A Performance Study of some Low Capacity Mixed-Feed Lime Kilns with Special Reference to Conical Kilns

by

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ABSTRACT

The low capacity cylindrical shaft and conical kilns producing less than 5 tonnes per day lime were extensively surveyed and some performance studies were carried out on two typical cinder-fired conical lime kilns. The study revealed that there were significant variations in the design and performance of these kilns. The existing methods of operation are quite inefficient and heat wasteful, resulting in low productivities and high thermal losses. A cylindrical kiln on an average has been found to be 30-40% cheaper than a conical kiln. The authors further conclude that a comparative study of these two types of kilns should be carried out under similar operating conditions to determine the superiority of one type over the other in respect of productivity, product quality and fuel consumption as obtained in these two designs.

INTRODUCTION

The production of building lime in India is largely governed by the small scale and cottage industries employing lime kilns of several designs, namely the country batch kilns and the semi-continuous type of cylindrical shaft and conical lime kilns.[3, 6-9] The design details and performance characteristics of kilns producing less than 5 tonnes per day lime, particularly in respect of mixed-feed conical kilns, are not available in the literature.[1-3, 6-9] The present study was, therefore, taken up in order to (i) collect the salient design data, (ii) study existing operational practices, (iii) estimate the thermal performance etc., so as to explore methods for improvement in the design and performance of these low cost kilns. Apart from the conventional cylindrical shaft kilns, conical type mixed feed kilns also find extensive applications in other developing countries such as Sri Lanka, where Fernando and Yoganandan[4] have described the production of building lime employing kilns of similar design.

The internal diameter of the conical kiln tapers downwards with consequent increase in wall thickness from top to bottom, contrary to he cylindrical shaft kiln wherein uniform inner diameters and consistent wall thicknesses are provided. A mixed-feed of limestone and fuel in appropriate proportion is charged into the kiln at the top. Both types of kiln operate continuously in three zones, namely, the preheating, the burning and the cooling zones. The product lime along with associated impurities is withdrawn from the bottom of the kiln through the discharge gates.

PRELIMINARY SURVEY

The low capacity lime kilns in the Meerut-Modinagar-Ghaziabad region of Uttar Pradesh were extensively surveyed. It was observed that, by and large, these kilns were constructed in low grade brick masonry. No fire bricks or any other high temperature abrasion resistant material linings were provided in the interior shell of the kiln. The data collected are reported in **Table 1.**. The kilns were normally cinder-fired with limestone and fuel charged in alternate layers. Mixed sizes of limestone, 15-150 mm, and cinder, 5-25 mm, were used in the burning process. Lime was usually discharged once a day in the early hours of the morning with fire zone at the top and kilns were charged thereafter. Significant differences in the designs and operations of these mixed feed kilns, as indicated by the survey, necessitated a study on the performance of such kilns in some detail.

EXPERIMENTAL

The performance of the running mixed-feed conical lime kilns was investigated under the normally existing conditions of operation. The general specifications of the two kilns selected for this study in the Ghaziabad region are given in **Table 2.** Limestone particles of size 15-150 mm and cinders of size 5-25 mm were burnt in the kilns. The chemical analyses of limestone samples and the proximate analyses of cinders are reported in **Tables 3** and **4** respectively.

Flue gas samples were withdrawn at different time intervals from just above the calcination zone by means of a rubber bladder type gas sampler and the same were analysed with the help of Orsat's apparatus. The representative time-averaged gas samples collected from the two kilns are reported in **Table 5.** Temperature measurements were carried out at different time intervals and height levels to locate the preheating, calcining and cooling zones and thus to estimate the retention times in the three zones. A stainless steel sheath type chromel-alumel thermocouple along with the indicating pyrometer were used for the measurement of temperature. The average temperatures of the outgoing gases and the product lime samples were also measured.

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TABLE 1

INITIAL DATA ON MIXED-FEED LIME KILNS

Sl. No.	Av. Output Lime (tpd)	Height (m)	Inner Dia. Top (m)	Inner Dia. Bottom (m)	Wall Thickness Top (m)	Wall Thickness Bottom (m)	Inner Wall Inclination with Horizontal (degrees)	Av. Stone to Fuel Ratio (W/W)	Remarks
1.	1.5	2.80	3.14	1.12	0.82	1.83	64	3.0	Cinder-fired conical kilns at Ghaziabad
2.	3.0	4.10	3.20	1.00	1.10	2.20	75	2.5	
3.	2.0	4.20	2.80	1.20	1.10	1.90	78	2.5	
4.	1.0	3.07	2.70	1.00	1.05	1.80	74	3.0	
5.	2.0	3.66	3.66	0.82	1.20	2.10	69	2.0	Cinder-fired conical kiln at Modinagar
6.	1.0	3.04	3.04	0.75	1.20	2.10	70	2.0	
7.	1.5	4.57	2.74	0.82	1.10	2.20	80	3.0	Cinder-fired conical kiln at Meerut
8.	1.0	3.60	1.35	1.35	1.00	1.00	90	2.0	Cinder-fired cylindrical kilns at Meerut
9.	1.2	2.90	1.62	1.62	1.70	1.70	90	2.0	
10.	1.8	2.95	2.22	2.20	1.50	1.50	90	2.0	
11.	3.0	3.05	3.00	0.80	0.95	2.05	70	5.0	Steam coal-fired conical kilns at Meerut
12.	5.0	3.75	3.00	0.80	2.00	3.10	74	5.0	

TABLE 2

GENERAL SPECIFICATIONS OF THE KILNS INVESTIGATED

Kiln No.			Height (m)	Inner dia Top (m)	Inner dia Bottom (m)	Wall thickness Top (m)	Wall thickness Bottom (m)	Inclination inner wall with horizontal (degrees)	Average Capacity (tpd)
1	...	...	3.05	2.67	1.0	0.36	1.83	75.0	1.0
2.	...	...	4.17	3.15	0.93	0.46	2.20	75.2	2.0

TABLE 3

CHEMICAL ANALYSIS OF LIMESTONE SAMPLES

S. No.	Constituents	Weight Percent Kiln No. 1	Weight Percent Kiln No. 2
1.	L.O.I.	39.29	42.40
2.	SiO_2	11.15	1.45
3.	R_2O_3	1.58	0.65
4.	CaO	42.54	53.40
5.	MgO	5.11	1.20
6.	Tr	0.33	0.90

TABLE 4

PROXIMATE ANALYSIS OF CINDERS

Kiln No	Fixed Carbon (W/W%)	Ash Content (W/W%)	Average Calorific Value K.Cal/Kg
1.	38.0	62.0	3,115
2.	29.5	70.5	2,420

TABLE 5

REPRESENTATIVE TIME AVERAGED ANALYSIS OF GAS SAMPLES

S. No.	Constituent	Percent by Volume Kiln No. 1	Percent by Volume Kiln No' 2
1.	CO_2	25.3	22.9
2.	O_2	3.9	5.9
3.	CO	1.6	2.3
4.	N_2	69.2	68.9

TABLE 6

DATA ON PRODUCT QUALITY OF CINDER FIRED LIME KILNS

Kiln No.	Average Production (P) tpd	Stone: Fuel by weight (X_R)	Product Distribution (% W/W) Lump Lime	Kiln Dust Lime+Ash	Underburnt Stone	Overburnt Lime	Unburnt Fuel
1. ...	1.0	2.5	39.5	52.6	6.6	0.7	0.6
2.	2.0	2.0	39.6	50.2	8.5	0.6	0.7

TABLE 7
PERFORMANCE RESULTS FOR THE CINDER-FIRED CONICAL LIME KILNS

Kiln No.	L/D Ratio	P_s (t/m²/d)	P_v (t/m³/d)	R_t (hrs.)	E_s (Kcal/kg lime)	F_s (t cinder)/t lime
1.	1.43	0.28	0.09	90	2,500	0.8
2.	1.95	0.55	0.13	80	2,420	1.0

The stone to fuel ratio in the feed, and production of the lime kiln were determined over a period of about three to four days and the average values were computed. The total output from the kiln was carefully sampled and the unburnt stone, over-burnt lime, powdered contaminated lime, lump lime, and unburnt fuel pieces were picked up separately and weighed to assess the product distribution. The data collected from the two kilns are as reported in **Table 6.**

RESULTS AND DISCUSSION

Productivity :

The initial four columns of **Tablo 7** represent the relevant productivity data obtained for the two conical kilns, where L/D is the height to diameter ratio; D is the diameter representing average inner cross-section of the kiln; P_s is the average daily output based on per unit cross-sectional area of the lime kiln (t/m²/d); P_v is the output based on kiln volume (t/m³/d) and R_t represents the average kiln retention time in hours. It is seen that kiln No. 1 yielded lower sectional and volumetric outputs than those obtained from kiln No. 2. This is on account of (i) the higher retention time (R_t) of about 90 hours imposed in kiln No. 1 compared to that in kiln No. 2 of about 80 hours, (ii) operational lapses and (iii) the design of the kiln in respect of the geometrical height to average diameter ratio. The greater height of kiln No. 2 resulted in increased draft over kiln No. 1. Thus it is inferred that the maximum attainable output from a kiln can be obtained by an experienced burner by regulating the retention times to an optimum lower limit, i.e., by operating the kilns in as continuous a manner as feasible.

Product Quality:

The data on the average quality of the product obtained from the two kilns are reproduced in **Table 6.** It is observed that the product is highly contaminated by as much as about 50 per cent of kiln dust consisting of powdered lime and fuel ash which is basically attributable to the high amount of ash content in the cinder **(Table 4).** On the whole it may be concluded that, depending upon the type of fuel used, the distribution of product from a conical kiln is quite satisfactory as the variations were found to be insignificant.

Thermal Performance :

The thermal performance of the conical lime kilns has also been elucidated in **Table 7,** where E_s is the specific energy consumption in terms of kcals per kg of lime and F_s represents the fuel consumption in tonnes per tonne of lime produced. The average E_s and F_s values were computed to be of the order of 2,450 kcals/kg and 0.9 tonnes of fuel per tonne of lime, respectively, which denotes a gross average thermal efficiency of 47 per cent. The thermal losses are accounted for by the cumulative effect of several operational interactions.

Firstly, the traditional method of kiln operation with a once-a-day charging and discharging schedule made an allowance for the fire zone to reach to the top of kiln surface during the early hours of the morning, usually from midnight onwards, thereby resulting in tremendous heat losses by way of radiations and transmission of high sensible heat through the flue gases. The temperature of the flue gases was observed to rise, with the upward movement of the fire zone, to as much as 700°C in the early hours of the morning. This significant amount of loss of heat could otherwise have been utilised in the preheating of fresh limestone, had the kiln been discharged and charged at frequent intervals. This conclusion is corroborated by some workers,[3, 5-7, 8] in so far as the general operation of a lime kiln is concerned. The temperature of the withdrawn lime going to as much as 400°C for the latter half of the product also accounted for the loss of sensible heat, which could otherwise have been utilised in the preheating of incoming air. Another significant loss of heat was by way of incomplete combustion of fuel resulting in high percentage of CO in the flue gases **(Table 5).** According to an estimate the presence of one per cent CO in the exhaust gases is tantamount to a loss of about 55-65 kcals per kg of lime.

COST ESTIMATES

The average initial installed costs for the cinder-fired conical lime kilns for nominal production capacities in the range of 0.5-3.0 tonnes per day of lime were estimated for the local market conditions and the same were compared with those of the conventional cylindrical shaft kilns for similar nominal productions. It has been conclusively brought out that for a given capacity of production a cylindrical shaft kiln is about 30-40 per cent cheaper than the conical lime kiln. Thus, costwise, conventional cylindrical lime shaft kilns can be designed and constructed economically compared to conical lime kilns when employing similar materials of construction for the two designs.

CONCLUSIONS

The performance of the kilns in respect of obtainable productivities can be enhanced by lowering the kiln retention times to an optimum value, determined by experienced burners under the local operating conditions, i.e. by incorporating frequent charging and discharging schedules at regular intervals of time contrary to the existing once-a-day practice of charging the raw materials and withdrawal of product lime. The quality of the produce obtained from cinder-fired kilns is, however, satisfactory notwithstanding the ash content of fuel. The fuel can be saved, and thus the energy conserved, by proper operation of the kiln in three distinct zones rather than allowing the fire zone to travel to the top of the kiln with virtual elimination of the preheating zone. The conventional cylindrical shaft kilns are about 30-40 per cent cheaper than conical lime kilns. However, it is considered imperative that a comparative study of the two designs, under similar operating conditions, be undertaken with a view to establishing the supremacy of one design over the other also in respect of productivity, product quality, and thermal performance. Thus the work on the design and performance of mixed-feed cylindrical shaft and conical lime kilns has been undertaken at the Central Building Research Institute, Roorkee.

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