A STUDY TO IMPROVE THE QUALITY OF CEMENT MANUFACTURING PROCESS BY USING STATISTICAL QUALITY CONTROL

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Introduction

Lime Saturation Factor (LSF) is the main quality characteristic of Cement manufacturing process which is composed on ingredients of its raw materials CaO, SiO_2, Al_2O_3 and Fe_2O_3 of their weight fraction as:

$$LSF = \frac{CaO}{2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3} \times 100$$

LSF is measured to which extent the CaO optimum compounds in clinker composition formed without necessary presence of free lime. The optimum value of LSF in the cement raw mix before burning is 101 % with the tolerance level +/-5 %. Limestone deposit does not show this optimum value of LSF. Mined High Grade (HGL) and Low Grade (LGL) limestones are mixed with correct proportions with additives and obtained this particular value of LSF. According to the specifications, LSF values of HGL and LGL are 80 % +/-15 and 120 %+/-15 respectively in the prepared mixed heaps. But in practice these values of LSF some times lie outside the specific range. This causes to reduce the quality level of Cement. In this research we have analyzed the variation of LSF in the raw HGL and LGL by using $\overline{X}$ and S control charts for variable sample size. Control charts are vital quality tools in many industries for quality monitoring, control and take corrective action. Past researches quoted some chance causes and assignable causes affect to this variation of LSF. Any point falls outside the control limits either $\overline{X}$ or S chart, it is considered as an out of control condition. (Bhattacharya and Sachdeva, 2005). Generally limestone deposits shows higher percentage of CaO than specification. This is caused to lie outside the LSF points above the Upper Control Limit. Improper blending, material dilution, incorrect estimation cause to the variation of LSF. (Bhattacharya *et al.*, 2007)

Methodology

Since the sample size varies with the yield of limestone, control charts with variable sample size are used. Weighted average $\overline{X}$ would be Center Line (CL) of the $\overline{X}$ Chart, and Upper Control Limit (UCL) is $\overline{\overline{X}} + A_3\overline{S}$ and Lower Control Limit (LCL) is $\overline{\overline{X}} - A_3\overline{S}$. For the S chart CL = $\overline{S}$, UCL = $B_4\overline{S}$ and LCL = $B_3\overline{S}$, where,

$$\bar{S} = \left[\frac{\sum_{i=1}^{m} (n_i - 1) S_i^{\,2}}{\sum_{i=1}^{m} n_i - m} \right]^{\frac{1}{2}}$$

and

$$\overline{\overline{X}} = \frac{\sum_{i=1}^{m} n_i \bar{x}_i}{\sum_{i=1}^{m} n_i}$$

$n_i = i^{\text{th}}$ samplesize,

$m = \#$ samples,

$\overline{X_i}$ = avearge of the i^{th} sample,

$S_i = i^{\text{th}}$ samplestandarddeviation

$\overline{\overline{X}}$ = weighted average,

$\bar{S}_i$ = Average Standard Deviation of i^{th} sample

A_3, B_3 and B_4 are constants for the sample sizes.

Data collection

The mixed heaps are prepared from the mined limestones as HGL and LGL separately. One mixed heap divided into 24 to 27 portions and transported for crushing. In this analysis, each portion is considered as a sample and according to the tonnage of this sample, where four to five LSF values are calculated by X ray fluorescence method. LSF formula was programmed in the XRF: ARL 9900 machine. Twelve numbers of HGL and LGL mixed heaps (six each) are analyzed and five sample numbers are randomly picked up to construct the control chart of each six data sets. These LSF values of HGL, LGL and the control limits of $\overline{X}$ and S charts are shown in Table 1a and Table 1b respectively.

Statistical data analysis

Figure 1a and 1b show the control charts for LSF values of HGL and LGL respectively. Average values of LSF are 135.3 in HGL and 71.97 in LGL. UCL and LCL varies between 152 and 118 in HGL but 83 and 60 in LGL. There are two consecutive points and three non consecutive points lie outside the UCL and two consecutive points lie outside from the LCL in HGL. In LGL, five LSF points lie outside the UCL and LCL. Average values of Standard Deviations of LSF are 11.66 in HGL, and 7.30 in LGL in S charts. There are two LSF points lie outside the UCL in HGL, but for LGL no points lie outside of the control limits.

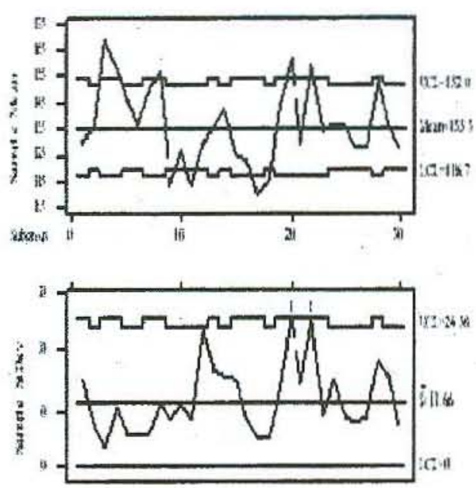

Figure 1a. $\overline{X}$ and S charts for HGL

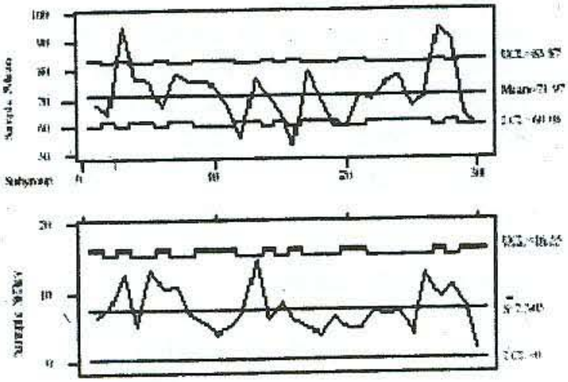

Figure 1b. $\overline{X}$ and S charts for LGL

Discussion and Conclusion

After observing the $\overline{X}$ and S charts, it was revealed that there are some chance and assignable causes affect to the variation of LSF. The main chance cause to the LSF variation in the limestone is due to uneven distribution of chemical composition through the deposit. Due to higher content of CaO, the average value of LSF in HGL is higher than the specification and that is lower in LGL. But this can be avoided by proper handling of material such as sampling methods, Drilling, Proper equipment handling, and specially mixed heap preparation. Reject material such as clay pocket should be detected by implementing prior identification method before the blasting of limestone bed. This can be done by improving the test hole sampling method.

Also, it can be identified that, relatively hard material or boulders exhibit higher value of LSF. Uneven spread of boulders may have caused to make LSF value higher in the sample. By implementing correct mixed heap preparation method to disperse hard material evenly through the heap, avoid LSF variation as much as possible in the cement raw mix and hence produce cement with high quality.

References

Bhattacharya, J. and Sachdeva, J., (2005).Control Chart for Limestone Quality for Supply to Cement Plant with Varying Sample Size, 116: 25-29.

Bhattacharya, J., Islam, M., Kumar, A. and Santosh, G. (2007). Application of statistical quality control for limestone grade, a case study, 116: 25-31.

Table 1a. Control limits of $\overline{X}$ and S charts for HGL

Sample #	Mixed Heap	Observations					n	X bar	S	A3	X bar chart		B3	B4	S chart	
											LCL	UCL			LCL	UCL
1	A 01	140.56	120.72	145.30	115.03		4	130.40	14.78	1.628	116.14	154.46	0.00	2.266	0.00	26.67
2		124.49	132.47	140.87	142.28	134.70	5	134.96	7.15	1.427	118.50	152.09	0.00	2.089	0.00	24.58
3		172.73	164.33	167.18	169.19		4	168.36	3.53	1.427	116.14	154.46	0.00	2.266	0.00	26.67
4		155.06	170.97	160.49	145.17		4	157.93	10.76	1.628	116.14	154.46	0.00	2.266	0.00	26.67
5		137.43	150.14	144.82	151.42	145.78	5	145.92	5.51	1.427	118.50	152.09	0.00	2.089	0.00	24.58
6	A 02	140.47	129.98	131.62	142.72	136.00	5	136.16	5.49	1.427	118.50	152.09	0.00	2.089	0.00	24.58
7		149.51	160.49	149.13	145.67		4	151.20	6.43	1.427	116.14	154.46	0.00	2.266	0.00	26.67
8		168.39	161.14	152.32	142.79		4	156.16	11.07	1.427	116.14	154.46	0.00	2.266	0.00	26.67
9		124.03	106.78	116.74	102.49	112.00	5	112.41	8.43	1.628	118.50	152.09	0.00	2.089	0.00	24.58
10		122.79	123.85	122.91	117.10	146.22	5	126.57	11.30	1.427	118.50	152.09	0.00	2.089	0.00	24.58
11	A 03	124.03	106.78	116.74	102.49	112.00	5	112.41	8.43	1.427	118.50	152.09	0.00	2.089	0.00	24.58
12		109.38	146.75	110.20	163.08	117.91	5	129.46	24.17	1.427	118.50	152.09	0.00	2.089	0.00	24.58
13		120.56	121.46	154.08	143.62		4	134.93	16.63	1.427	116.14	154.46	0.00	2.266	0.00	26.67
14		161.53	128.09	156.39	136.59	130.04	5	142.53	15.43	1.427	118.50	152.09	0.00	2.089	0.00	24.58
15		109.96	137.16	113.50	138.71		4	124.83	15.21	1.628	116.14	154.46	0.00	2.266	0.00	26.67
16	A 04	112.35	131.54	120.44	127.67		4	123.00	8.46	1.628	116.14	154.46	0.00	2.266	0.00	26.67
17		106.52	115.67	110.43	104.87		4	109.37	4.81	1.628	116.14	154.46	0.00	2.266	0.00	26.67
18		119.78	111.79	108.05	119.83	116.80	5	115.25	5.19	1.427	118.50	152.09	0.00	2.089	0.00	24.58
19		145.25	143.17	123.87	155.62		4	141.98	13.24	1.628	116.14	154.46	0.00	2.266	0.00	26.67
20		126.09	173.94	186.46	160.68		4	161.79	26.02	1.628	116.14	154.46	0.00	2.266	0.00	26.67
21	C 02	110.73	131.22	131.66	145.65		4	129.82	14.38	1.628	116.14	154.46	0.00	2.266	0.00	26.67
22		139.48	145.56	196.84	157.23		4	159.78	25.78	1.628	116.14	154.46	0.00	2.266	0.00	26.67
23		144.21	138.99	122.35	130.26		4	133.95	9.64	1.628	116.14	154.46	0.00	2.266	0.00	26.67
24		159.77	128.00	140.88	128.28	122.70	5	135.93	14.91	1.628	118.50	152.09	0.00	2.089	0.00	24.58
25		138.61	133.01	131.74	125.07	148.68	5	135.42	8.84	1.427	118.50	152.09	0.00	2.089	0.00	24.58
26	C 04	122.4	118.7	129.2	127.9	138.91	5	127.44	7.69	1.628	118.50	152.09	0.00	2.089	0.00	24.58
27		137.36	126.26	113.01	130.10	129.24	5	127.19	8.92	1.427	118.50	152.09	0.00	2.089	0.00	24.58
28		172.37	133.63	165.35	141.58		4	153.23	18.56	1.628	116.14	154.46	0.00	2.266	0.00	26.67
29		119.08	143.31	120.01	136.61	155.12	5	134.83	15.45	1.628	118.50	152.09	0.00	2.089	0.00	24.58
30		132.80	125.35	128.68	135.02	117.22	5	127.81	7.00	1.427	118.50	152.09	0.00	2.089	0.00	24.58

Table 1b. Control limits of $\overline{X}$ and S charts for LGL

Sample #	Mixed Heap	Observations					n	X bar	S	A3	X bar chart		B3	B4	S chart	
											LCL	UCL			LCL	UCL
1	B 01	67.91	77.02	65.57	62.53		4	68.26	6.24	1.628	60.07	83.87	0.00	2.266	0.00	16.56
2		56.90	59.38	65.67	66.12	76.89	5	65.00	7.75	1.427	10.43	82.40	0.00	2.089	0.00	15.27
3		101.51	108.79	91.08	79.90		4	95.32	12.59	1.628	60.07	83.87	0.00	2.266	0.00	16.56
4		74.86	70.06	82.66	77.95	77.42	5	76.59	4.61	1.427	10.43	82.40	0.00	2.089	0.00	15.27
5		59.56	81.12	64.10	83.78	91.30	5	75.97	13.53	1.427	10.43	82.40	0.00	2.089	0.00	15.27
6	E 01	68.91	64.44	55.55	80.97		4	67.47	10.58	1.628	60.07	83.87	0.00	2.266	0.00	16.56
7		84.37	91.22	79.67	61.33	77.84	5	78.89	11.09	1.427	10.43	82.40	0.00	2.089	0.00	15.27
8		76.73	66.99	85.56	75.78	75.83	5	76.18	6.58	1.427	10.43	82.40	0.00	2.089	0.00	15.27
9		81.91	78.43	73.33	69.27		4	75.73	5.56	1.628	60.07	83.87	0.00	2.266	0.00	16.56
10		77.16	77.52	69.63	73.67		4	74.49	3.68	1.628	60.07	83.87	0.00	2.266	0.00	16.56
11	E 02	62.88	63.20	66.38	73.50		4	66.49	4.93	1.628	60.07	83.87	0.00	2.266	0.00	16.56
12		51.71	53.27	54.61	67.64	49.99	5	55.44	7.03	1.427	10.43	82.40	0.00	2.089	0.00	15.27
13		68.20	86.77	56.61	94.69	78.28	5	76.91	15.03	1.427	10.43	82.40	0.00	2.089	0.00	15.27
14		66.08	77.47	76.44	68.28		4	72.07	5.73	1.628	60.07	83.87	0.00	2.266	0.00	16.56
15		63.99	52.08	63.93	66.90	75.41	5	64.46	8.36	1.427	10.43	82.40	0.00	2.089	0.00	15.27
16	G 01	56.38	45.44	57.77	52.34		4	52.98	5.53	1.628	60.07	83.87	0.00	2.266	0.00	16.56
17		83.35	84.52	78.24	73.01	79.58	5	79.74	4.57	1.427	10.43	82.40	0.00	2.089	0.00	15.27
18		72.32	75.36	70.09	65.01	70.54	5	70.67	3.78	1.427	10.43	82.40	0.00	2.089	0.00	15.27
19		52.57	68.04	57.72	65.54	60.51	5	60.87	6.17	1.427	10.43	82.40	0.00	2.089	0.00	15.27
20		55.31	56.72	64.68	62.96		4	59.92	4.60	1.628	60.07	83.87	0.00	2.266	0.00	16.56
21	G 02	66.86	77.39	71.60	70.36		4	71.55	4.38	1.628	60.07	83.87	0.00	2.266	0.00	16.56
22		70.71	80.90	62.29	70.85	66.84	5	70.32	6.87	1.427	10.43	82.40	0.00	2.089	0.00	15.27
23		73.32	85.93	75.37	73.50	68.32	5	75.29	6.50	1.427	10.43	82.40	0.00	2.089	0.00	15.27
24		83.85	67.72	83.20	73.19	81.62	5	77.91	7.13	1.427	10.43	82.40	0.00	2.089	0.00	15.27
25		66.37	72.88	68.70	68.19	62.60	5	67.65	3.57	1.427	10.43	82.40	0.00	2.089	0.00	15.27
26	G 03	92.0	63.3	69.4	58.1	70.4	5	70.64	12.94	1.427	10.43	82.40	0.00	2.089	0.00	15.27
27		96.06	101.05	81.99	100.95		4	95.01	8.99	1.628	60.07	83.87	0.00	2.266	0.00	16.56
28		102.72	86.12	94.99	74.20	95.60	5	90.73	10.96	1.427	10.43	82.40	0.00	2.089	0.00	15.27
29		54.48	62.33	67.77	72.63		4	64.30	7.78	1.628	60.07	83.87	0.00	2.266	0.00	16.56
30		61.57	59.33	60.42	58.14		4	59.86	1.47	1.628	60.07	83.87	0.00	2.266	0.00	16.56