Synthesis and Characterization of fly ash brick Formed with rise husk and lime

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Abstract:

Fly ash is a waste by-product from combustion of fossil fuels in the thermal power stations for the thermal generation of electricity. Several pollution problems arise nearby those thermal power stations due to its accumulation. Under the concern of disposal and maintaining ecological balance many researchers are working on novel and improvised methods of combating this waste management issue. For that utilization of fly ash as resource material for brick manufacturing will be more than valuable in terms of environmental and economic aspect as well.

In this paper we have discussed about the method of preparation of fly ash bricks with the incorporation of lime and rice husk in it. Micro Cylindrical Fly ash bricks prepared by using air-cured method were tested for their properties including compressive strength with the help of Dak System Inc. Universal Testing Machine, water absorption capacity and efflorescence were also tested in accordance with IS: 3495 (Part 2-3) – 1992. They have found that the compressive strength of brick sample prepared at 10 ton casting pressure exhibits highest compressive strength while the same shows lowest water absorption. Structural analysis is explained using XRD spectra and observed hexagonal structure of the sample.

Keywords: Air-cured method, Fly Ash, Micro-Cylindrical brick, Rice Husk, Compressive Strength, Water absorption.

1. Introduction:

Coal Combustion Residuals (CCR) or by-products are produced by the burning of the coal in coal based thermal power stations. The produced CCR includes fly ash, bottom ash, boiler slag and flue gas desulfurization residue. Out of the total produced coal combustion residue more than 70 % is recognized as fly ash (FA) which are fine particles ranging from 0.5 mm to 300 mm captured by particulate control equipment [1].

In 2015, fly ash utilization rates were 70% for China, 43% for India, and 53% for the US [2]. This suggests that there a lot of opportunity for us to utilize and increase the use of fly ash in various areas. Utilization of fly ash can leads to a decrement in the disposal cost in waste management as the most of waste fly ash will be hired for utilization in various applications. It will also reduce the amount of fly ash to be treated for the sake of environmental aspect although it replaces the non-renewable and expensive resources.

There has been an increasing attempt for fly ash utilization in different sectors identified top areas for the quantity of fly ash utilization in the year 2019-20 as 26 to 27 % in cement and concrete sectors, 9.27 % of ash in roads, embankments and 9.80 % in ash dyke raising, followed by 15.50 % in reclamation of low lying areas and land filling, 4.69 % in mine filling, 9.46 % in bricks, blocks and tiles, 0.06 % in agriculture and 7.92 % in others [3].

Here it is clear from the report of CEA that the utilization of fly ash in each scope is not upto mark. Thus for the proper waste management and to restructure the economic backward class fly ash can be used as a resource material for eco-friendly fly ash bricks.

Use of fly ash as resource material in producing high quality bricks not only reduces the magnitude of environmental issues but also added values in developing entrepreneurship [4]. Use of fly ash in bricks also brings safety for the issue of soil erosion and saves agricultural land as well.

2. Material and Synthesis:

In the present paper two different types of components are added with fly ash for the preparation of micro cylindrical FALRH bricks samples. First one is Lime and the second one is rice husk. The reason behind the selection of these two components is that the lime can be utilized as a binding agent and rice husk will provide the fly ash brick more stability as it posses ample amount of silica [5] which is also present in fly ash.

There are several methods of preparation of bricks but we are acquiring the method which involves the proportioning of components in definite size, mixing of fly ash with the other component, moulding and then settling down the mixture by air-cured method [6].

2.1 Casting of Bricks:

Initially the mixture of fly ash, lime and rice husk was mixed in the proportion of 7:2:1 and palletized at different pressures of 1 ton, 2 ton, 3 ton, 4 ton, 5 ton and 10 ton for the preparation of micro cylindrical FALRH brick samples.

Table 1: Fly ash + Lime + Rice Husk sample composition percentage

Composition	Fly Ash %	Lime %	Rice Husk %	Casting Pressures
S_0	70	20	10	1 ton
S_1	70	20	10	2 ton
S_2	70	20	10	3 ton
S_3	70	20	10	4 ton
S_4	70	20	10	5 ton
S_5	70	20	10	10 ton

Three samples of all above compositions were prepared by mixing all the components at two levels. First mixing of dry components thoroughly with mechanical mixer and after that mixing all components in addition with binder material. Mixed materials are pressed by using KBr pallet machine.

3. Testing and Result Analysis:

After the sample preparation we will process for testing of strength of compression, water absorption and efflorescence properties. Initially, we will discuss here the compressive strength testing of sample.

3.1 Structural Analysis:

The structural determination of the present FALRH brick is done by X-Ray Diffraction performed by PANalytical 3kW Xpert Powder X-ray Diffractometer. The samples are having components as quartz, calcite and hematite in more percentage showing hexagonal structure after well matched JCPDS cards # 00-046-1046. Figure 1 shows the XRD pattern of the brick sample prepared using fly ash, lime and rice husk.

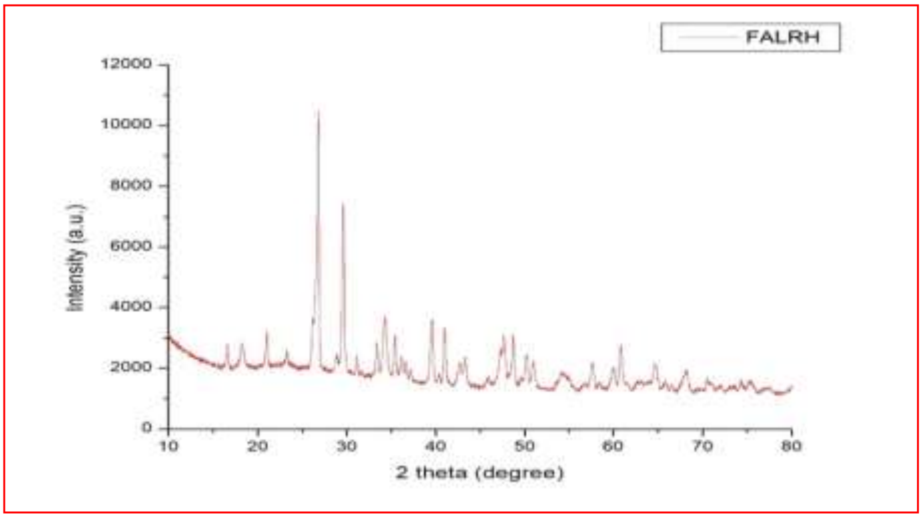


Figure 1: XRD pattern of Fly Ash + Lime + Rice Husk brick sample

3.2 Compressive Strength test:

To test the compressive strength of a FALRH brick sample we have to put brick sample into calibrated compression testing machine. In this case we have Dak System Inc. Universal Testing Machine which applied 100 kN load at uniform speed of 1.3 mm/min. The maximum load at which brick sample fails to produce any further resistance is recorded in the indicator of compression testing machine [7]. Thus three numbers of bricks were tested for each mix proportion. Each brick may give different strength. Hence, average of three bricks was taken.

Since, we have opted micro frame of cylindrical shaped samples. In the Air-Cured method we require casting pressure (in tons), width, thickness, Guage length, curved surface area and peak load on samples for the determination of compressive strength of sample bricks at different specific pressures. The bricks samples were prepared by pressing them with KBr Pallet machine at different casting pressures of 1 ton, 2 ton, 3 ton, 4 ton, 5 ton and 10 ton.

The compressive strength of the micro brick samples were calculated through the formula given below:

$$\textbf{Compressive Strength } (\mathbf{F_c}) = \frac{\textbf{Peak Load (in N)}}{\textbf{Cross Sectional Area (in sq.mm)}}$$

Thus, average compressive strength of brick sample at 7 days, 14 days, 28 days and 45 days age is displayed in table 2.

Table 2: Compressive strength of Fly ash + Lime + Rice Husk bricks at different ages

S.No.	Sample	Casting Pressure	Average Compressive Strength at 07 days (MPa)	Average Compressive Strength at 14 days (MPa)	Average Compressive Strength at 28 days (MPa)	Average Compressive Strength at 45 days (MPa)
01	S_0	1 ton	3.703	4.010	4.152	4.359
02	S_1	2 ton	4.137	4.524	5.496	5.692
03	S_2	3 ton	4.437	5.107	5.873	5.964
04	S_3	4 ton	3.856	4.732	5.924	6.170
05	S_4	5 ton	5.682	6.085	6.741	6.809
06	S_5	10 ton	7.136	7.825	8.864	9.177

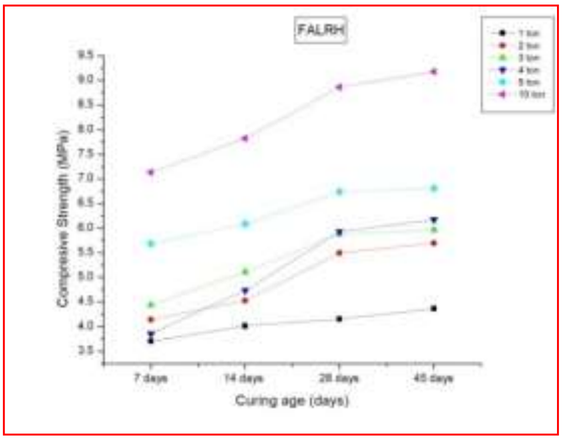


Figure 2: Comparison of compressive strength of FALRH at different ages.

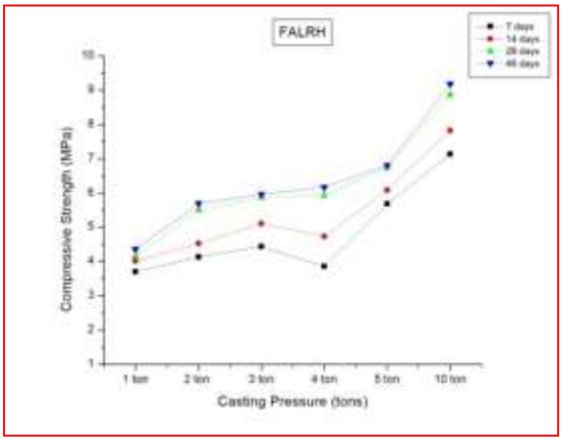


Figure 3: Behavior of compressive strength with increasing casting pressure.

So, from Figure 2 we can have a comparative knowledge of how compressive strength of brick sample varies with increasing age. Sample S_5 casted at 10 ton pressure exhibits highest compressive strength. Sample S_5 shows highest average compressive strengths after 7 days, 14 days, 28 days and 45 days of ages as 7.136 MPa, 7.825 MPa, 8.864 MPa and 9.177 MPa respectively. While sample S4 which is prepared at 5 ton pressure shows 5.682 MPa after 7 days, 6.085 MPa after 14 days, 6.741 MPa after 28 days of age and 6.809 MPa in 45 days of age. Brick sample casted at 4 ton pressure exhibits 3.856 MPa at early 7 day age and increases in compressive strength as it gains 4.732, 5.924 and 6.170 MPa at 14, 28 and 45 days curing age respectively. Sample casted at 3 ton pressure shows lowest and highest compressive strength as 4.437 and 5.964 while brick sample at 2 ton pressure shows 4.137 MPa as lowest and 5.692 MPa as highest compressive strength values by growing curing ages. Another sample casted at 1 ton pressure shows relatively low strength as compared to other samples at higher casting pressures of same composition.

Figure 3 exhibits the behavior of material prepared that as the casting pressure increases the compressive strength of the brick material increases. At curing ages of 28 days and 45 days the binding of components is strengthened and the compressive strength increases with increasing casting pressure. At early age of 7 and 14 days initially at low casting pressure upto 3 ton the strength of compression increases linearly then there is a slight hump occur at 4 ton. Again as the pressure goes up it exhibits linear growth in compressive strength with casting pressures.

3.3 Water Holding Capacity:

Initially bricks prepared by the air-cured method after mixing all components were dried at room temperature. As it attains constant weight cool the bricks at room temperature and weight that will be initial weight (W1).

Completely dried and weighted bricks were now immersed in water for 1 complete day at 27±20 ºC. Next day bricks were taken out from water and wiped out all the moisture and weigh which would be Final Weight (W2). The average of three bricks should be taken. Thus the water holding capacity will be estimated by the formula given below:

$$\mathbf{WHC} = \left(\frac{\mathbf{W2 - W1}}{\mathbf{W1}}\right) \mathbf{x\ 100\ \%}$$

$$\text{If } A = \left(\frac{W2 - W1}{W1}\right)$$

$$\text{then, } \mathbf{WHC = A\ x\ 100\ \%}$$

Table 3: Water Holding Capacity of Fly Ash +Lime + Rice Husk bricks at different age

S. No.	Sample	Casting Pressure	Water Absorption at 7 days age	Water Absorption at 14 days age	Water Absorption at 28 days age	Water Absorption at 45 days age
1	S_0	1 ton	6.470	6.091	5.330	5.271
2	S_1	2 ton	5.623	5.267	4.805	4.785
3	S_2	3 ton	5.313	5.167	4.625	4.583
4	S_3	4 ton	4.820	4.773	4.438	4.351
5	S_4	5 ton	4.433	4.248	3.784	3.760
6	S_5	10 ton	4.116	3.837	3.401	3.381

From figure 4 we can see that FALRH brick sample at 1 ton absorbs maximum 6.470 % of water only; which is way more less than the standard 12 % [8]. Similarly for samples casted at 2, 3, 4, 5 and 10 ton exhibits relatively low water absorption.

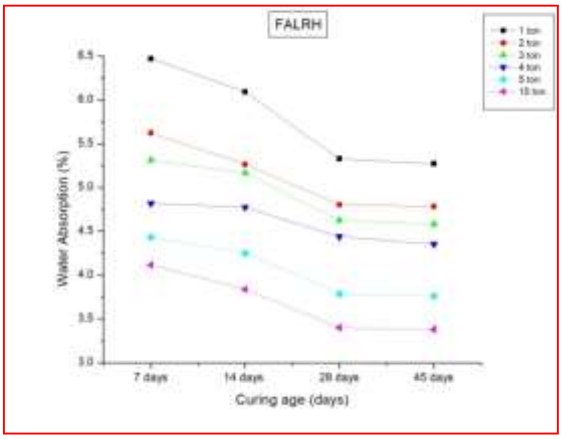


Figure 4: A plot of Curing age Vs Water absorption Capacity at different casting pressure.

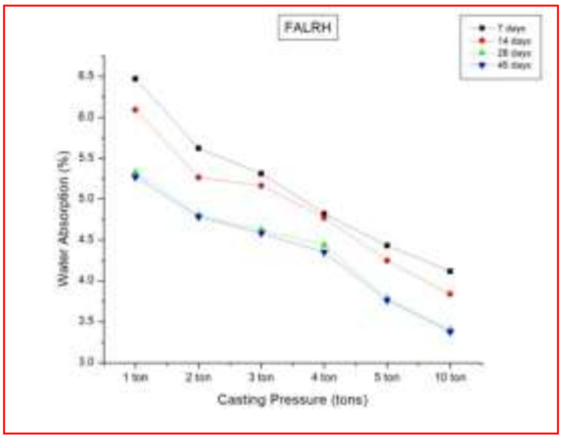


Figure 5: A plot of Casting Pressure Vs Water Capacity at different age.

Thus it is clear from figure 4 that our brick sample having composition "Fly Ash + Lime + Rice Husk" has less water absorption property.

The Figure 4 shows that the sample having highest water absorption capacity was casted at lower pressure. As we the increase the curing time the water absorption capacity of the entire sample goes down as it is inverse of compressive strength. Water absorption is also decreasing with increasing casting pressure as we can see from Figure 5. It is highest for 1 ton casting pressure then lowering down for 2 ton, 3 ton, 4 ton, 5 ton and 10 ton.

3.4 Efflorescence Test:

The efflorescence test of the FALRH brick is performed on samples casted at different pressures is displayed in Table 4. Different pressures on 18 samples of bricks are applied as 1 ton, 2 ton, 3 ton, 4 ton, 5 ton and 10 ton at different curing ages. The samples are classified in Moderate, Slight and Nil categories of efflorescence. While heavy and serious classification is not showed by any of the sample.

Table 4: Efflorescence test of FALRH brick samples

Brick Sample	Casting Pressure	Efflorescence
S1a	1 ton	Slight
S1b		Moderate
S1c		Moderate
S2a	2 ton	Moderate
S2b		Slight
S2c		Slight
S3a	3 ton	Slight
S3b		Slight
S3c		Nil
S4a	4 ton	Slight
S4b		Nil
S4c		Nil
S5a	5 ton	Nil
S5b		Nil
S5c		Nil
S10a	10 ton	Nil
S10b		Nil
S10c		Nil

3.5 Relation between Compressive Strength and Water Absorption Capacity:

As we know from various literatures [9] that the there is an inverse relation between the water absorption capacity of any brick sample and its compressive strength at a particular age. Thus, we have plotted the water absorption Vs compressive strength graph shown in Figure 6 (a) at 7 day curing age in order to verify the relation between them. Figure 6 (b) illustrates the linear fit between the two parameters. The figure 6 (b) shows the standard deviation calculated is 0.90345.

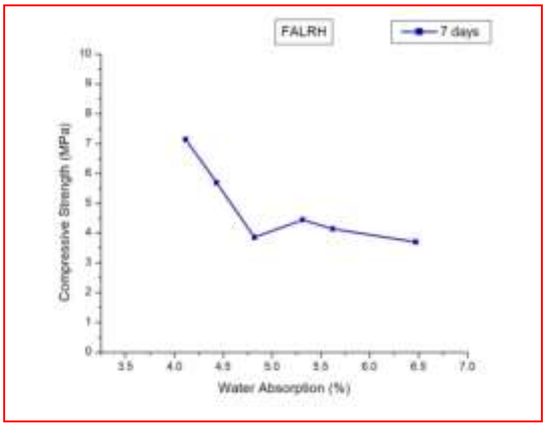


Figure 6 (a)

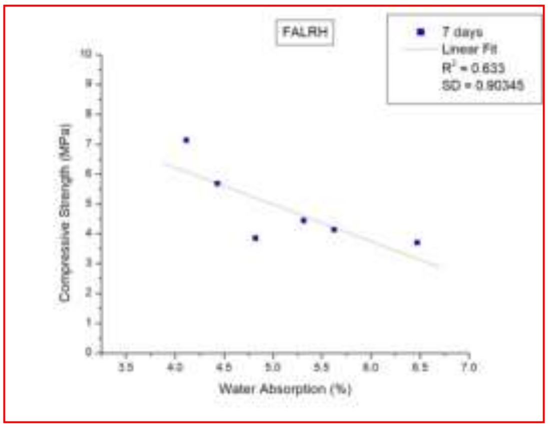
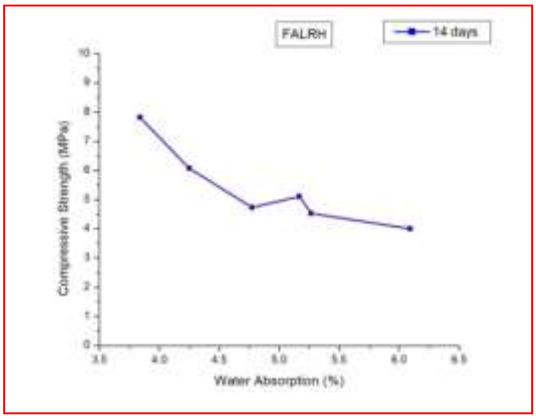


Figure 6 (b)

Figure 6 (a) clearly states that as the compressive strength of FALRH decreases its water absorption will be increased. This relation can be verified from figure 6 (b) with the linear fit plotted using same points.



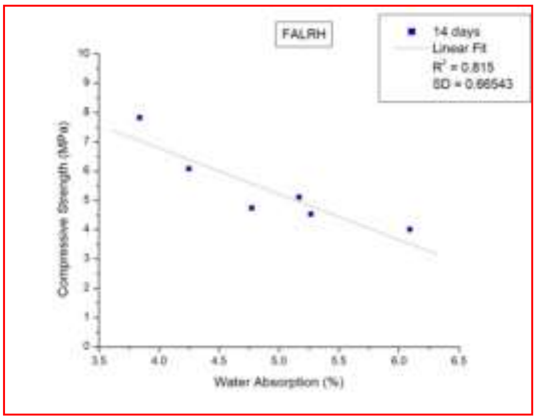
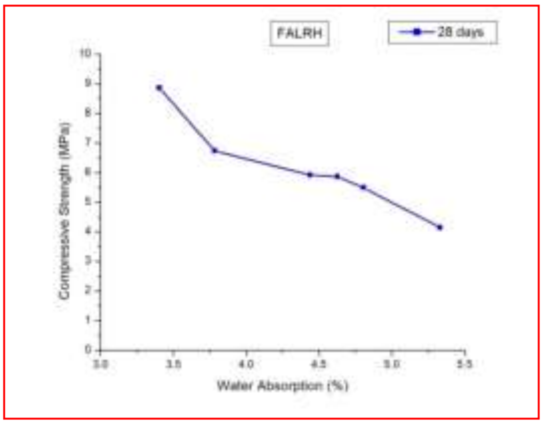


Figure 6 (c) **Figure 6 (d)**

Similarly Figure 6 (c) and Figure 6 (d) stated about the water absorption and compressive strength relation at curing period of 14 days and linear fit for graph of water absorption Vs compressive strength with standard deviation 0.66543 respectively for FALRH brick sample.

From figure 6 (e) and Figure (f) we can see that at 28 days of curing age the compressive strength and water absorption relation is steadier with increasing casting pressure. The ranges of water absorption decrease while the ranges of compressive strength increases in X and Y axis respectively. The standard deviation in plot 6 (f) calculated is 0.49160.



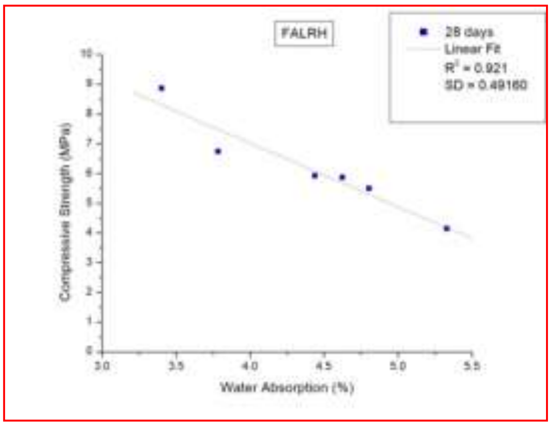
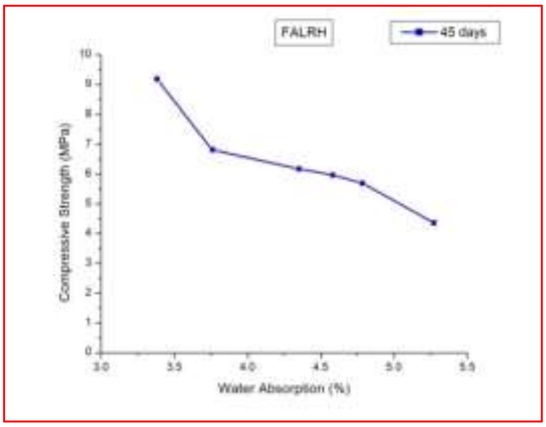


Figure 6 (e) **Figure 6 (f)**

For curing period of 45 days the relation between compressive strength and water absorption as explained in Figure 6 (g) is much more flat than any other plot at different curing ages.



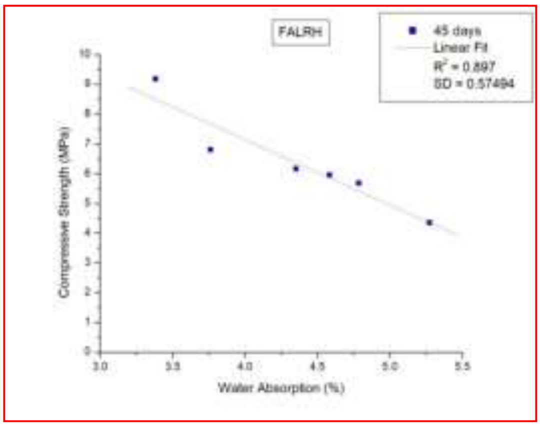


Figure 6 (g) **Figure 6 (h)**

The highest compressive strength is reported for FALRH is 9.177 MPa (Table 3) and it decreases upto 4.359 MPa with the increase in water absorption from 3.381 % to 5.271 % shows there is a linear relation between these two parameters of bricks. The inverse relation is represented with a linear fit plotted in Figure 6 (h) with a standard deviation calculated is 0.57494.

Figure 6 (a) and 6 (c) shows a small hump at initial point 4.5 MPa to 6 Mpa as at this point there is a slight non-linear decrement in compressive strength instead of linear. This may be because of low binding pressure at the time of casting. While in Figure 6 (e) and 6 (g) we have observed the desired slop also verified by linear fit in figure 6 (f) and Figure 6 (h). Thus, we found FALRH sample cured at 28 and 45 days of age suitable for construction application.

The efflorescence test on the 18 samples of FALRH composition at different casting pressures shows that most of the brick samples are having no efflorescence and only 3 and 6 samples shows moderate and slight efflorescence which is good sign for bricks samples to be used.

4. Conclusion:

The present paper focuses on the purposeful utilization of fly ash generated from various thermal power plants due to combustion of coal. The compressive strength of FALRH bricks its water absorption capacity and efflorescence is estimated as a part of utilization and waste management purpose. The brick sample in this paper shows hexagonal structure as well matched with JCPDS card # 00-046-1046. It is much lighter than any other brick, even with other fly ash brick samples.

The water absorption capacity of FALRH brick sample varies at different casting pressures. As the casting pressure increases compressive strength increases but if pressure decreases it decreases. Also with increasing curing age the compressive strength of the brick increases. In this paper for our brick sample we have estimated highest compressive strength 9.177 MPa for the sample casted at 10 ton pressure at 45 days curing age.

Again in other case, the water absorption capacity of the brick sample increased with decreasing casting pressure. Since water absorption capacity is inversely proportional to compressive strength thus we estimated 3.381 % water absorption at 45 days of curing age. In such sample at 1 ton pressure shows highest water absorption capacity after 45 days age. While the sample casted at 10 ton shows lowest water absorption.

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