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RESEARCH ARTICLE

The Effect of Temperature on Ergonomic Efficiency of Workers in Traditional and Flyash Brick Kilns in Bagru, Jaipur District (Rajasthan)

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Abstract

Brick kiln workers that manufactured millions of bricks that build construction industry of every country. This study investigates how temperature affects the ergonomic efficiency of workers in conventional and fly ash brick kilns in Jaipur district, Rajasthan, India. It compares environmental conditions, working conditions, productivity, and health outcomes between the two kiln types. The research uses temperature measurements and subjective worker's comfort. Data collected via questionnaires from 50 workers (30 from conventional kilns and 20 from fly ash kilns), over one year (six-six months each year) in 2024-2025. The study finds both kiln types experience reduced production efficiency as temperature rise, especially during hot months (April to June), demonstrating an inverse relationship between temperature and workers productivity.

Although fly ash kilns have relatively better design features. The negative impact of heat on efficiency is evident in both kiln types. Demographic factors such as age and height showed no statistically significant correlation with production efficiency. When adjusting for the number of workers efficiency differences between kiln types becomes negligible, indicating that temperature alone does not significantly differentiate ergonomic efficiency between them. The study highlights the challenges posed by extreme heat on brick kiln workers health and productivity and suggests the need for practical ergonomic interventions to improve labor welfare in these environments. It also identifies scope for future research to further explore these relationships.

Keywords: Efficiency, Ergonomics, Flyash brick kiln, Traditional brick kiln, Worker's comfort, Worker's health.

Introduction

The brick manufacturing industry is integral to India's construction sector, especially in rapidly urbanizing areas, such as Rajasthan. If we talk about brick industry production then, the brick industry in the India is the second largest brick producer in the world, after China (Qutubuddin et M., et. al., 2013). The Rajasthan Jaipur district, known for its architectural heritage and expanding infrastructure, hosts numerous brick kilns, both traditional and modern fly ash-based units. These kilns are labour-intensive and rely heavily on manual work for molding, stacking, and transporting bricks. Despite their economic significance, the working conditions in traditional kilns, rather than fly ash, remain harsh, especially due to extreme heat exposure. Therefore, the postures adopted by workers in their workplace depend on the type of work, design of the workplace, personal characteristics, tools required to perform particular work, and duration and frequency of the work cycle (Bridger, R. S. 1995) and also brick manufacturing units suffer musculoskeletal problems (Chung, M. K. et. al., 2000) thus, it is more important. Environmental ergonomics is a scientific discipline that investigates the effects of environmental factors on human well-being, performance, and health (Hedge et al., 2000). It examines the interaction between individuals and their surroundings from an ergonomic perspective and is an essential tool in the design of workshop buildings (Dianat et al., 2016). Brick manufacturing can cause work-related injuries (Joshi et al., 2013). This can be reduced by searching for best practices to close these gaps (Redinger C. 2019) and preventive and corrective action and continual improvement (Machida, S., et. al., 2001).

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Figure 1: Area of research study (Source: Google Map)

The climate of Rajasthan is semi-arid, with summer temperatures often exceeding 45°C, which poses a serious challenge to the health and productivity of kiln workers. The combination of high ambient temperatures and radiant heat from kiln furnaces creates a microenvironment with intense thermal stress. Workers, often from marginalized communities, perform physically demanding tasks under these conditions, leading to fatigue, dehydration, and musculoskeletal injuries. These factors collectively reduce the ergonomic efficiency. Ergonomic efficiency is defined as the ability to perform tasks safely, comfortably, and productively.

In the workplace, the ongoing and fluctuating relationship between individuals and their surroundings may result in physiological stress, which may negatively impact comfort, efficiency, productivity, safety, and overall well-being (Parsons et al., 2000), as well as atmospheric emissions (Akinshipe et al., O.B. 2017). To guarantee accuracy in evaluating the ergonomic conditions of each workspace, it is crucial to consider both objective data, such as physical measurements of variables such as temperature, and subjective assessments, which consider factors such as comfort, satisfaction, perceived job performance, and health and safety implications (Dianat et al., 2013). Inadequate management of environmental factors and poorly designed working environments can significantly impact health, well-being, and overall performance (Skilling et al., 2017).

Traditional brick kilns, which are typically open and unmechanized, expose workers to higher levels of heat and physical strain than fly ash kilns, which are relatively modern and offer better design features, such as improved ventilation and mechanized handling. However, even flyash kilns are not immune to the challenges posed by high temperatures, particularly during the peak summer months.

This study aimed to investigate the impact of temperature on the ergonomic efficiency of workers in traditional and flyash brick kilns in the Jaipur district. By comparing environmental conditions, working conditions, productivity efficiency, and health outcomes across kiln types, this study seeks to identify key stressors and recommend practical interventions. The findings will contribute to a deeper understanding of occupational ergonomics in extreme climates and support policy efforts to improve labor welfare in the brick industry. This comparative study evaluated the key differences in the effect of temperature on workers' efficiency.

Methodology

Profile of Study area

A comparative study was conducted on workers in two different types of brick kilns. The study workers were selected from conventional and fly ash brick kilns in different locations. The total sample size of the study was 50 workers, of which 30 workers from a conventional brick kiln in Rohini village near Jaipur and 20 from a fly ash brick kiln near Kalwar, Jaipur was included. The study was conducted in January, February, March, April, May, and June of the year 2024-2025.

Geographically, the Jaipur district is located at $26^0 23'$ and $27^0 51'$ north latitudes and at $74^0 55'$ and $76^0 50'$ east longitudes. More specifically, the study was conducted in the surrounding regions of Bagru in the Jaipur district. According to the classification by the Department of Agriculture, Government of Rajasthan, the Research study was carried out in the semi-arid Eastern Plains Agro-climatic zone of Jaipur district, Rajasthan state, India. Figure 1 showing area of study.

Data collection

The current study used a cross-sectional comparison to determine the relationship between temperature conditions and worker comfort during working hours among flyash and conventional brick kiln workers. This study examined the impact of temperature on worker comfort and performed ergonomic evaluations. A questionnaire was used to obtain information from the workers and measure their comfort levels. A total of 50 workers were selected from both sides, 30 from conventional brick kilns and 20 from fly ash brick kilns..

Every year, the period of brick manufacturing is best suited in January, February, March, April, and May, but in 2024, the weather was very hot and dry in June. Therefore, the collection of data and major work carried out during the months of January, February, March, April, May, and June in 2024 and 2025.To determine the frequency of a specific phenomenon, a modified Nordic questionnaire (Kuorinka et. al., 1987) was employed, and environmental ergonomic conditions, such as temperature, were assessed using physical measurements (1WEATHER and HuaFeng AccuWeather) and the other factor like height and age also collected from workers during interaction. The tools utilized for this purpose were mostly digital and compatible with both Android and Windows PCs. A thermometer was used to measure the temperature.

Questionnaire Generation

According to the standard Nordic questionnaire (Kuorinka et. al., 1987), this research study questionnaire was formed. In this study, we included a total of 50 workers from both conventional and fly ash brick kilns. In which 30 from conventional kilns and 20 from flyash brick kilns. In the final questionnaire, two parts were chosen. The first part included common questions asked of workers, such as their sex, height, weight, age, and education level. The second part discussed the jobs of workers and the problems arising from them, such as duty time, how much rest is given between duties, and how much work-related pain the workers experience in their bodies. Since the workers were uneducated, a verbal interview was conducted in the local language (Rajasthani and Hindi), and their responses were noted. The activity was observed using both direct and indirect methods, and this type of analysis has been established in a few studies (Maiti, 2008; Winkel and Mathiassen, 1994).

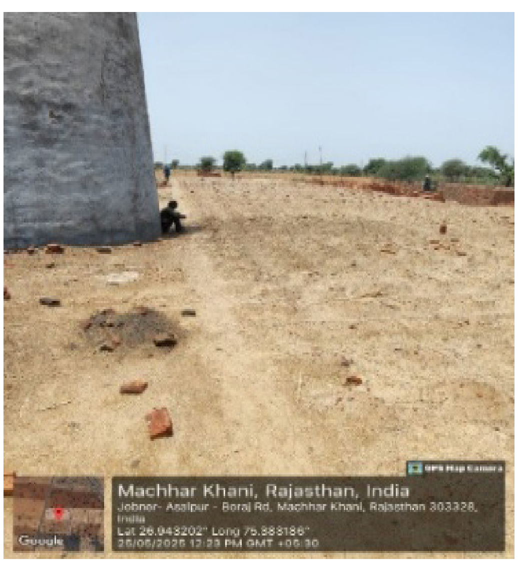


Figure 2: Area of conventional brick kiln

Figure 3: Moulding (Bharai) Process

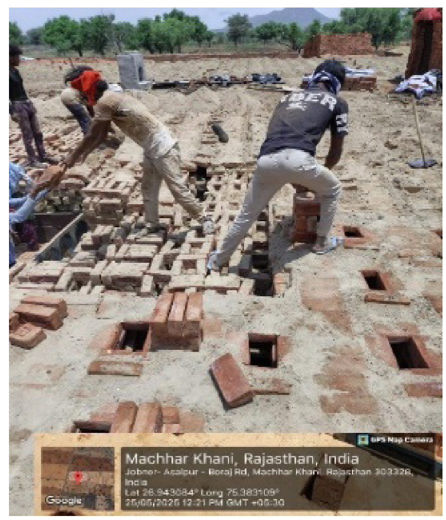


Figure 4: Process of Sorting (Nikashi) after Firing

Figure 5: Conventional bricks (Red bricks)

Figure 6: Area of fly ash brick kiln

Figure 7: Curing chamber

Data Analysis

Data analysis, including descriptive statistics and graphs, was performed using Microsoft Excel 2021 MSO version 2505 64 bit, IBM SPSS statistics software, and Origin 2018 software. All of this software was used to obtain the frequency, percentage, standard deviation, and mean value (average) of the statistical data on environmental ergonomics and worker comfort. This software was also used to determine the normality of the data for hypothesis testing and to compare the means of data analysed using the t-test, which is a parametric data analysis method.

The study between the fly ash brick kiln and traditional brick kiln workers shows a significant relationship, such as the data from Table 1, which is necessary to study the potential relationships between the demographics and productivity of the fly ash brick workers, in which the average height is 67 inches, the value of standard deviation is approximately 4.97, and the average age is approximately 29.69 years, with a standard deviation of approximately 9.31 years. Along with this, the average number of bricks produced per day is 1027.5, and the standard deviation is approximately 472.62, which is further explained by Graph 1.

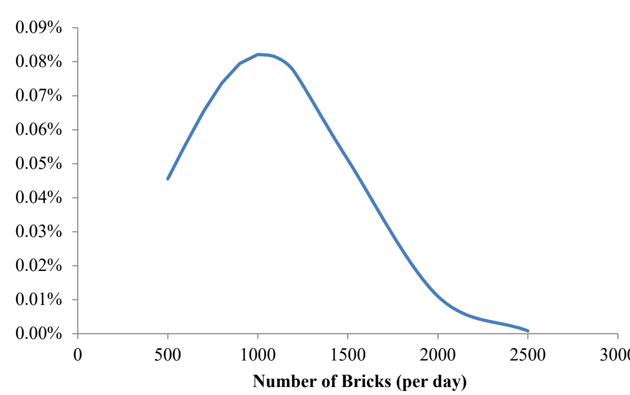
Table 1 represents fly ash brick kiln workers, and the data from this table are necessary to align the possible relationships between the demographics and productivity of the workers, as explained by Graph 1.

Graph 1 shows the frequency and distribution of fly ash brick production. The graph shows a bell-shaped distribution that resembles a normal distribution. The most common production range is approximately 1500 to 2000 bricks per day because the curve is highest around this range (approximately 0.08% frequency). The probability of producing a very low number of bricks (like 0-500) and a very high number of bricks (like 2500-3000) is low because the curve is low at both extremes. The data presented in Graph 1 indicate that the average is approximately 1750 bricks per day, and on most days, production close to this average is performed by the workers.

Likewise, flyash brick kiln workers, traditional brick kiln study take 30 workers from the kiln and Table 2 represents traditional brick kiln workers data that make a potential relationship between the demographics and productivity of workers, in which the average height is 66.2 inches, the standard deviation is around 4.76 and the average age is approximately 26.4 years, the deviation is around 9.08 years. Along with this, the average number of bricks produced per day is approximately 888.67, and the standard deviation is around 433.73. This is further explained in Graph 2.

Table 2 represents traditional brick kiln workers, and the data from this table are necessary to align the possible relationships between the demographics and productivity of the workers, as explained by Graph 2.

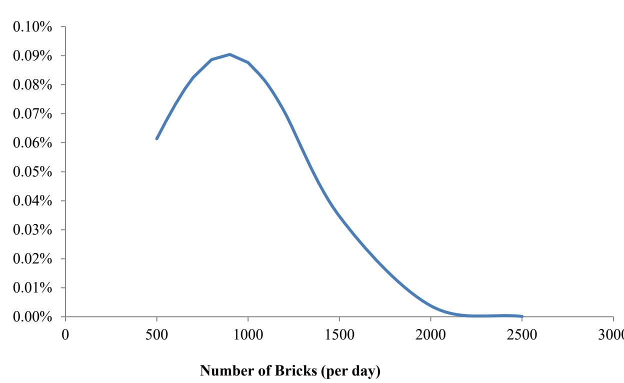
Graph 2 explains the frequency and distribution of traditional brick production. The graph shows an asymmetrical bell-shaped distribution. The most common



Graph 1: Frequency and distribution of fly ash brick production

Table 1: Relationships between the demographics and productivity of the fly ash brick kiln workers

Flyash Brick kiln workers			
S. No.	*Height (Inches)*	*Age*	*Number of Bricks (per day)*
1	64.8	40	500
2	63.6	26	550
3	58.8	21	600
4	57.8	24	700
5	61.2	26	700
6	63.6	30	800
7	62.4	28	800
8	73.2	30	800
9	69.8	35	900
10	70.8	25	900
11	69.8	29	1000
12	72	33	1000
13	73.2	30	1000
14	74.4	32	1000
15	66	40	1000
16	69.8	24	1100
17	61.2	22	1200
18	70.8	26	1500
19	70.8	21	2000
20	66	27	2500
Avg.	67	29.69	1027.5
Std. Dev.	4.968702044	9.306229097	472.6190326



Graph 2: Frequency and distribution of traditional brick production

production range is approximately 700 to 1200 bricks per day because the curve is highest around this range (approx. 0.075 %). The probability of brick production per day is very low at both extremes (like 0-500 and 2000-3000). The data represented in Graph 2 indicate that the average is around 950 bricks per day, and most days, production close to this average is done by the workers of traditional brick kilns, which is minimal compared to fly ash brick kiln production.

Table 2: Relationships between the demographics and productivity of the traditional brick kiln workers.

Traditional Brick kiln workers			
S. No.	*Height (Inches)*	*Age*	*Number of Bricks (per day)*
1	64.8	35	500
2	63.6	26	550
3	70.6	27	550
4	67	19	550
5	58.8	21	600
6	68.3	22	600
7	65.4	20	600
8	59.8	16	600
9	59	18	600
10	63.4	20	600
11	60.1	18	650
12	64.4	17	660
13	57.8	24	700
14	61.2	26	700
15	68	21	700
16	63.6	30	800
17	62.4	28	800
18	73.2	30	800
19	69.8	35	900
20	70.8	25	900
21	69.8	29	1000
22	72	33	1000
23	73.2	30	1000
24	74.4	32	1000
25	66	40	1000
26	69.8	24	1100
27	61.2	22	1200
28	70.8	26	1500
29	70.8	21	2000
30	66	27	2500
Average	66.2	26.39333333	888.6666667
Std. Dev.	4.746718165	9.077074908	433.7336612

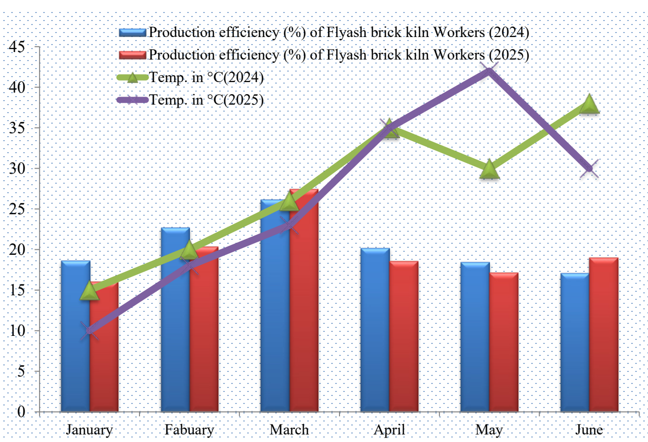
Table 3 shows the monthly efficiency. From January to June, 2024 and 2025, the efficiency % was different for both. The highest efficiency was observed in March in both years (that is, 26.15% in 2024 and 27.5% in 2025). June 2024 had the lowest efficiency (17.1%), and January 2025 had the lowest efficiency (16.05%). The table 3 also concluded average efficiency, in which the average efficiency for 2024 was approximately 20.55% and for 2025 was approximately 19.79%. For fly ash brick kiln workers, the t-value was 0.3522 and P t p-value was 0.6769, which was higher than the

Table 3: The comparison of production efficiency (%) for Fly ash brick kiln workers for 2024 and 2025 year

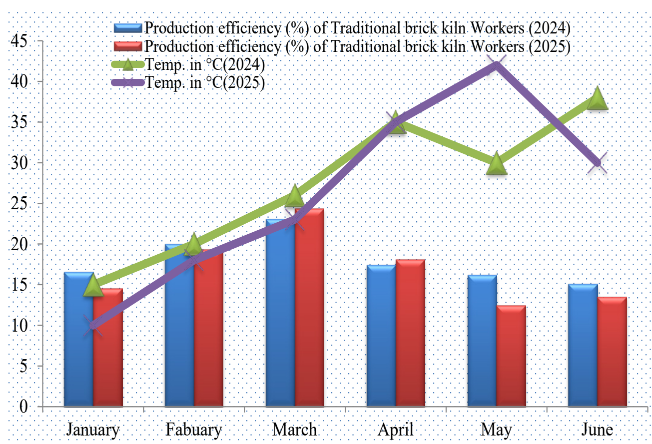
MONTH	*Production efficiency (%) of Flyash brick kiln Workers (2024)*	*Production efficiency (%) of Flyash brick kiln Workers (2025)*
January	18.65	16.05
February	22.7	20.4
March	26.15	27.5
April	20.2	18.6
May	18.5	17.16
June	17.1	19.05
Average ±SE	20.55 ± 1.364	19.79 ± 1.660
t Value	0.3522	
p-value	0.6769	
p-value summary	Non- significant	

Table 4: The comparison of production efficiency (%) for Traditional brick kiln workers for 2024 and 2025 year

MONTH	*Production efficiency (%) of Traditional brick kiln Workers (2024)*	*Production efficiency (%) of Traditional brick kiln Workers (2025)*
January	16.566	14.56
February	20.03	19.36
March	23.06	24.4
April	17.43	18.1
May	16.2	12.46
June	15.13	13.54
Average ±SE	18.07 ± 1.205	17.07 ± 1.826
t Value	0.4568	
p-value	0.3826	
p-value summary	Non- significant	



Graph 3: Month-wise temperature (°C) and production efficiency(%) of flyash brick kiln workers (six month)



Graph 4: Month-wise temperature (°C) and production efficiency(%) of traditional brick kiln workers (six month)

normal significance level of 0.05. This indicates that the difference in production efficiency between the two years was not significant, meaning that there was no statistically significant difference.

The average efficiency of traditional brick kilns from Table 4 is concluded here. The average efficiency from January to June 2024 was 18.07%, and in 2025, it was 17.07%. The highest efficiency was observed in March in both years (that is 23.06% in 2024 and 24.4% in 2025), and the efficiency generally remained low in May and June. The statistical analysis for traditional brick kiln workers showed a t-value of 0.4568 and a p-value of 0.3826. The P-value summary indicates that the difference in production efficiency between 2024 and 2025 is not significant. This means that the difference between the average production efficiencies in both years was not statistically significant.

Results and Discussion

The present study shows an association between temperature and demographic factors, such as age and height, with the ergonomic efficiency of workers in both fly ash brick and conventional brick kilns. The major level of temperature prevalence observed in conventional brick ergonomic efficiency in 2025, and the same scenario was observed in the fly ash brick kiln in 2025.

From this, it can be interpreted that the fly ash brick kiln in January 2025 has its lowest efficiency (16.05%), and June 2024 also has its lowest efficiency (17.1%). In the conventional brick kiln, apart from the number of workers compared to the fly ash brick kiln, the ergonomic efficiency in June 2024 was 18.07% i.e. very close to flyash efficiency in June 2024 and in January 2025, which was 17.07%, that also near to fly ash efficiency in January 2025. It was concluded that if the study excludes the variation in the number of workers in both brick kilns, then the efficiency will be very close to each other. This means that the study did not show a significant association between the effect of temperature on workers efficiency in fly ash and conventional brick kilns. This may be due to climatic conditions, seasonal variations, seasonal occupations, or variations in health and favourable environmental conditions during the study.

Graph 3 compares the monthly temperature and production efficiency of fly ash brick kilns in 2024 and 2025. January to March i.e. cold months, temperature is low (approximately 10° C to 20° C), and production efficiency (approximately 15% to 20%) is highest during these months. From April to June, that is, the hot months, there is a significant increase in temperature (approximately 35–42 °C). As the temperature increased, the production efficiency decreased (approximately 5 to 10%). Study comparison between 2024 versus 2025, the temperature was slightly higher in 2025 compared to 2024 year and in the year 2025, production efficiency was slightly lower compared to 2024. The study found a correlation, and the graph shows a clear inverse relationship between temperature and production efficiency (when the temperature is low, the efficiency is high, and when the temperature is high, the efficiency is low). Graph 4 shows the relationship between the monthly production efficiency and temperature of traditional brick kiln workers, covering data from January to June of 2024-25. This shows that as the months progress and the temperature increases, the production efficiency generally decreases. From January to March, the temperature remains low (approximately 15°C–25 °C) and production efficiency is higher (approximately between 15% and 20%). While from April to June, the temperature increased significantly (approximately 30°C to 43°C), and production efficiency decreases about 3 % to 8%.

The study concluded that high temperatures negatively impact the production efficiency of both traditional and fly ash brick kiln workers, but the level of affectedness varies from kiln to kiln as well as from worker to worker.

$$Temperature \propto \frac{1}{Production\, efficiency}$$

The study also concluded that age and height, that is, demographic parameters, also have a correlation with production efficiency, as shown in Graphs 1 and 2 and Tables 3 and 4. Data values show a non-significant correlation, that is, P>0.05 on both fly ash brick kiln workers and traditional brick kiln workers respectively.

Conclusion

Brick manufacturing involves highly variable workstations. The study concluded that if the variation in the number of workers in both brick kilns (fly ash and conventional) is excluded, then the efficiency levels will be very close to each other. This suggests a non-significant association between the effect of temperature on workers ergonomic efficiency in the different kilns. The study also concluded that high temperatures negatively impact the production efficiency of both traditional and fly ash brick kiln workers. However, the level of impact varies depending on the specific kiln environment and the individual workers. This study leaves scope for future investigators to fill this gap.

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