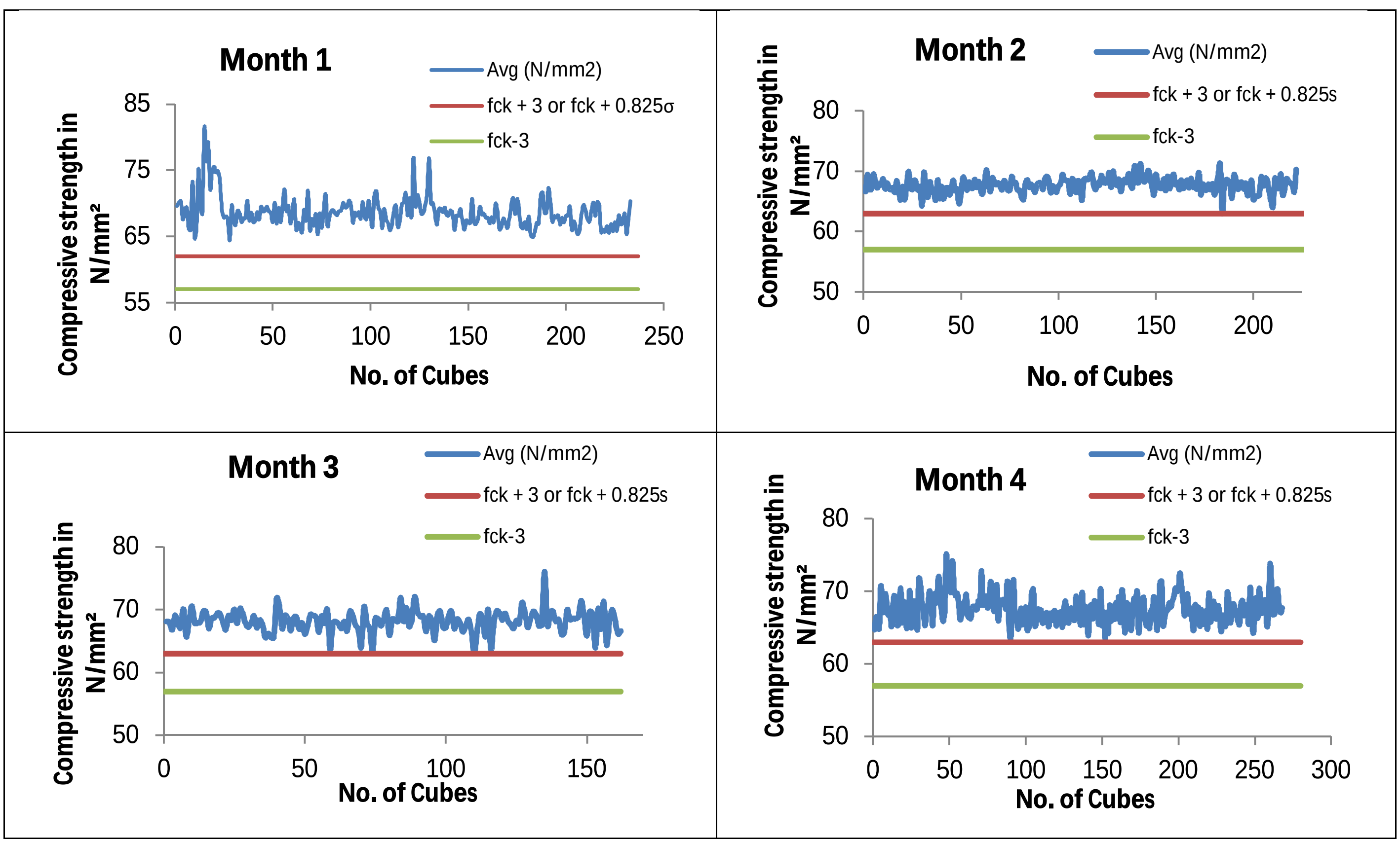
The scope of laboratory studies involves mix design of M60A20 grade concrete. For the mix, Portland Pozzolana cement, for fine aggregate natural river sand and aggregates obtained from charnokite group rock of dark grey in colour and coarse to medium grained rock were used.

Table 1: Concrete Mix Proportion

Mix Type	M60A20
Cement content (kg/m^3)	450
Micro Silica (kg/m^3)	22.50
Water (kg/m^3)	151
Coarse Aggregate (kg/m^3)	1222
20-10 mm	733
10-4.75 mm	489
Fine Aggregate (kg/m^3)	687
Water (Kg/m^3)	126
Admixture (kg/m^3)	4.02

To study the variability of concrete cube strength, fifteen months' data has been taken and compressive strength results were plotted.

It has been seen that



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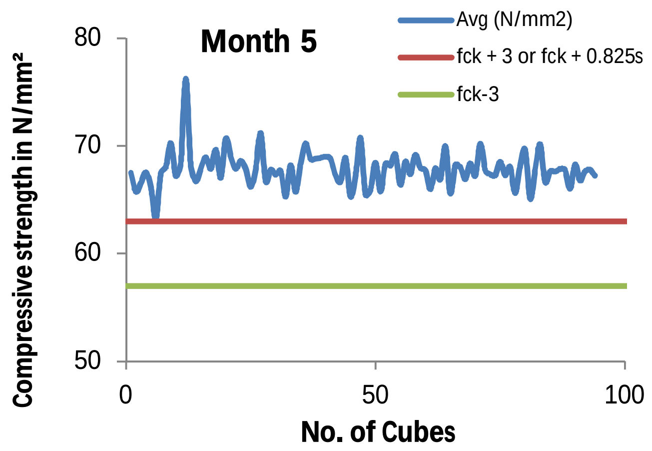
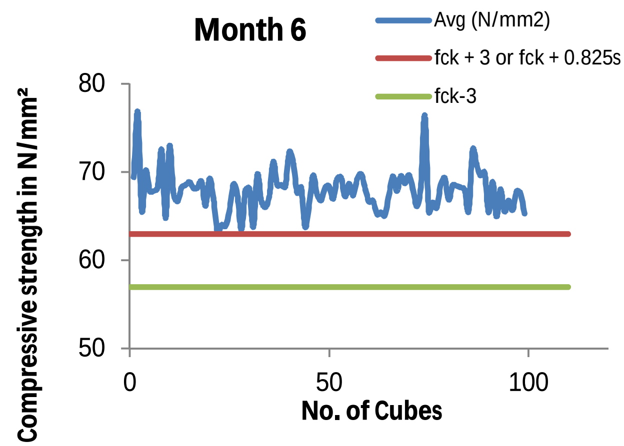
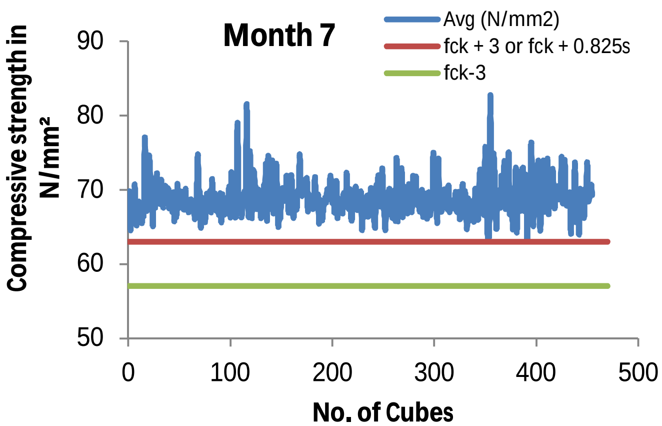
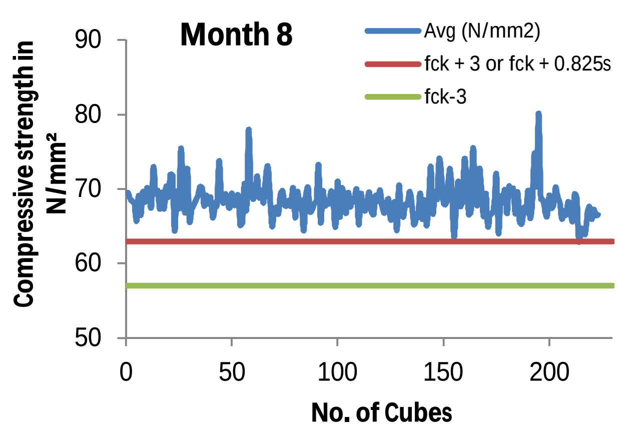
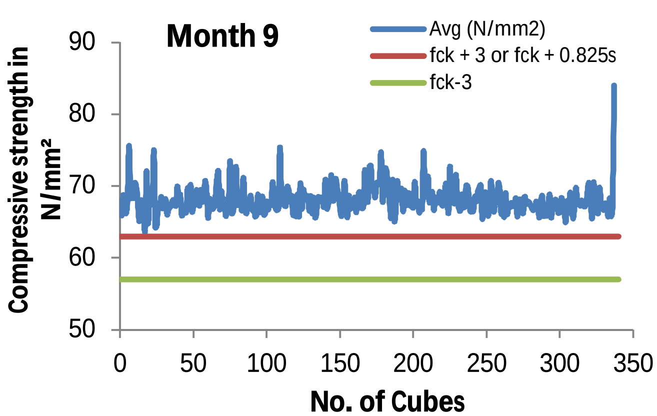
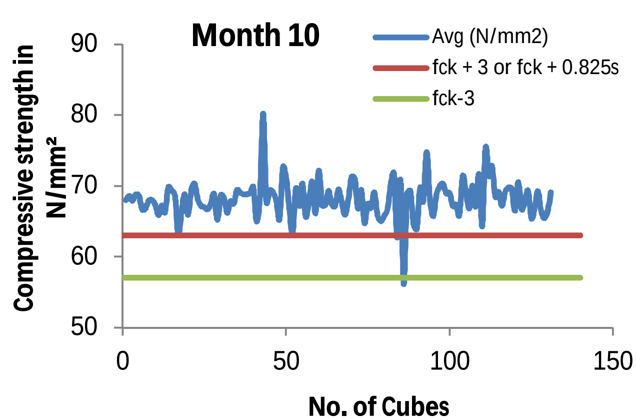


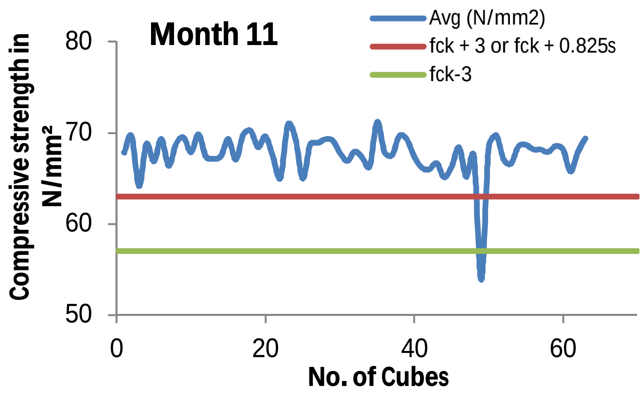


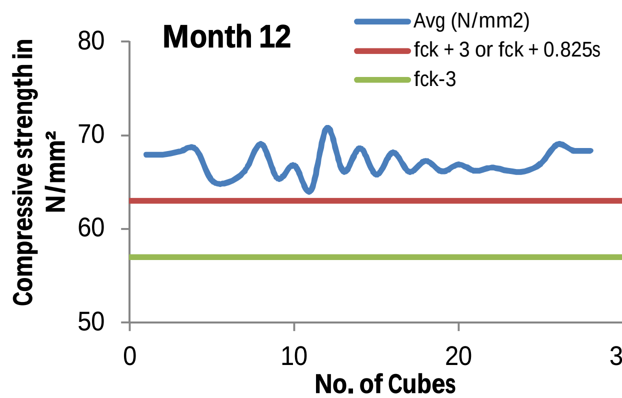


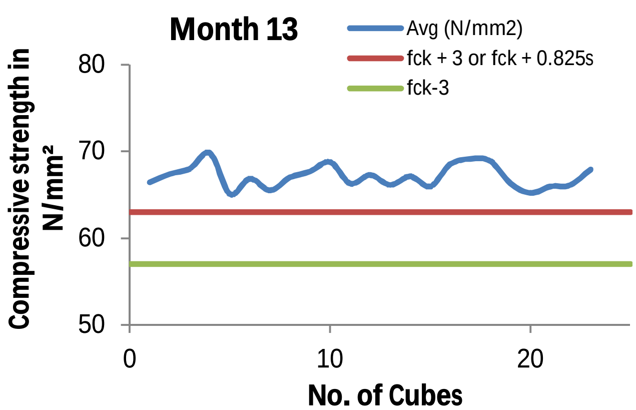


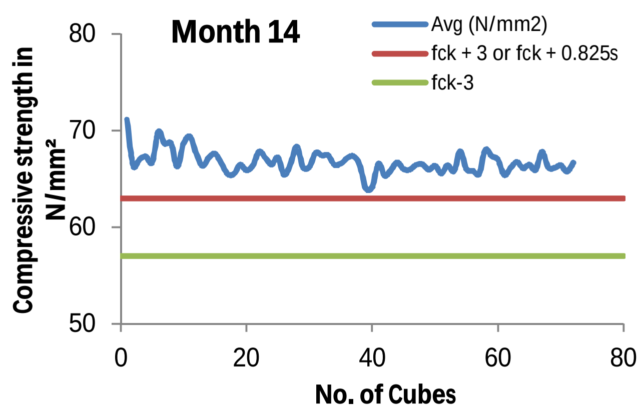


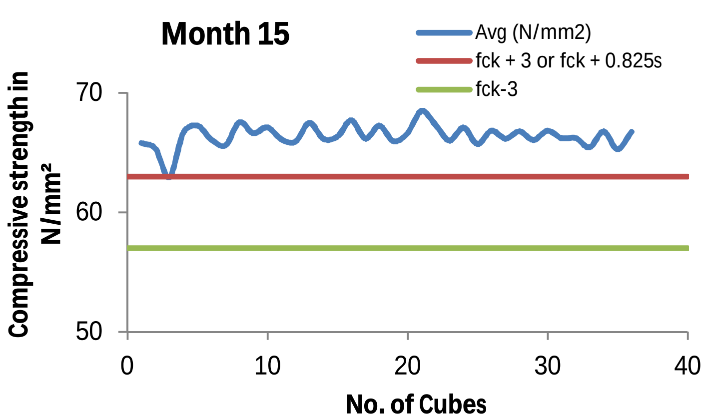


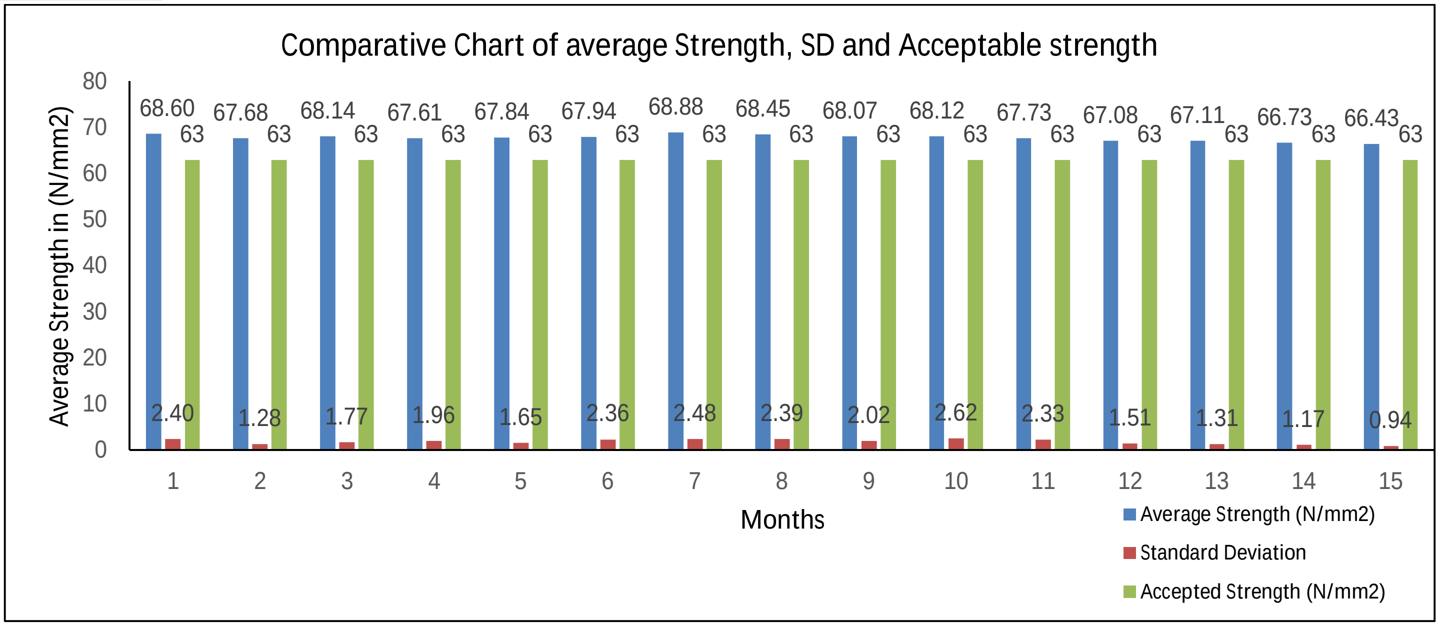

Month 11
Avg (N/mm2)
fck + 3 or fck + 0.825s
fck-3
Compressive strength in N/mm²
No. of Cubes
80
70
60
50
0
20
40
60

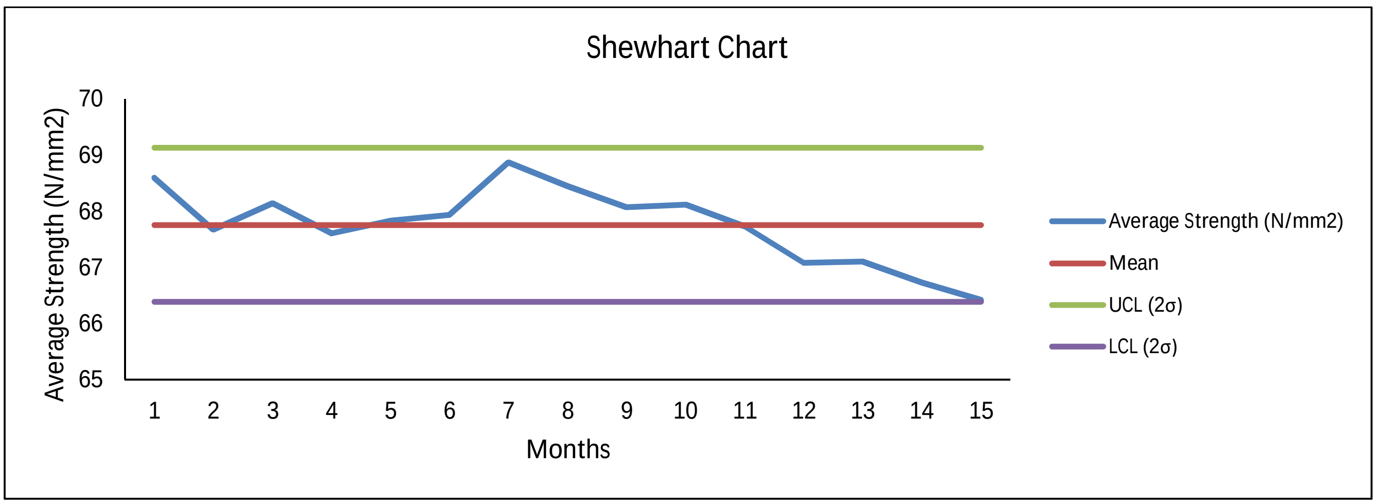

Month 12
Avg (N/mm2)
fck + 3 or fck + 0.825s
fck-3
Compressive strength in N/mm²
No. of Cubes
80
70
60
50
0
10
20
30

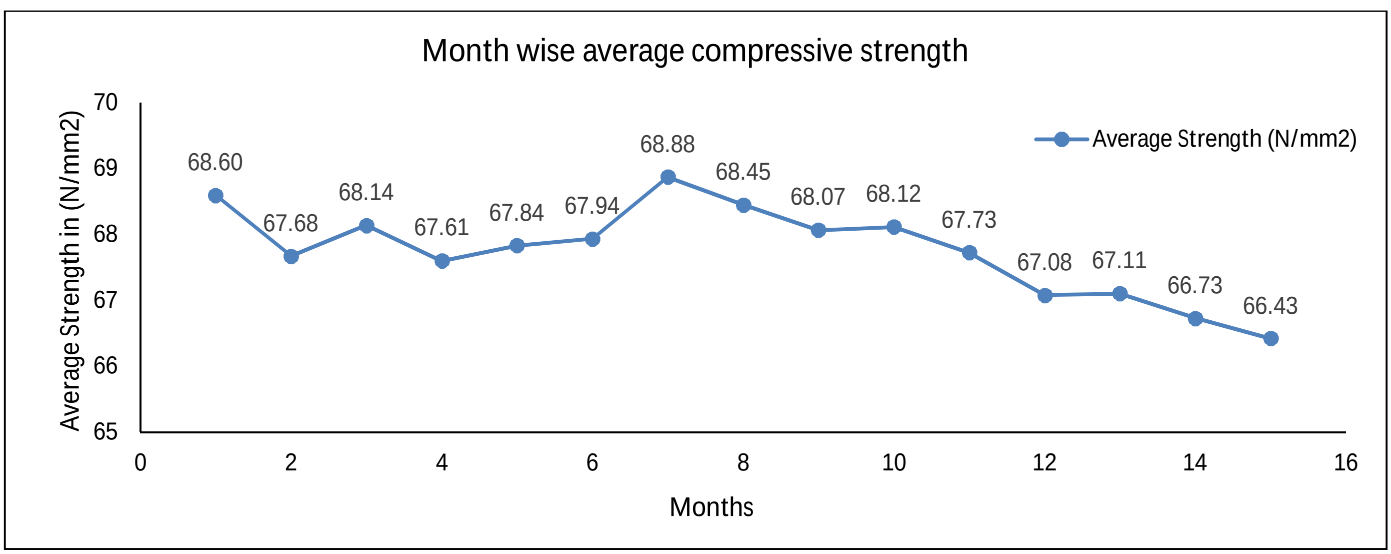

Month 13
Avg (N/mm2)
fck + 3 or fck + 0.825s
fck-3
Compressive strength in N/mm²
No. of Cubes
80
70
60
50
0
10
20


Month 14
Avg (N/mm2)
fck + 3 or fck + 0.825s
fck-3
Compressive strength in N/mm²
No. of Cubes
80
70
60
50
0
20
40
60
80


Month 15
Avg (N/mm2)
fck + 3 or fck + 0.825s
fck-3
Compressive strength in N/mm²
No. of Cubes
70
60
50
0
10
20
30
40


Comparative Chart of average Strength, SD and Acceptable strength
Average Strength in (N/mm2)
Months
Average Strength (N/mm2)
Standard Deviation
Accepted Strength (N/mm2)
68.60 67.68 68.14 67.61 67.84 67.94 68.88 68.45 68.07 68.12 67.73 67.08 67.11 66.73 66.43
2.40 1.28 1.77 1.96 1.65 2.36 2.48 2.39 2.02 2.62 2.33 1.51 1.31 1.17 0.94
63


Shewhart Chart
Average Strength (N/mm2)
Months
Average Strength (N/mm2)
Mean
UCL (2σ)
LCL (2σ)


Month wise average compressive strength
Average Strength in (N/mm2)
Months
Average Strength (N/mm2)
68.60 67.68 68.14 67.61 67.84 67.94 68.88 68.45 68.07 68.12 67.73 67.08 67.11 66.73 66.43

.Month	Average Strength (N/mm^2)	Standard Deviation (N/mm^2)	Accepted Strength (N/mm^2)	Coefficient of Variance	Degree of Quality Control
1	68.60	2.40	63	3.50%	Excellent according to ACI Committee 214 criteria with a Coefficient of variance less than 7 %.
2	67.68	1.28	63	1.88%	
3	68.14	1.77	63	2.60%	
4	67.61	1.96	63	2.90%	
5	67.84	1.65	63	2.43%	
6	67.94	2.36	63	3.47%	
7	68.88	2.48	63	3.60%	
8	68.45	2.39	63	3.49%	
9	68.07	2.02	63	2.97%	
10	68.12	2.62	63	3.85%	
11	67.73	2.33	63	3.44%	
12	67.08	1.51	63	2.24%	
13	67.11	1.31	63	1.95%	
14	66.73	1.17	63	1.76%	
15	66.43	0.94	63	1.41%	

III. DISCUSSION

Any batch of concrete is produced based on a mix design aiming to achieve a nominal strength value f_{ck} specified by the structural designer. An optimum result of the concrete production is a batch with all cubes giving compressive strength exactly equal to $f_{ck.}$. Realistically, the tested strength of concrete samples will differ lower or higher from f_{ck}. Lower values may pose a risk and indication of abnormality in mix. The primary objective of the statistical analysis of concrete strength data is to assess the quality of the concrete which conforms the design parameters. From the statistical analysis of the strength test results, it reveals that variation of standard deviation is very small which implies that of very good quality control.

IV. CONCLUSION

The following conclusions were generated on the basis of the above study:

1) The standard deviation of the M60A20 grade concrete was between 0.94 N/mm^2 and 2.62 N/mm^2. The assessment of the concrete quality of project revealed that the degree of quality control was excellent according to ACI Committee 214 criteria with a Coefficient of variance ranging from 1.41% to 3.85% (< 7 %).

2) The difference between the monthly average strength and the accepted strength is from 3.43 to 5.88.

3) The results of compressive strength are within the upper and lower limits except one test each in month 10 and 11 which falls below the accepted strength.

4) The month wise average strength ranges from 68.88 N/mm2 to 66.43 N/mm2 which shows that there is little variation in the strength over the fifteen months.

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