Determination of existing relationship among grindability, chemical composition and particle size of raw material mix at Aruwakkalu Limestone.

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Abstract— *In the production process of the Siam City Cement (Lanka) Ltd, grindability can be mainly effected by the chemical composition of the raw materials, ball mill performance and moisture content. However, currently, in the production process ball mill performance is in its optimum stage and moisture content remains constant at 7%. On account of that the chemical composition and particle size of raw material are the main effecting factors to the lower grindability.*

This research study is expected to make a relationship between the grindability and the chemical constituents and particle size of limestone in the raw meal feed. Percentages of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Cl-, SO_3, Na_2O and K_2O in limestone are observed for this research. The suitable analysis method (time series and scatter plot analysis) was performed to correlate the chemical constituents with the grindability. The company has been already used a method to check the chemical composition and the grindability hourly of these samples. The XRF (X - ray Fluorescence) analysis is used to check the chemical composition and grindability is checked in the form of residue test of No 212 sieve residue. These chemical analysis and residue test results data of year 2016 were used in data analysis of the research study.
The distribution curves of the variables were analyzed to examine the skewness of the distribution. The time series analysis was carried out to find the best fitting curve between grindability and the variables. Scatter plot analysis was finally performed and the results show the effect of chemical components such as SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, SO_3, Cl-, Na_2O, K_2O and particle size distribution of raw meal were found to be range correlated with the raw meal grindability.
Standard normal distribution analysis of Percentages of SiO_2, Al_2O_3, Fe_2O_3, CaO and LSF, AR and SR follow the standard normal distribution perfectly. It means it gives unbiased estimation of statistical parameters of the population. Therefore the quality parameter such as LSF, AR and SR lie on the required quality target range upheld by the company. The mathematical relationship among the grindability and variables Silicon Oxide (SiO_2), Aluminium Oxide (Al_2O_3), Ferric Oxide (Fe_2O_3) Calcium Oxide (CaO), LSF and SR cannot be given in the form of polynomial, exponential or logarithmic manner, since R^2 values do not equal to the unity.
The most suitable chemical constituents range for improved grindability of raw meal are given based on 68% , 95% and 99% confidence interval. The quality parameters such as Lime Saturation Factor (LSF), Alumina Ratio (AR) and Silica Ratio (SR) also evaluated based on certain error level.

Keywords— **X-ray Fluorescence, Lime Saturation Factor (LSF), Alumina Ratio (AR), Silica Ratio (SR)**

I. INTRODUCTION

In the cement making process of the Siam City Cement (Lanka) Ltd, it has been identified that there are some raw meal loads that are hard to grind. This low grindability raw meal load causes to get lower output which ultimately results in negative impact to the entire process and sometimes it needs to clear the ball mill manually. It takes a big effort to clear the ball mill and needs to stop the whole production line. In this case the Siam city Cement (Lanka) Ltd still hasn't developed any method to pre-identify the raw meal loads by its grindability.

The production rate and ball mill efficiency getting low when the low grindability raw meal load is fed into the ball mill. During a situation like this, a sample from the low grindability raw meal load is taken to the testing laboratory and check the grindability of the sample by a lab scale ball mill in order to identify whether the problem has occurred due to ball mill defect or change in chemical composition of the raw meal load. However for checking the grindability of a sample takes about two days. Because of that it's not possible to check the grindability of every limestone load in laboratory. At the time when a sample taken to the grindability test and its results release, that load is already fed to the process. On account of these reasons Siam City Cement (Lanka) Ltd emphasized the developing a method to optimize the grindability of raw meal with its chemical composition.

In the cement making process of the Siam City Cement (Lanka) Ltd, there is a facility to check the chemical composition of a limestone sample within 30 minutes in laboratory. Therefore the company has taken action to check the chemical composition of limestone for every four hours period for the crusher outputs and hourly check for the blending cyclone feed (i.e., ball mill output).

Grindability can be mainly effected by the chemical composition of the raw materials or ball mill performance. Chemical composition, moisture content, particle size can be identified as effecting factors of raw material for the grindability. In this case ball mill performance is in its optimum stage and moisture content remains constant at 7%. Because of that the chemical and physical factors of raw material are the mainly effecting factors to the low grindability (Kural and Ozsoy, 2004).

Hence in this research study, it is expected to make a relationship between the grindability and the chemical composition percentages and particle size of limestone. Percentages of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Cl-, SO_3, Na_2O and K_2O in limestone are observed for this research study. The suitable analysis was performed to correlate the chemical constituents with its grindability.

II. METHODOLOGY

The analysis was carried out based on the company recorded data of entire year 2016. Nevertheless three samples were collected hourly using the raw meal auto sampler in the ball meal output for us to get familiarize with the operation procedure of XRF(X - ray Flurocence) analyser. Furthermore sample size was reduced by coning and quartering in to 200g.

The size reduced samples were heated on the hot plate till particles show considerable low cohesion (until it reaches 7% moisture content). The weight of 200g of the sample was fed to the disc mill and operated for 60 seconds. The disc mill output was used to prepare the tablets for XRF analyser. The tablet was prepared by the pressed powder method. These tablets then used as an input for the XRF analyser and the chemical composition results were shown with in few seconds. Then the results were recorded on the relevant databases.

Research study has been carried out based on chemical analysis and raw meal residue test data of the year 2016. It consist hourly records of chemical composition and the residue test results of the raw meal. These data were subjected to standard normal distribution analysis, Pearson coefficient of correlation analysis, time series analysis and scatter plot analysis.

III. RESULTS AND DISCUSSION

The results of distribution analysis, time series analysis and scatter plot analysis of the chemical constituent percentages, particle size distribution and No 212 sieve residue values of hourly recorded data of entire year 2016 are described briefly.

A. Standard Normal Distribution

Standard normal distribution analysis is performed for SiO_2, Al_2O_3, Fe_2O_3, CaO, LSF, SR, AR and No 212 sieve residue. The main reason for the analysis of normal distribution is to check the accuracy of the predicted population parameters, which are required in the following analysis methods.

The statistical parameters of the Silicon Dioxide, Aluminium Oxide, Ferric Oxide, Calcium Oxide, and quality parameters such as Lime Saturation Factor, Silicon Ratio and Alumina Ratio and residue test results of the No 212 sieve residue are summarized in Table 1, Table 2 and Table 3.

Table 1. Statistical parameters of variables

variable	μ(mean)	σ(S.D)*	-1<Z<1	-2<Z<2	-3<Z<3
SiO_2(%)	13.98	0.56	68.49	95.45	99.69
Al_2O_3(%)	1.57	0.17	70.79	95.67	99.32
Fe_2O_3(%)	2.15	0.29	72.57	95.94	98.90
CaO(%)	44.14	0.60	70.29	95.34	99.34
LSF(%)			67.92	95.52	99.69
SR(%)			69.37	95.34	99.52
AR(%)			68.62	95.59	99.34
No 212 sieve residue(%)	1.92	0.28	67.57	95.28	99.58

Table 2. Statistical parameters of quality ratios

variable	LSF	SR	AR
μ(mean)	99.4	2.57	1.58
σ(S.D)*	3.5	0.18	0.17

Table 3. Skewness values of variables

variable	Skewness(S_K)
SiO_2	0.09
Al_2O_3	0.61
Fe_2O_3	1.11
CaO	-0.45
LSF	-0.04
SR	-0.15
AR	0
No 212 sieve residue	0.13

***S.D = Standard Deviation**

The above Table 3 shows the skewness values of all variables are nearly equal to zero. This implies these chemical parameters follow the perfect standard normal distribution.

Furthermore, it shows there is no any significant variation of these chemical parameters in the raw meal over the

observed year of 2016, which ultimately gives smooth operation and constant value for the quality parameters.
The Lime Saturation Factor (LSF) is used for kiln feed control. Consequently, the larger variation of the LSF results in, makes it difficult to burn raw meal, tends to cause unsoundness of cement and causes slow setting with high early strength (Almeida, Rocha and Teixeira, 2004). But the results show there is no any significant variation in LSF over the observed time period and results show most of the data are lie on the company's threshold value range of LSF 96-106.

The large variation in Silicon Ratio and Alumina Ratio in the clinker can be an indication of poor uniformity in the kiln feed (Bye, 1983). These variation may result in harder to burning and high fuel consumption, deteriorate the kiln lining and tends to cause unsoundness of cement (Hassaan, 2001), (Shih, Chang and Chiang, 2003). Since the skewness values of the SR and AR are nearly zero, it has no fluctuations over the time period.

B. Time Series Analysis

The time series analysis results show the mathematical trend line relationship among No 212 sieve residue, chemical constituents and quality ratios such as LSF, SR and AR and particle size distribution of raw meal feed.

The relationship between CaO% of the raw meal data obtained and respective No 212 sieve residue is shown in the Figure 1. The overall relationship (solid line) shows there is a decrease in residue with the increase in the CaO%. It means grindability increases with the increase of CaO%.

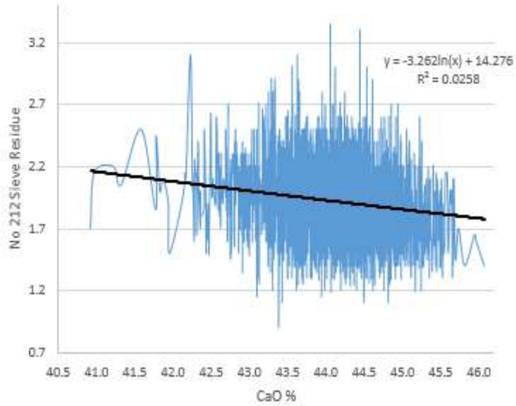

Figure 1. Graph of CaO% vs. No 212 sieve residue

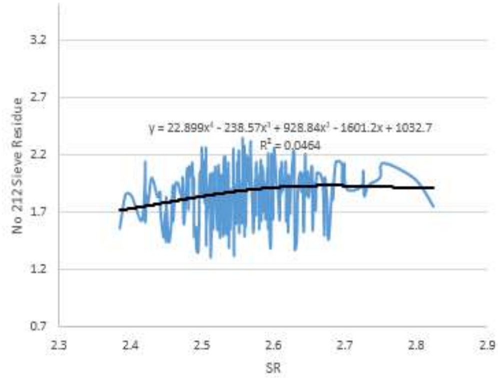

Figure 2. Graph of SR vs. No 212 sieve residue

The relationship between SR of the raw meal and respective No 212 sieve residue is shown in the Figure 2. The overall relationship (fourth order polynomial) shows there is an increase in residue with the increase in the SR. It means grindability reduces with the increase of SR.

The fourth order polynomial trend line between SiO_2% present in raw meal and No 212 sieve residue shown in the figure 3 has no any significant variation over the SiO_2% values.

The Al_2O_3% present in the raw meal and the respective No 212 sieve residue values show significant reduction of residue values in the higher Al_2O_3% content. The Figure 4 shows the fourth order polynomial relationship between Al_2O_3% and No 212 sieve reside values.

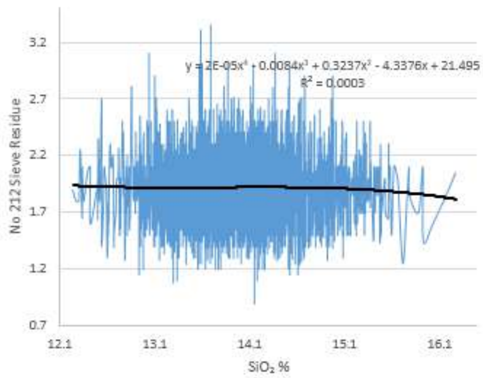

Figure 3. Graph of SiO_2% vs. No 212 sieve residue

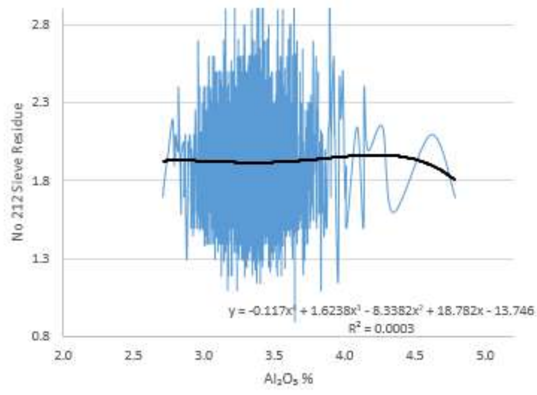

Figure 4. Graph of Al_2O_3% vs. No 212 sieve residue

C. Scatter Plot Analysis

Scatter plot analysis is performed for percentages of chemical constituents, particle size distribution (PSD) < 25mm, PSD > 25mm and No 212 Sieve Residue of the raw meal under different confidence interval such as 68%, 95% and 99%.

The 68%, 95% and 99% confidence interval value range of the variables are calculated based on (μ-σ, μ+σ), (μ-2σ, μ+2σ) and (μ-3σ, μ+3σ) values of the each variable respectively. Where μ is the mean and σ is the standard deviation of the variable. The Table 4 shows the confidence interval value range of the mentioned variables. According to above values, the selection of SiO_2%, Al_2O_3%, Fe_2O_3% and CaO% based on 68%, 95% and 99% confidence interval will result in a No 212 residue in between 1.7 - 2.2, 1.37 - 2.47 and 1.09 - 2.75, respectively.

Table 4. Confidence interval values of variables

	68% Confidence Interval		**95% Confidence Interval**		**99% Confidence Interval**	
Item (%)	μ-σ	μ+σ	μ-2σ	μ+2σ	μ-3σ	μ+3σ
CaO	43.55	44.74	42.95	45.34	42.35	45.93
SiO_2	13.42	14.54	12.86	15.1	12.3	15.66
Fe_2O_3	1.86	2.45	1.56	2.74	1.27	3.04
Al_2O_3	3.15	3.51	2.97	3.69	2.79	3.87
No 212 sieve residue	1.7	2.2	1.37	2.47	1.09	2.75

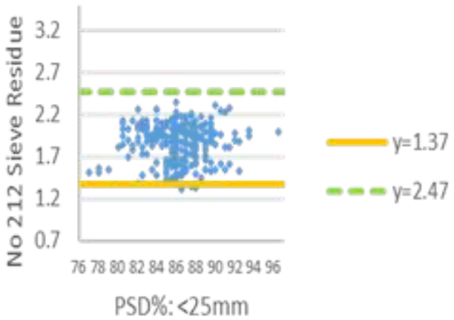

Figure 5. Graph of PSD% < 25 mm vs. No 212 sieve residue

The Figure 5 and Figure 6 show the scatter plots of PSD < 25 mm and PSD > 25 mm in the raw meal and respective No 212 sieve residue values. Graphs show all the values of PSD < 25mm and PSD > 25mm are result in residue in between 1.7 and 2.2. It implies there is no any significant effect from the particle size distribution to the raw meal grindability.

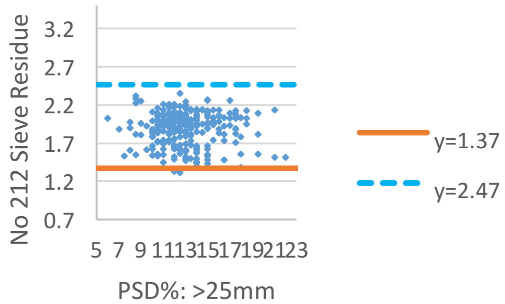

Figure 6. Graph of PSD% > 25 mm vs. No 212 sieve residue

IV. CONCLUSIONS

The conclusions based on the results of standard normal distribution analysis;

- Percentages of SiO_2, Al_2O_3, Fe_2O_3, CaO and LSF, AR and SR follow the standard normal distribution, perfectly. It means it gives unbiased estimation of statistical parameters of the population. Therefore the quality parameter such as LSF, AR and SR lie on the required quality target range upheld by the company.

The conclusions based on the results of the time series analysis;

- The mathematical relationship among the grindability and variables Silicon Oxide (SiO_2), Aluminium Oxide (Al_2O_3), Ferric Oxide (Fe_2O_3) Calcium Oxide (CaO), LSF and SR cannot be given in the form of polynomial, exponential or logarithmic manner. Since R^2 values do not equal to the unity.

The conclusions based on the results of the scatter plot analysis;

- The 68% confidence interval has the lowest value range for No 212 sieve residue (easy for grinding), but it comprised with the highest error.

- The 95% confidence interval has the middle value range for No 212 sieve residue (moderate for grinding) but it comprised with the lower error.

- The 99% confidence interval has the highest range for No 212 sieve residue (difficult for grinding) but it comprised with the lowest error.

- Since all the value ranges for particle size <25mm and >25mm are resulted in 68% confidence interval range, particle size does not show any significant impact on grindability.

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