Quality Analysis of Some Characteristics of Cement Using Cusum and Shewart Control Charts: A Case of Lafarge Elephant Cement

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Abstract:
This paper examines the quality characteristic of cement production in Nigeria in an attempt to understand some of the reasons of the rampant f collapse of buildings and lack of durable roads and bridges in Nigeria using Elephant cement produced by Lafarge company in Nigeria as a case study, the paper finds that the quality characteristics of Elephant Cement is under statistical control when analyzed using the Cusum and Shewart control chart. However, it is advised that cement companies adequately monitor the quality of their products and regularly service their production plants to improve cement quality.

Key words: Cusum Chart, Control limits, Defective

Introduction

Quality control (QC) focuses its attention on testing of products to discover defects and make report to management who takes the decision to either allow or deny the release. SPC is the statistical methods used in monitoring and improving the quality of the output of a manufacturing process, which also includes the use of quality control charts. Statistical quality control (SQC) is the term used to describe the set of statistical tools used by quality professionals for analyzing quality. The rate of collapse of buildings and lack of durable roads and bridges in Nigeria is a quality issue which this research seeks to examine. Cement production companies need to be adequately monitored and advised on when to service their plants and the right quality level of cement production to forestall further disheartening events in Nigeria. Cement is produced with many quality characteristics such as setting time of the cement (The time at which cement completely loses its plasticity and became hard is a final setting time of cement), strength of the cement (The grades that corresponds to the minimum number of days-28 days for its compressive strength), soundness of the cement (soundness of cement is the ability of a hardened paste to retain its volume after setting) etc. Quality of Lafarge products sometimes fails to meet specification because of some assignable causes, operation errors, defective materials, manpower and other unassignable causes. In general terms, there are two enemies of product quality, and they are: deviations from target specifications and excessive variability around target specifications (Hill and Lewicki, 2006). Therefore, the tools needed in order tostudy and ultimately reduce the variation in a production process is the control charts. There are several control charts, the cusum, x-bar & s control charts will be discussed and used on some of the characteristics of cement production process.

Theoretical Framework

Huang and Shen (2011) did the analysis of variance for testing method of cement in grit of strength. It uses descriptive statistics, as the statistical tools which are full factorial design and analysis to identify the potential factors that impact the validity of testing method for determining the strength of cement. The results they got showed that the personal error stayed between both accuracy and precision of the test. Experimental time associated with temperature vacillation resulted in strength variation but did not impact the precision of test in all curing ages. Different compression did not impact the precision of test but resulted in the strength variation on 3 days and 28 days significantly. Different methods for the initial moist air curing significantly impacted the precision of testing method and resulted in the strength variation of cement on 1 day.

Gibb and Harrison (2010) did an analysis on the use of control charts in the production of concrete to check the condense strength for the concrete by making use of statistical tools like Shewhart control chart, Cusum control chart. In this paper the shewhart and cusum chart will be used to analysis the characteristics of cement and the analysis is will not be for only strength, but also for setting time and soundness.

Literature Review

Abariye (2016), stated that in the 1980s, during the economic recession which witnessed a decrease in the demand for cement that the supply gaps were still very much evident. The unpretentious but continuous growth in the Nigerian economy is a prospect for cement plants to increase local production. The rise in the demand for cement has led to a significant decrease in the quality of cement produced today in other to meet up this growing demand. The recent collapse of buildings in Nigeria maybe as a result of the inept of the contractors but can be major as a result of the quality of cement and other building materials used in the construction of these buildings. The rate of collapse of buildings in Nigeria has geometrically increased over time leading to the loss of lives and valuables. He concluded that the company focus more on production but neglected aspects of the quality of the product.

Bo (1962) concluded that one problem which constantly confronts the industry is control of quality. He commented on the specifications issued by the main control laboratory of Ideal Cement Company, that compressive strength should be maintained. Because he found out that in reality the larger number is completely arbitrary, and the lower figure should be interpreted as a minimum specification requirement. He used Shewhart control charts but needed another chart to validate his findings.

Dimitris (2017) looked at several non-destructive assessment methods which have been developed. He stated that these methods are almost based on the fact that some physical properties of concrete can be related to the compressive strength of concrete. The Schmidt rebound hammer (SRH) and the ultrasonic pulse velocity (UPV) tests are combined to develop a correlation between hammer/ultrasonic pulse velocity readings and the compressive strength of the concrete materials. He too left the issue of the quality content unattended.

Skrzypczak, Kokoszka, Pytlowany and Radwański (2020) analysed the strength quality control of ready-mixed concrete for rigid tarmac using control charts. The results show that by combining the CUSUM control chart and the Shewhart control chart, higher accuracy of quality control analysis could be achieved, though CUSUM statistical analysis is more sensitive than the Shewhart control chart.

Desmond (2016) developed a chart for assessing the in-situ grade strength of concrete. Four grades of concrete after the Nigerian General Specification for Roads and bridges (NGSRB-C20, C25, C30 and C35, is studied at different water-cement ratios for medium and high slump range. The concrete mixes are made from crushed granite rock as coarse aggregate with river sand as fine aggregate. He employed a simple algorithm using nonlinear regression analysis performed on each experimental data set produced Strength-Age (S-A) curves which were used to establish a quality control chart. It was revealed that the absolute average error of estimate (Abs. EoE) recorded was less than Â±10% tolerance zone for concrete works.

Layth and Harry (1988) proposed and illustrate statistical modelling and fitting of time-series effects on cement concrete and the application of standard control-chart procedures to the residuals from these fits. The fitted values can be plotted separately to show estimates of the systematic effects.

Debasis and Goutam (2010), designed and apply a new cumulative sum procedure for the ready mixed concrete industry, which takes care of the risks involved in and associated with the production of concrete. A risk-adjusted cumulative sum model was developed by imposing the weighted score of the estimated risks on the conventional cumulative sum plot. This model is a more effective and realistic tool for monitoring the strength of ready-mixed concrete.

Pieter, Elias and Kolentino (2018) stated that early detection of low cement strength is important as continued production. It would result in large quantities of unusable cement and wastage to the environment. The paper stated that continued monitoring of the mean strength of cement in manufacturing is essential to avoid waste. Cumulative Sum (CUSUM) control chart was adapted together with regression analysis

Aleksandra, Mateusz, and Paweł (2018) used CUSUM and Shewart control charts to determine and the conformity of the hardened concrete with the parameters declared by the manufacturer. The research used a dynamic method of measurement by evaluating the change in the energy of the beater after rebounding from a given surface and conclusions were made based on the analysis.

Table 1: $\bar{X}$ and S values for setting time

Date	$\bar{X}$	S
10/1/2019	133.21	2.29309
14/1/2019	134.50	2.87563
18/1/2019	134.43	2.68082
22/1/2019	133.64	2.59013
26/1/2019	133.79	2.15473
30/1/2019	134.29	2.33464
3/2/2019	133.79	2.75062
7/2/2019	134.43	3.15532
11/2/2019	135.21	2.83328
15/2/2019	133.64	2.34052
19/2/2019	134.57	2.62281
23/2/2019	134.14	2.41333
27/2/2019	133.57	2.37663
2/3/2019	133.07	2.30265
6/3/2019	133.79	2.80600
10/3/2019	133.07	2.30265
14/3/2019	135.93	2.16490
18/3/2019	133.07	2.30265
22/3/2019	134.29	2.78536
26/3/2019	133.07	2.30265
30/3/2019	134.14	2.59755
3/4/2019	134.36	3.10353
7/4/2019	135.00	2.71746
11/4/2019	133.64	2.34052
15/4/2019	134.57	2.62281
19/4/2019	133.50	2.24465
23/4/2019	133.86	2.74162
27/4/2019	133.07	2.30265
1/5/2019	133.43	2.02729
5/5/2019	135.00	2.71746
9/5/2019	134.14	2.90509
13/5/2019	132.64	2.23975
17/5/2019	133.57	2.44050
21/5/2019	133.79	2.48623
25/5/2019	133.07	2.40078
29/5/2019	135.36	2.92488
2/6/2019	134.29	2.39963
6/6/2019	134.93	2.40078
10/6/2019	134.64	2.64886
14/6/2019	133.93	2.70226
18/6/2019	134.43	2.97979
22/6/2019	134.00	2.85549
26/6/2019	134.21	2.35922
30/6/2019	134.57	2.62281

Monitoring The Setting Time

The $\bar{X}$& S and cusum charts will be applied to the data (appendix 1) using the mean and standard deviation values from table 1.

$\bar{X}$ and S Control Chart For Setting Time

From the above table 1, the expression for $\bar{S}$ stated in Eq. 15 and that of $\bar{\bar{X}}$ stated in Eq.16 of this study are computed below and given as

$$\bar{S} = \left(\frac{3758.64}{616-44}\right)^{1/2} = 2.563 \text{and} \; \bar{\bar{X}} = \frac{82567}{616} = 134.037$$

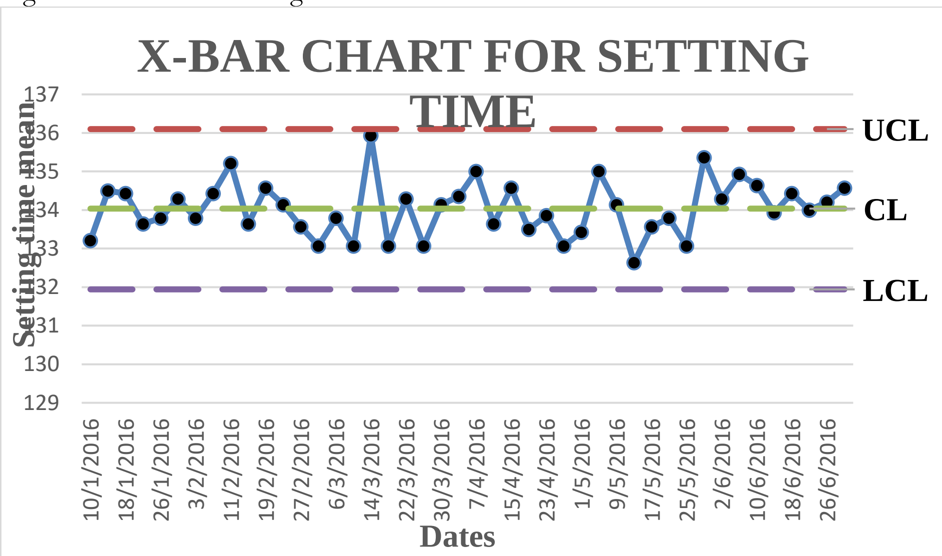
Using the expressions in Eq.14, the control limits for the $\bar{X}$ and S charts are computed. The obtained limits are summarized in the table below (table2).

Table 2: Control limit value for setting time

N	A_3	B_3	B_4	UCL_S	LCL_S	$UCL_{\bar{X}}$	$LCL_{\bar{X}}$
14	0.8174	0.4051	1.5949	4.0877	1.0383	136.1000	131.942

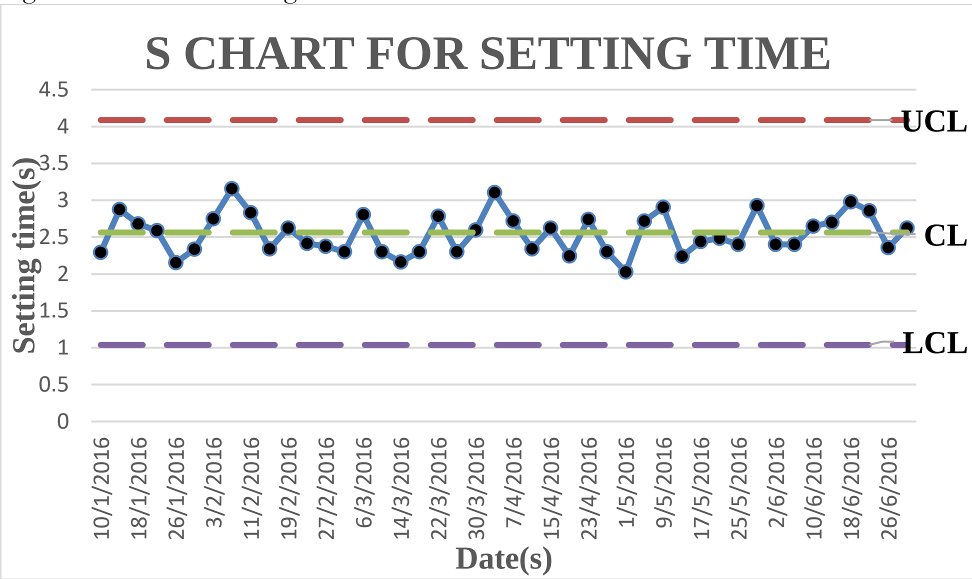
On plotting the values of $\bar{X}$ and S in table 1 along with the control limits in table 2, the control charts for the $\bar{X}$ and S is obtained and presented in figures 1 and 2 respectively.

Figure1: $\bar{X}$ chart for setting time



All plotted point's lies within the upper and lower control limit. If any point is below lower control limit (LCL), it indicates that the point is outside control limit ditto for upper control limit. The same setting is applied to figure II also.

Figure 2: S chart for setting time



Cumulative Sum Control Chart For Setting Time

The cusum which was described in section 3 of this paper is used for monitoring the setting time, making use of the mean values in table 1. The overall mean as computed from table 1 is given to beT= $\bar{\bar{X}} = \mu\_0=$ 134.037.

From Eq.5 in section 3, 〖 μ〗 _1is therefore 137.9564.

To determine the decision interval for the setting time is given as follows; Assuming, L_0= 500

To find L_1, the compound value of B = 0.75

h =((3.80×2.6129))/(√1)= 9.9291, as stated in Eq. 9

Thus, from Eq. 2, the cusum statistic is computed and shown in table 3 below and hence when S_m>± 9.9291, this is the signal that there is a shift in process mean.

Figure 3 below gives the cusum for the mean values of setting time

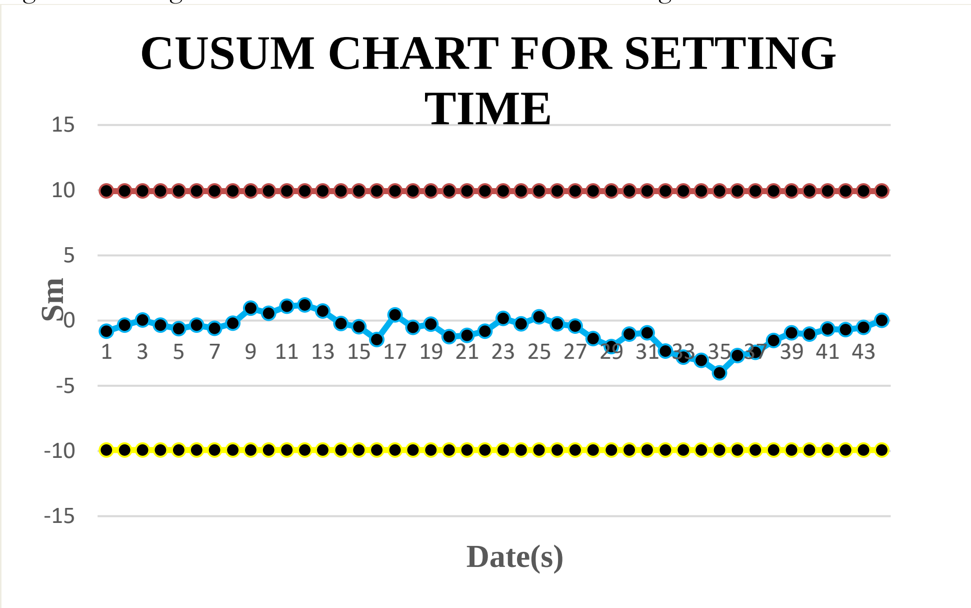


Figure 4:X̄ chart for degree of soundness.

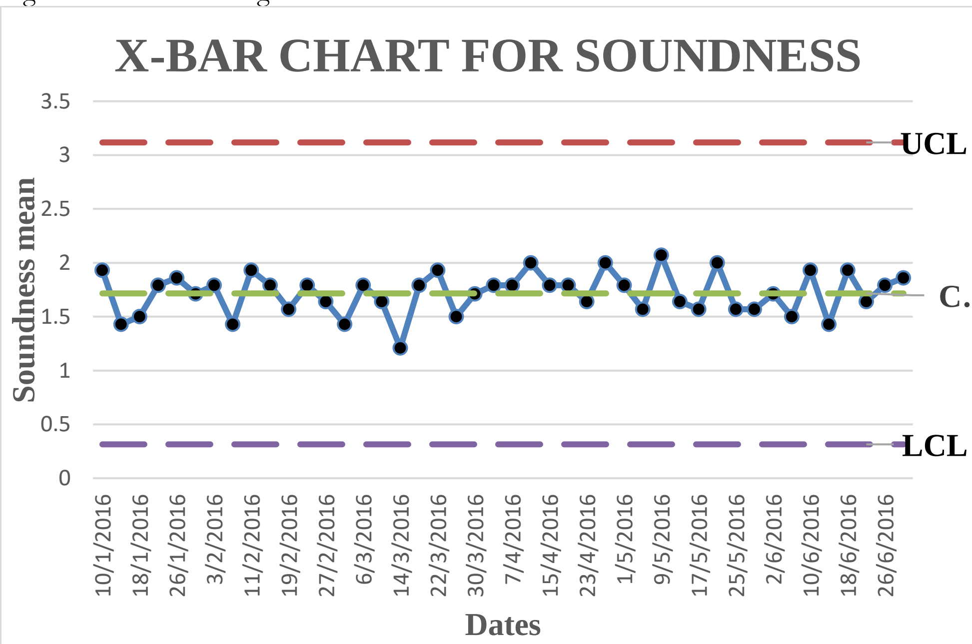


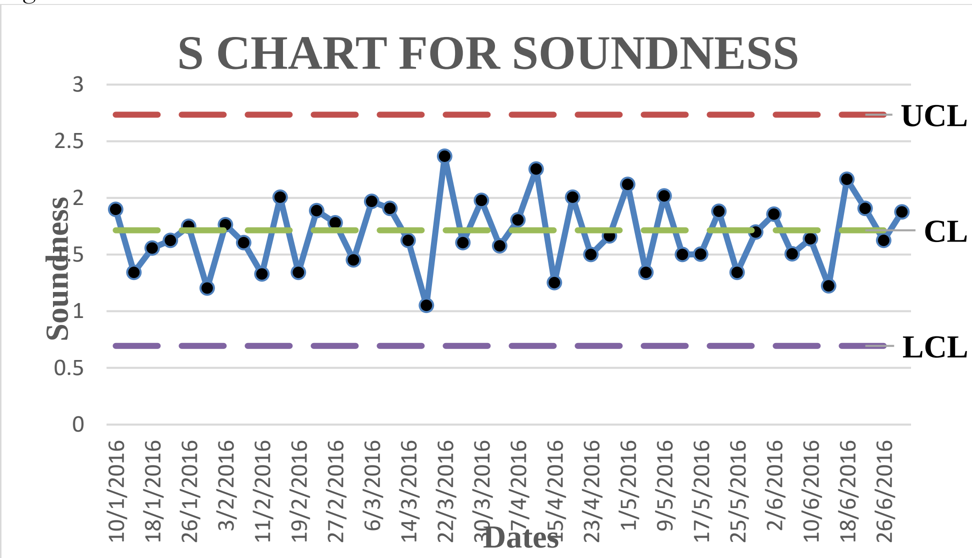
Table 4: $\bar{X}$ and S values for Degree of soundness

Date	$\bar{X}$	S
10/1/2019	1.93	1.89997
14/1/2019	1.43	1.34246
18/1/2019	1.50	1.55662
22/1/2019	1.79	1.62569
26/1/2019	1.86	1.74784
30/1/2019	1.71	1.20439
3/2/2019	1.79	1.76193
7/2/2019	1.43	1.60357
11/2/2019	1.93	1.32806
15/2/2019	1.79	2.00686
19/2/2019	1.57	1.34246
23/2/2019	1.79	1.88837
27/2/2019	1.64	1.78054
2/3/2019	1.43	1.45255
6/3/2019	1.79	1.96815
10/3/2019	1.64	1.90575
14/3/2019	1.21	1.62569
18/3/2019	1.79	1.0509
22/3/2019	1.93	2.36852
26/3/2019	1.50	1.60528
30/3/2019	1.71	1.9779
3/4/2019	1.79	1.57766
7/4/2019	1.79	1.80506
11/4/2019	2.00	2.2532
15/4/2019	1.79	1.25137
19/4/2019	1.79	2.00686
23/4/2019	1.64	1.49908
27/4/2019	2.00	1.6641
1/5/2019	1.79	2.11873
5/5/2019	1.57	1.34246
9/5/2019	2.07	2.01778
13/5/2019	1.64	1.49908
17/5/2019	1.57	1.50457
21/5/2019	2.00	1.88108
25/5/2019	1.57	1.34246
29/5/2019	1.57	1.6968
2/6/2019	1.71	1.85757
6/6/2019	1.50	1.5064
10/6/2019	1.93	1.63915
14/6/2019	1.43	1.2225
18/6/2019	1.93	2.1649
22/6/2019	1.64	1.90575
26/6/2019	1.79	1.62569
30/6/2019	1.86	1.87523

Analysis of Degree of Soundness

Soundness of cement is the ability of a hardened paste to retain its volume after setting. From the data given in table 2, the mean values ($\bar{X}$) and standard deviation (S) values of the setting time are computed. The obtained $\bar{X}$ and S values are presented in table 4.

Figure 5: S control chart for soundness



The cusum control chart in figure 5 obtained in monitoring the amount of strength gave an indication of a shift in the process mean. This shift occurred at about point 4 with an upward and downward movement and thus revealed several processes occurring. The cusum chart in addition, indicates no evidence of lack of control in the amount of strength in the process of cement. This therefore indicates that the process is in a state of statistical control.

Conclusion

Based on the analysis done in this paper, with the result discussed above, the process means in the setting timeand degree of soundness, in the production process of cement under study was found to be in statistical control, since both the Shewart and cusum control chart did fall within control process mean.

The results of the current study demonstrated that it is feasible to use both the Shewart and CUSUM control charts. Both Shewart and CUSUM control charts can readily detect Out-of-control data points. The two control charts reported similar findings; this bring remedial actions plans which must be timeously to avoid waste which will eventually reach the environment.

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