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An Empirical Study for Improving the Quality of Fly Ash Added Bricks

Madhuri Bhattacharya and Abhijit Chakraborty*

Research Scholar, Department of Management, Maulana Abul Kalam Azad University of Technology (MAKAUT), Nadia - 741249, West Bengal, India; madhuri1103@gmail.com, chakrabortyabhijit100@gmail.com

Abstract

Because of urbanization, demand for housing is increasing day by day in India. Traditional clay brick leads to resource scarcity and environmental pollution. To overwhelmed this problem, manufacturing of bricks was done using the waste of thermal power plants like Fly Ash along with Sand and Cement (FAS-C Brick) as key ingredients. Fly ash is an Industrial by-product of thermal power plant. An experimental study of mix-design was carried out to increase the quality of the FAS-C brick. This paper attempt to formulate the mix design of fly ash based brick by process planning. Laboratory tests were conducted to determine the compressive strength and water absorption of the bricks. The main objective of the research study was to design the Fly Ash, Sand, Cement (FAS-C) brick and find the compressive strength using different mix design methods as a part of quality improvement process.

Keywords: *Fly Ash, Quality, Mix Design, Process Planning, Productivity*

1.0 Introduction

Currently the generation of fly ash is 232.56 million tonnes (Source: CEA report, 2022). Managing this solid waste of Thermal Power Plants (TPPs) is becoming a major challenge in developing countries. Waste has always been a constant problem for any organization/Government/ Nation so the objective should be utilizing the waste as a raw material may be for production or energy supply. This research is projected at finding out the way to utilize the fly ash for value added applications in the development of bricks by analysis and developing new mix design continuing all quality parameters. And this will help to solve the environmental problems.

In today's competitive world, any organization can sustain if it put emphasis on quality product. This can be done by maintaining the production system mainly the process planning. Process planning includes all the functions to improve productivity, quality, and cycle time of production in an organization in a sustainable way to design and provide quality products that fulfil the needs of the customers. The prime motive of this study is to offer a new aspect for the design and development of industrial waste based brick (FAS-C brick) for almost 100% utilization of Fly ash and also save our environment by reducing Green House gases. Production of fly ash brick reduces fuel consumptions and it is a good replacement of traditional bricks that saves considerable amount of resources.

2.0 Literature Survey

The review study of Zaman[1] reported on "the utilization of fly ash" that the chemical composition of coal fly ash can be typically as follows (in wt %): SiO_2 : 15–60; Al_2O_3 : 3.68–35; Fe_2O_3 : 4–40; CaO : 1–40; MgO : 0–10; LOI : 0–18.77. He also highlighted that the features of Pozzolans and lime binding capacity of fly ash makes it possible for

*Author for correspondence

the production of high strength bricks and cement. The studies of Das[2] is devoted on "Strength Characterization of fly ash composite material" said that Class C fly ash has some self-cementing properties which in the presence of water will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Class F fly ash is pozzolanic in nature, and contains less than 10% lime (CaO). Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime in order to react and produce cementitious compounds in the presence of water. David *et al.*[3] studied "the advantages of green building". They reported the fly ash as an eco-friendly building material. Fly ash is a pollutant but when used as ingredient for brick manufacturing industry, it becomes as an eco-friendly product. Fly ash can be used for making variety of building products using simple low-cost processes and other. As per the study of Dhadse *et al.*[4] on "characteristics of fly ash", they said fly ash can be used as a partial replacement of Portland cement more than 20% to 30%. They also stated that concrete made with fly ash is stronger and more durable than traditional concrete because fly ash with lime creates more durable binder. More over fly ash concrete is less susceptible to chemical attack and hence suitable for coastal atmosphere. Shetkar, *et al.*[5] emphasize on their study "fly ash based lime brick" that the fly ash generation is increasing in such a proportion that it will not be possible for the cement industry alone to utilize the same. New avenues of gainful utilization of fly ash have to be found and promoted. Dhrumil[6] made a comparative assessment between clay bricks and fly ash bricks. His research stated that the fly ash bricks are lighter, higher compressive strength, low cost, uniform shape and smooth finishes, less porous, less Water Absorption (WA), low thermal conductivity, environmentally friendly and saving fertile land and groundwater. Experimental Study of Coal Cinder Added Fly Ash Bricks has been performed by Suresh[7]. In the study of Nithya[8], experimental investigation of brick manufactured by earth (clay) material with granite waste, eggshell powder and coconut fiber has been discussed. A review on fly ash bricks over use of red clay bricks has been presented in the study of Sahu[9]. Based upon the comprehensive review and identifying the appropriate gap this paper is focused attempt to formulate the mix design of fly ash-based brick by process planning.

3.0 Objectives of Proposed Work

The objectives of the proposed work are:

1. To explore all the physical properties of Fly ash, and find out the best procedure to develop Fly ash, Sand, Cement (FAS-C) brick.
2. To find out the influence of different parameters and their effects on FAS-C brick and also develop the suitable mix design of Fly ash, Sand, Cement (FAS-C) brick for construction industry.

4.0 General Observation of The Research Study

Generally, most of the fly ash based brick industries are facing a problem connected with productivity as well as brick quality.

5.0 Experimental Materials and Characterization

a. Fly Ash: For this mix design, Class F (low calcium) dry fly ash was used as main ingredient. The Physical and

Table 1. Physical Properties of Fly ash

Sl. No.	Parameters tested	Results obtained	Requirement as per specification IS 3812
1	Specific Gravity	2.10	---
2	Fineness or Specific Surface Area(m^2/kg)	350	320 min
3	Residue on 45μ sieve (%)	25	34 max
4	LOI (%)	2	5

Table 2. Chemical properties Fly ash

Sl. No.	Component	Test results (%)
1.	SiO_2	55
2.	Al_2O_3	26.4
3.	Fe_2O_3	3.3
4.	CaO	0.66
5.	LOI	3

chemical properties of fly ash taken are given below in the Table 1 and Table 2.

b. Fine Aggregate: Sand is used as fine aggregate and selected based on its Zone (Table 3).

Sand Zone is II.

c. Cement: For this research study OPC (Ordinary Portland Cement) 53 grade cement is used. The Physical properties of cement are given Table 4.

6.0 FAS-C Brick and Quality

Mix design of Fly Ash-Sand-Cement (FAS-C) brick is prepared after several physical and chemical analysis of Fly ash, Sand and Cement. The quality of FAS-C brick should be controlled and maintained at every stage of manufacturing right from the raw material to the finished product (Figure 1).

So, it is recommended to check the quality of ash as well as other raw materials to get quality bricks. It has been found during the physical analysis of the raw materials that carbon content of fly ash and size varies from one Thermal Power Plant to another. The Carbon in fly ash has a bad impact on the strength of the concern bricks. So, after doing proper research perspective, changes have been made in the mix design ratio of fly ash for a particular period regarding high carbon content of the same.

Table 3. Sieve analysis of Sand

Sieves	Sample taken	Sample passing	Sample retain	Percentage (%)
10mm	500	494	6	98.8
4.75mm	494	463	31	93.7
2.36mm	463	362	101	78.1
1.18mm	362	299	63	82.5
600µ	299	78	221	26.08
300µ	78	68	10	87.1
150µ	68	10	58	14.7

Table 4. Physical properties of Cement

Sl. No.	Parameters tested	Results obtained	Requirement as per specification IS 12269	IS method followed
1	Specific Gravity	3.16		
2	Fineness or Specific Surface Area (m^2/kg)	330	225 min	IS 4031 : part 2
3	Normal consistency	28	---	IS 4031 : part 4
Setting time, minutes				
4	Initial setting times Final setting times	108 183	Not less than 30 mins Not more than 600 mins	IS 4031 : part 5

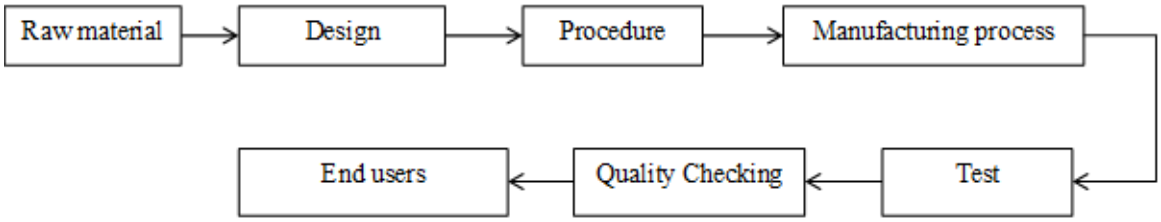


Figure 1. FAS-C brick and Quality.

7.0 Mix Design

A. The productivity and quality of Fly ash, bricks may vary with the factors like:

a. Quality of fly ash, quality of cement, quality of sand, water content in sand.
b. Improper mixing ratio of raw materials.
c. Improper mixing timing.
d. Machine inefficiency.

B. Main objective is to observed

a. The basic mixing proportion of Fly Ash-Sand-Cement (FAS-C) for fly ash based brick
b. Differences among compressive strength when mix design is changed with good quality of raw materials
c. The water-cement ratio with changing cementitious materials.

The mixture proportioning was done on the basis of the physical and chemical analysis of the raw materials. The mix design was done in such a way that fly ash is used in different proportion (Table 5).

8.0 Casting of FAS-C Brick

Brick moulds of size 190mm x 90mm x 90mm and 230mm x 110mm x 70mm were taken for this experiment. FAS-C bricks were design, casts using standard methods and came in a variety of mixing ratios. Proper mixing of Fly ash, sand cement along with water is highly required. After production, let it air dry at ambient temperature. Samples were taken periodically at 7, 14 and 21 days and the samples were tested for different mix ratios of materials to study the compressive strength and water absorption. Minimum sample of 5 bricks need to be tested in each and every mix to know the quality of the brick properly.

9.0 Analysis

To know the characteristics like compressive strength and water absorption of FAS-C brick, bricks were tested in the regular intervals like 7^{th} day, 14^{th} day and 28^{th} day.

9.1 Compressive Strength

Compressive strength of FAS-C brick is measured as per standard practice. Test was conducted on five samples from each mix design and compressive strength is checked after 7 days, 14 days and 28 days respectively (Table 6 and 7). Fly ash used as a main ingredient in this study, so if the quality of fly ash comes under Grade I or Grade II, then up to 50 – 60% of it can be used. To reduce

Table 5. Mix Proportion of Raw Materials for FAS-C Brick

Material	MD1	MD2	MD3	MD4	MD5
Fly ash (%)	50	46	50	46	46.4
Sand (%)	40	45	41.6	46	46.6
Cement (%)	10	9	8.4	8	7
Water ratio (Excluded)	0.183	0.189	0.178	0.185	0.187

Table 6. Compressive Strength of 7 days

Brick size	Mix Design (MD)	7 Days Compressive Strength (Date 23.09.2022)		
		Weight (Kg)	KN	N/mm²
230mmx110mmx70mm	MD1	3.329	90	3.55
		3.606	100	3.95
		3.215	94	3.71
		3.220	102	4.03
		3.303	106	4.18
190mmx90mmx90mm	MD2	2.593	70	4.09
		2.519	80	4.67
		2.511	75	4.38
		2.520	70	4.09
		2.543	94	5.49
230mmx110mmx70mm	MD3	3.465	82	3.20
		3.196	78	3.08
		3.225	80	3.16
		3.350	76	3.00
		3.290	78	3.08
190mmx90mmx90mm	MD3	2.920	62	3.62
		2.973	56	3.77
		3.065	58	3.39
		3.110	66	3.85
		2.87	60	3.50
230mmx110mmx70mm	MD4	3.222	74	2.92
		3.219	76	3.00
		3.309	80	3.16
		3.188	70	2.76
		3.197	78	3.08
190mmx90mmx90mm	MD4	2.848	60	3.50
		2.798	58	3.39
		2.839	50	2.92
		2.672	60	3.50
		3.041	54	3.15
190mmx90mmx90mm	MD5	2.818	52	3.04
		2.882	54	3.15
		2.936	48	2.80
		2.873	56	3.27
		2.893	50	2.92

Table 7. Compressive Strength of 14 Days and 28 Days

Brick size	Mix Design (MD)	Compressive Strength					
		14 Days (30.09.2022)			28 Days (14.10.2022)		
		Weight (Kg)	KN	N/mm²	Weight (Kg)	KN	N/mm²
230mmx110mmx70mm	MD1	3.123	290	11.46	3.058	388	15
		3.255	262	10.35	3.221	350	13.8
		3.131	272	11	3.197	368	14.5
		3.139	288	11.38	3.150	372	14.7
		3.226	300	11.85	3.187	388	15
190mmx90mmx90mm	MD2	2.731	146	8.53	2.851	240	14
		3.054	152	9	3.045	254	14.85
		2.745	168	9.82	2.858	248	14.5
		2.867	170	10	2.894	238	14
		2.892	140	8.18	2.667	236	13.8
230mmx110mmx70mm	MD3	3.275	184	7.27	3.232	332	13
		3.305	195	7.7	3.151	308	12
		3.275	220	8.69	3.062	300	11.85
		3.167	176	6.95	3.119	296	11.69
		3.129	182	7.19	3.393	316	12.49
190mmx90mmx90mm	MD3	2.777	110	6.4	2.877	230	13.45
		2.847	115	6.7	2.687	238	13.9
		2.780	122	7	2.527	192	11
		2.802	130	7.6	2.805	180	10.5
		2.699	115	6.7	2.771	210	12.28
230mmx110mmx70mm	MD4	3.265	174	6.87	3.277	335	13.24
		3.240	170	6.71	3.206	310	12.25
		3.208	160	6	3.120	300	11.85
		3.275	148	5.84	3.149	298	11.77
		3.185	182	7.19	3.218	306	12
190mmx90mmx90mm	MD4	2.800	110	6.43	2.650	190	11
		2.825	100	5.84	2.693	210	12.28
		2.795	89	5	2.786	195	11.4
		2.687	98	5.73	2.817	188	11
		2.850	112	6.54	2.757	186	10.87

190mmx90mmx90mm	MD5	2.884	90	5.26	2.761	190	11
		2.711	88	5	2.574	180	10.52
		2.780	108	6	2.638	160	9.35
		2.755	99	5.78	2.593	164	9.59
		2.778	100	5.84	2.745	196	11.46

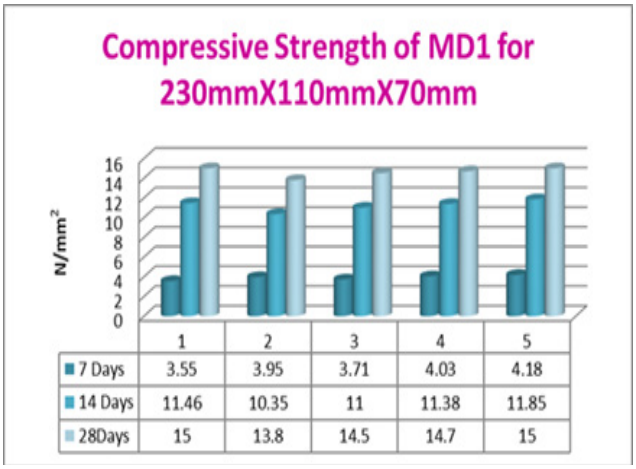


Figure 2. Compressive Strength of MD1 for Brick size 230mmx110mmx70mm.

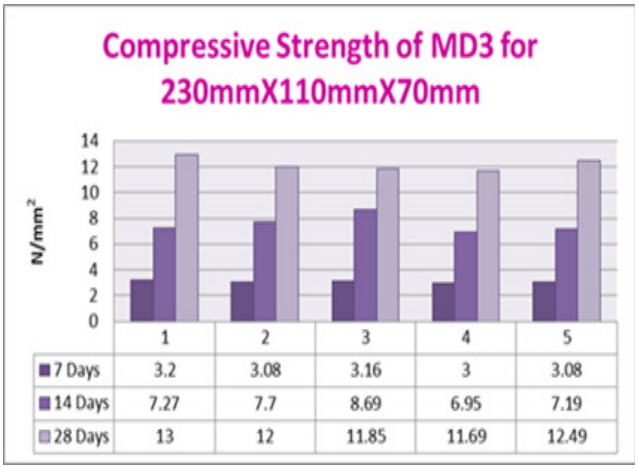


Figure 4. Compressive Strength of MD3 for Brick size 230mmx110mmx70mm

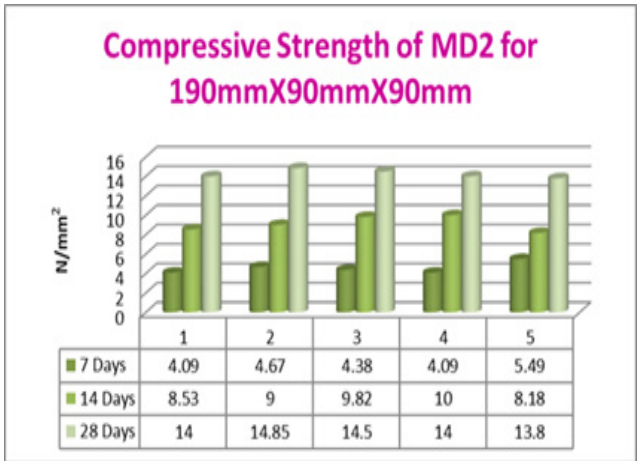


Figure 3. Compressive Strength of MD2 for Brick size 190mmx90mmx90mm

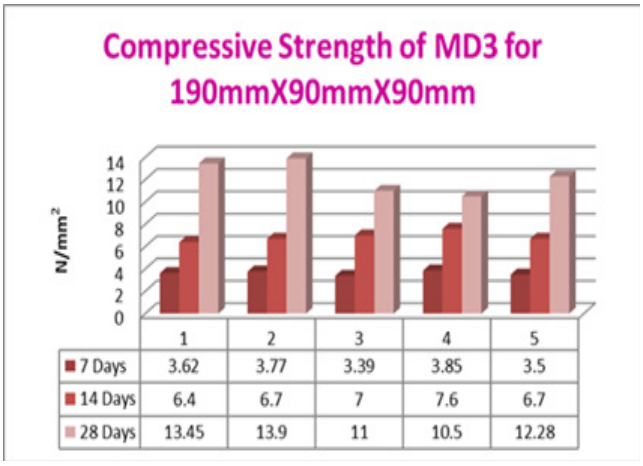


Figure 5. Compressive Strength of MD2 for Brick size 190mmx90mmx90mm

the production cost and product cost, we made five mix designs with different percentage of cement. The price of FAS-C brick mainly varies for the cost of the cement. As per standard norms the required Compressive Strength for Fly Ash based bricks are generally of the order 7.5-10 N/mm^2 after 21 days of curing.

9.2 Water Absorption

The water absorption of fly ash bricks should not be greater than 10%. Sample bricks are tested by keeping them in the water for 24 hours and weighted as W_2. The weight before placing in the water is denoted by W_1 (Table 8).

Table 8. Water Absorption

Mix Design	Brick Size	Sample	Brick Weight (W_1)	Brick Weight (W_2)	Water Absorption
MD_1	230mmx110mmx70mm	1	3.058	3.398	8.17%
		2	3.221	3.431	
		3	3.197	3.448	
		4	3.150	3.389	
		5	3.187	3.440	
MD_2	190mmx90mmx90mm	1	2.662	2.899	8.26%
		2	2.740	2.904	
		3	2.669	2.889	
		4	2.674	2.910	
		5	2.678	2.930	
MD_3	230mmx110mmx70mm	1	3.275	3.540	8.35%
		2	3.305	3.561	
		3	3.275	3.535	
		4	3.167	3.426	
		5	3.129	3.438	
MD_3	190mmx90mmx90mm	1	2.686	2.919	8.75%
		2	2.775	3.027	
		3	2.701	2.956	
		4	2.708	2.957	
		5	2.718	2.918	
MD_4	230mmx110mmx70mm	1	3.265	3.552	8.79%
		2	3.240	3.515	
		3	3.208	3.498	
		4	3.275	3.567	
		5	3.185	3.463	
MD_4	190mmx90mmx90mm	1	2.650	2.858	9.37%
		2	2.693	2.871	
		3	2.786	3.096	
		4	2.817	3.128	
		5	2.757	3.035	
MD_5	190mmx90mmx90mm	1	2.761	2.919	9.53%
		2	2.574	2.745	
		3	2.638	2.940	
		4	2.593	2.971	
		5	2.745	3.005	

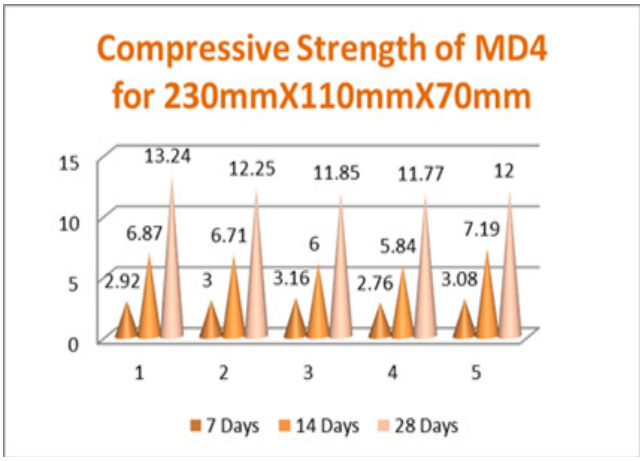


Figure 6. Compressive Strength of MD4 for Brick size 230mmx110mmx70mm

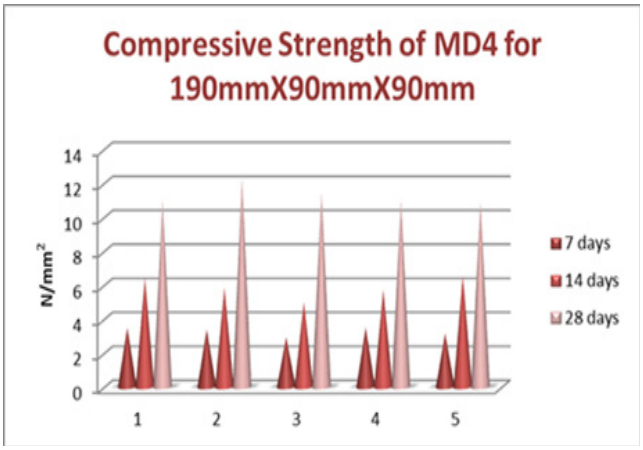


Figure 7. Compressive Strength of MD4 for Brick size 190mmx90mmx90mm

10.0 Conclusion

The process planning includes all the functions to improve productivity, quality, and cycle time of production in an organization in a sustainable way to design and provide quality products that fulfil the needs of the customers.

Ultimately it can be conducted that to utilise the waste of thermal power plant to produce eco-friendly product like FAS-C brick through quality analysis is giving positive result. FAS-C bricks were tested for properties like compressive strength and water absorption. Based on the experimental study, the results of compressive strength of fly ash based brick is higher than traditional brick. FAS-C brick can act as a replacement of traditional brick as all

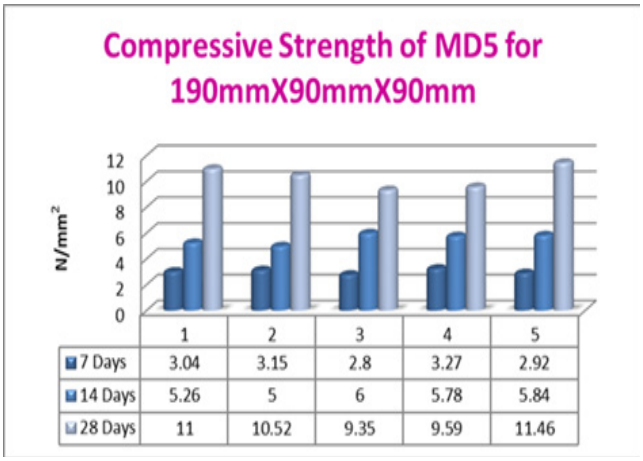


Figure 8. Compressive Strength of MD5 for Brick size 190mmx90mmx90mm

the results shows the satisfactory performance. In FAS-C brick, fly ash is added in different proportions – 50%, 46% 46.4%. Best result is achieved with the proportion fly ash 50%, sand 40% and cement 10%. Water absorption is observed low with high compressive strength. As fly ash is a waste product, it will reduce the problem related with disposal and landfill.

This ecofriendly product reduces the emissions of pollutants and no effluent is discharged into air. As Production process of FAS-C brick do not consume any fuel hence replacement of traditional brick with it will save considerable amount of energy and resources.

11.0 References

1. Ahmaruz Zaman M. A review on the utilization of fly ash. Prog Energy Combust Sci. 2010; 36:327–63.
2. Das A. Strength Characterisation of fly ash composite material from the thesis submitted in NIT Rourkela. 2009.
3. David Kumar C, Kathirvel P. A Study on Factors Influencing Quality of Construction Projects. Int J Res Appl Sci Eng Technol-IJRASET. 2015 May; 3(V):13.98. ISSN: 2321-9653.
4. Dhahse S, Kumari P, Bhagia LJ. Fly ash characterization, utilization & Government initiatives in India- a review. Sci Ind Res. 2008; 67:11-18.
5. Shetkar A, Hanche N, Shashishankar A. Experimental Studies on Fly Ash Based Lime Bricks. Int J Recent Adv Eng Technol. 2016; 4(7):102-109.

6. Chokshi DS, Pitroda J, Makwana AH. A Competitive Assessment on Fly-Ash Bricks and Clay Bricks in Central Gujarat Region of India Using Chi-Square Test($\chi 2$) through SPSS Software. Int J Eng Sci Res Technol - IJESRT. 2014 May; 320-331.
7. Suresh M, Ajith Kumar P, et al. An Experimental Study of Coal Cinder Added Fly Ash Bricks. Int J Eng Sci Comput - IJESC. 2017 March; 7(3):6061-6064.
8. Nithya R. Experimental Investigation of Bricks by Using Various Waste Materials. Int J Latest Trends Eng Technol. 2016; 6:395-402.
9. Sahu MK, Singh L. Critical Review on Types of Bricks Type 2: Fly Ash Bricks. Int J Mech Prod Eng. 2017; 5(11).