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Assurance of Efficiency and Environmental Improvement in a Cement Plant by using Hypothesis (Special Reference to Cement Industry in Satna District, M.P)

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***Abstract:** Cement industries are continuously growing from the past few decades and are constantly trying to improve the efficiency and trying to reduce bad emissions. Major technological enhancements in systems, processes and equipment design of cement plants are helping to enhance the productivity as well as reducing the emissions. From the literature review, it was found that efforts in enhancing efficiency help in reducing harmful emissions and thus reduce the awful impact on the environment. More the investments in energy-efficient technologies more would be a contribution to protecting the environment. This paper tries to analyze the technological improvements in the cement industry, cost-saving methods without affecting productivity and its impact on the environment. We analyzed energy-saving methods statistically by framing hypothesis. Hypothesis testing was done by one way ANOVA (Analysis of Variance) method and results found that there is a significant impact of energy-saving on cost, efficiency, and environment. Our conclusion suggests that the industry should constantly work towards improvements and invest in energy-saving methods by which they would help in making the environment better. This will leads to the direct and indirect positive effect on health and workforce and it will also lead to the productivity of industry and progress of the country.*

***Index Terms**: Cement industry; Efficiency improvement; Environment impact; Energy saving methods; ANOVA analysis.*

I. INTRODUCTION

Indian cement industry is highly energy concentrated industry and also the 2nd largest manufacturer of cement in the world after China with a total established capacity of 502 Million Ton Per Annum (MTPA) as of 2018 which is expected to grow up to 550 MT by 2025 as per India Brand Equity Foundation (IBEF) [1]. It is also the third-largest consumer of coal in the country after the power and steel industry [2]. It needs both electrical and thermal energy for its operations.

Satna district, where the project is carried out lies on the limestone belts of the Indian state of Madhya Pradesh and thus adds around 8% to 9% of India's entire cement production [3]. Cement plants have various energy-intensive divisions such as quarrying raw materials, crushing raw material, grinding of raw material, dry mixing and blending, preheater, rotary kiln, clinker cooler, finish grinding, etc. Therefore various energy-efficient technologies are developing to minimize energy consumption and making the production more efficient, cost-effective and environment-friendly. It is a blessing that the improvements in increasing efficiency cause reductions in harmful emissions. Therefore we will use the above study in the context of the Cement Industries in Satna district of Madhya Pradesh, India and focus on quantifying the measures for the energy efficiency improvements.

To carry out the project we visited several plants in the region and find the technical efforts that industries are applying to improve their efficiencies by saving energy. As the industry is highly competitive, several methods to save energy have been taken as reference in this study from the collected data and figured out how much cost saving is done and this helped us in correlating the impact of improving efficiency on the environment. Based on the literature review the hypothesis was developed and tested by one way ANOVA (Analysis of Variance) method for hypothesis testing and the results were carried out.

II. ENERGY CONSUMPTION AND SAVINGS

A cement plant needs both Electrical as well as Thermal energy for its operation. Taking examples from a cement plant of 6000 TPD capacity, the energy consumption breakup is done. Thermal specific energy consumption is 3382 Kcal/KWh.

Electrical energy consumption (up to clinkerisation) is 29.24 KWh/Ton of clinker.

Electrical energy consumption (cement grinding) is 28-34 KWh/Ton of clinker.

The industry is constantly working on finding and developing various technical measures to reduce energy consumption. These days the cement grinding ball mill are getting replaced by Vertical roller mills (VRM's) as VRM's are much more efficient than the ball mills. But engineers are also trying to make improvements in the ball mills so that they can take the best out of it. Taking the example of changes made in a cement grinding ball mill the cost saving is explained.

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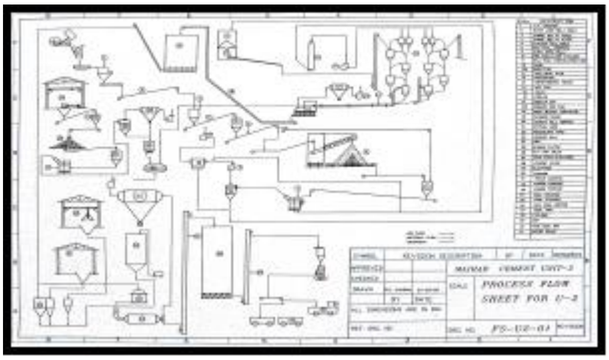

Figure 1. Process flow diagram of cement manufacturing process

A. Changes done in cement mill:-

1. Pregrinding
2. Hydraulic roller crusher
3. Grinding media optimization
4. Minimizing pressure drop
5. Idle running minimization
6. Mill internal water supply
7. Tripping material high temperature

Table 1. Energy consumption of Cement mill

	Previous running (KWh)	Now running Mill 1 (KWh)	Now running Mill 2 (KWh)
Mill main motor	2500	2300	2250
Separator fan	450	400	380
HRC	700	400	350
Auxiliaries	600	550	500
Total	**4250**	**3650**	**3480**

Energy consumption and changes due to the above implementations are shown below:-
As there were different mills for grinding Pozzolona Portland cement and Ordinary Portland cement, the energy consumption were carried out on basis of tons of material flow per hour.
Savings:
Mill 1 = 110 Ton of PPC per hour.
Total energy consumption previous = 4250 KWh,
Energy consumption per ton of Clinker = 4250/110=38.63. KWh
Total energy consumption after improvements = 3650KWh.
Energy consumption per ton of Clinker = 3650/110=33.18 KWh
Now if the running hour of the mill 1 of PPC is 24hrs then the total production of the day would be 110 X 24 = 2640 Tons.

The energy used earlier was 2640 X 38.63 = 100795.2. KWh
The energy consumption after improvements is 2640 X 33.18 = 87,595.2 KWh.

This gives difference of 13200 KWh saving of energy after the improvements. This energy saved when calculated with 6/- per unit would give us the saving of **Rs 79,200 /-** Per day. Similarly there are various measures have been taken to save energy and fuel. Such as:

B. Energy saving measures [6]:

i- Using low NO_x burners
ii- Replacement of cooler (grate cooler) gives a direct cost saving by reducing heat consumption by 5% around 37 to 38 Kcal. Means a saving of Rs 40-45 per ton of clinker.
iii- Grinding media optimization by enhancing the surface area of grinding balls.
iv- Reducing pressure drops in ducts by specific power consumption saves 2 units per ton of clinker.
v- Low pressure drop cyclone for suspension preheater.
vi- Monochamber mill converted into bichamber in cement mill.
vii- Use of VRM instead of ball mill for cement grinding.
viii- Controlling the running load. Maximum feed and maximum running hour for better efficiency.
ix- Replacement of cement mill vent fan with high efficiency fan.
x- Installation of variable frequency drive & replacement of coal mill bag dust collector's fan with high efficiency fan.
xi- Replacing a ball mill with vertical roller mill in finish grinding.
xii- High-Efficiency classifiers for finish grinding
xiii- Replacing a ball mill with vertical roller mill for coal grinding
xiv- Efficient (mechanical) transport system for raw materials preparation.
xv- Energy management & process control in grinding.
xvi- Adjustable speed drives.

C. Fuel saving measures [2]:

i. Blended cement (Additives: fly ash, pozzolans, limestone or/and blast furnace slag)
ii. Kiln shell heat loss reduction (Improved refractories)
iii. Use of Alternative Fuels
iv. Optimize heat recovery/upgrade clinker cooler.
v. Energy management and process control systems in clinker making.
vi. Upgrading of a Preheater kiln to a Preheater / Precalciner Kiln

All of these measures to reduce the energy consumption and fuel saving are very helpful in reducing carbon emissions too. According to the literature review, the amount of CO_2 emission reduction is quite equal to the electricity saved and the methods/measures to improve fuel efficiency and fuel saving plays a very significant role in reducing harmful emissions [2].

III. HYPOTHESIS DEVELOPMENT

According to the above observations it is observed that the changes made in process or system or equipments, brings a significant change/reduction in the power consumption. There are a lot of energy intensive divisions in a cement plant from quarrying to cement grinding and packing and this kind of changes throughout the plant causes significant savings. Therefore this analysis posits the Hypothesis about equipment/process change and energy saving.

IV. METHOD AND SAMPLE DATA

In cement plants, lots of measures have been taken to reduce emissions as well as dust,

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as the process involves transferring of raw material from one place to another by mechanical means. This material handling involves occurrence of stack emissions, which are regulated by the limits set by Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Government of India. The industry follows the limits of (Particulate Matter) PM 10 (Above 100 microgram Nm) and PM 2.5 (Above 60 microgram Nm). It also has the limits for Carbon emission i.e. 2000 microgram, oxides of Sulphur i.e. 100 microgram and oxides of Nitrogen i.e. 800 microgram. The sample data for the calculations were collected from the reverse air baghouse section of the plant which is dust colleting equipment. Recently, the fan motor of the RABH was changed from 1000rpm to 750rpm and it was working more efficiently and helped in energy saving. Therefore the readings of the power consumption were noted and calculated the difference between the energy consumption of both the motors.

Reverse air baghouse (RABH) is a system in which air is cleaned by bags made of various materials, which are cleaned timely to remove the collected dust. In an RABH, unclean air enters the collector and dust collects on the outside of the bags, which are supported by a metal cage to keep the air pressure from collapsing them. Steady air circulation constantly pulls air through the filter bags. For cleaning, a fan rotates over the bags, blowing reverse air into them to remove dust. Reverse air baghouse generates a lower pressure than the compressed air pulses of a pulse jet, which can decrease wear and tear on the bags and save on the cost of compressed air. They are usually very cost-efficient and if used within the parameters for which they were designed, they are very effective.

The analysis uses one way ANOVA method for testing of hypothesis. The sample data are collected from a Reverse air bag house (RABH) section of the cement plant.

Hypothesis (H_1): Energy consumption per ton of clinker production at 750 rpm speed of fan motor is less than that of 1000 rpm fan motor.

Null hypothesis (H_0): Energy consumption per ton of clinker production at 750 rpm speed of fan motor is equal to that of 1000 rpm speed of fan motor.

It is a factor response model which tests the hypothesis that the means of the two groups are equal. The one way analysis of variance is used to determine whether there are any significant differences between the means of these groups. It compares the means between the groups and determines whether any of those means are statistically significantly different from each other, it tests the null hypothesis.

$$H_0 = \mu_{X1} = \mu_{X2}$$; where, μ = group mean,

If, however, the one way ANOVA returns a statistically significant result, we accept the alternative hypothesis (H_1), which is that there are at least two groups which are statistically significantly different from each other. Here we have two groups and we need to see that if there any difference among the mean of these groups.

Alpha value to be set for the experiment i.e. $\alpha = \mathbf{0.05}$ also called as level of significance.

To begin the calculation we need to calculate the degree of freedom *(Df)*

$Df_{(Between)} = k\text{-}1 = 2 - 1 = 1$; where k is the number of conditions (Numerator)

$Df_{(Within)} = k\,(n\text{-}1) = 2(61\text{-}1) = 120$; where N is the total number of observations (Denominator)

$$Df_{(total)} = Df_{(Between)} + Df_{(Within)}$$

$$Df_{(total)} = 1 + 120 = 121$$

According to the frequency distribution curve the F critical value is 3.94 at (1, 121) at alpha level 0.05.

Calculation of sum of square deviations from the mean (SS):

$$Mean\ of\ Group\ \overline{X1} = \frac{sum\ of\ observation\ \sum X1}{Total\ number\ of\ observation\ (n)} = \frac{361.03}{61} = 5.92$$

$$Mean\ of\ Group\ \overline{X2} = \frac{sum\ of\ observation\ \sum X2}{Total\ number\ of\ observation\ (n)} = \frac{219.86}{61} = 3.60$$

$$\text{Grand mean } \overline{X} = \frac{sum\ of\ observation\ \sum \overline{X1} + \overline{X2}}{Total\ number\ of\ observation\ (n)} = \frac{5.92 + 3.60}{2} = 4.76$$

Now when we get the means of the two groups we can now calculate sum of square deviation

$$SS_{(total)} = \sum (X - \overline{X})^2 = 200.5993$$

$$SS_{(within)} = \sum (X1 - \overline{X1})^2 + (X2 - \overline{X2})^2 = 37.2481$$

$$SS_{(between)} = SS_{(total)} - SS_{(within)} = 163.3522$$

Now after getting the values for all the means, we have to calculate the sum of squares.

Calculate variance between and variance within

$$MS_{(between)} = \frac{SS(between)}{Df(between)} = \frac{163.3522}{1} = 163.3522$$

$$MS_{(within)} = \frac{SS(within)}{Df(within)} = \frac{37.2481}{120} = 0.3104$$

Calculation of F statistics.

$$F = \frac{MS(between)}{MS(within)} = \frac{163.3522}{0.3104} = 526.2635$$

Then we will compare the calculated F value with the tabulated F value. If the calculated F value is less than tabulated F value, accept the Null hypothesis. And if the calculated F value is more than the tabulated F value, we reject the Null hypothesis and accept the alternate hypothesis.

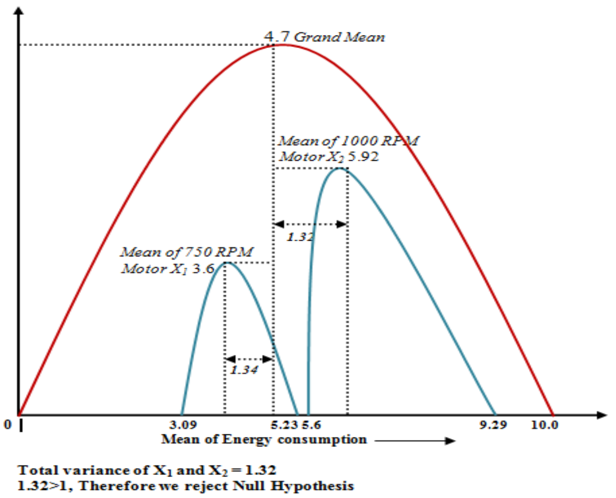

Figure 3. Graphical representation of Means of X1 and X2

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Table 2. Comparison of energy consumption between two different types of motors

COMPARISON OF ENERGY CONSUMPTION OF 750 RPM MOTOR WITH 1000 RPM MOTOR		
DAYS	**With 1000 RPM Motor**	**With 750 RPM Motor**
Days	**KWh/Ton of Clinker (X1)**	**KWh/Ton of Clinker (X2)**
Day 1	7.33	4.09
Day 2	9.29	5.23
Day 3	6.6	3.8
Day 4	5.66	3.47
Day 5	5.66	3.45
Day 6	5.66	3.32
Day 7	5.9	3.4
Day 8	5.66	3.5
Day 9	5.66	3.78
Day 10	7.33	4.41
Day 11	7.33	4.61
Day 12	7.33	3.91
Day 13	6.6	3.98
Day 14	7.33	4.22
Day 15	5.66	3.33
Day 16	5.66	3.36
Day 17	5.66	3.36
Day 18	5.66	3.36
Day 19	5.66	3.44
Day 20	5.66	3.42
Day 21	5.66	3.29
Day 22	5.66	3.52
Day 23	5.66	4.43
Day 24	5.66	3.43
Day 25	5.66	3.43
Day 26	5.66	3.37
Day 27	5.66	3.37
Day 28	5.66	3.7
Day 29	5.66	3.74
Day 30	5.66	3.71
Day 31	5.66	3.71
Day 32	5.66	3.5
Day 33	5.66	3.69
Day 34	5.66	3.82
Day 35	5.66	3.51
Day 36	5.66	3.56
Day 37	5.66	3.23
Day 38	5.66	3.09
Day 39	5.66	3.56
Day 40	5.66	3.23
Day 41	5.66	3.96
Day 42	7.33	4.34
Day 43	5.66	3.24
Day 44	5.66	3.72
Day 45	5.66	3.23
Day 46	5.66	3.09
Day 47	5.66	3.63
Day 48	5.66	3.2
Day 49	5.66	3.48
Day 50	5.66	3.7
Day 51	5.66	3.57
Day 52	5.66	2.96
Day 53	5.66	3.65
Day 54	5.66	3.3
Day 55	5.66	3.23
Day 56	5.66	3.22
Day 57	5.66	3.62
Day 58	5.66	3.66
Day 59	5.66	3.71
Day 60	5.66	3.57
Day 61	5.66	3.45

Table 3. Observations of One way ANOVA

Anova: Single Factor SUMMARY						
Groups	**Count**	**Sum**	**Average**	**Variance**		
KWh/Ton of Clinker (X1)	61	361.03	5.92	0.46		
KWh/Ton of Clinker (X2)	61	219.86	3.6	0.16		
ANOVA						
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**	**F critical**
Between Groups	163.3522041	1	163.35	526.28	0	3.92
Within Groups	37.2468590 2	120	0.31			
Total	200.5990631	121				

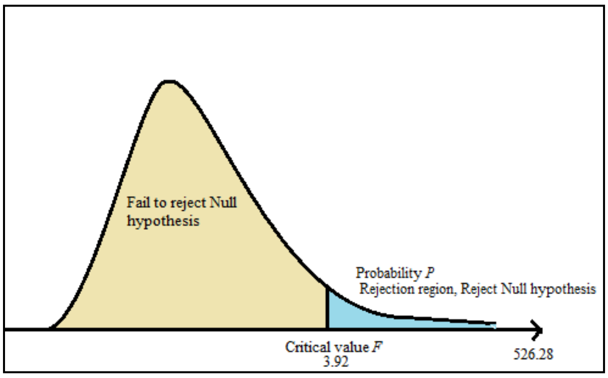

Figure 2. F Distribution graph

V. RESULT

The calculated F value i.e. 526.28 is found to be higher than the tabulated F value i.e. 3.92. Hence we reject the Null hypothesis and accept the alternate hypothesis. This means there is a significant difference between the energy consumption of two different motors. It was found that the improvements in the energy efficiency cause a significant saving and a positive impact on the environment. The analysis shows that the even a small change could make a significant savings without affecting the productivity.

VI. CONCLUSION

1. As per the ANOVA analysis the null hypothesis is rejected at 5% confidence level and it has been established beyond doubt that the energy consumption is distinctly less for the change in speed of RABH fan motor.
2. The saving in energy indirectly reflects low production of CO_2 in the environment.
3. The small step improvements throughout the plant can help in significant energy saving and gives a positive impact on environment.

REFERENCES

1. IBEF, 2019, Indian cement industry analysis 2019 Available at https/www.ibef.orgindustrycement-presentation

2. Morrow, W. R., Hasanbeigi, A., Sathaye, J., & Xu, T. "Assessment of energy efficiency improvement and CO2 emission reduction potentials in India's cement and iron & steel industries." Journal of Cleaner Production, 65, 131–141. doi:10.1016/j.jclepro.2013.07.022, 2014
3. GOI, Ministry of MSME, Brief Industrial Profile of Satna District Madhya pradesh. Available at http://dcmsme.gov.in/dips/District Industrial Profile Satna.pdf
4. GOI,2009, Technical EIA Guidance manual for cement industry, Ministry of environment and forest, Government of India, Available at http://www.indiaenvironmentportal.org.in/files/Cement.pdf
5. S.P. Deolalkar. Designing Green Cement Plants (book) Available at https://www.sciencedirect.com/book/9780128034200/designing-green -cement-plants
6. Madlool, N. A., Saidur, R., Rahim, N. A., & Kamalisarvestani, M. "An overview of energy savings measures for cement industries." Renewable and Sustainable Energy Reviews, 19, 18–29. doi:10.1016/j.rser.2012.10.046, 2013
7. Zhang, S., Ren, H., Zhou, W., Yu, Y., & Chen, C. "Assessing air pollution abatement co-benefits of energy efficiency improvement in cement industry: A city level analysis." Journal of Cleaner Production, 185, 761–771. doi:10.1016/j.jclepro.2018.02.293, 2018
8. Altun, O. "Energy and cement quality optimization of a cement grinding circuit." Advanced Powder Technology, 29(7), 1713–1723. doi:10.1016/j.apt.2018.04.006, 2018
9. Zhang, S., Worrell, E., & Crijns-Graus, W. "Cutting air Pollution by Improving Energy Efficiency of China's Cement Industry." Energy Procedia, 83, 10–20. doi:10.1016/j.egypro.2015.12.191, 2015
10. Ing. Miroslav Stajanča, doc. RNDr. Adriana Eštokova, PhD, "Environmental Impacts of Cement Production." http://ena.lp.edu.ua/bitstream/ntb/16692/1/55-Stajanca-296-302.pdf
11. Impact of cement industry on environment, Available at https://www.researchgate.net/publication/323029097 Impacts of Cement Industry on Environment - An Overview

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