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Study and Analysis of Compressive Strength with Varying Material Composition Ratio and Curing Temperature for Fly ash Bricks

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ABSTRACT: In Present scenario the application and utility demand of fly ash is increases in many areas and has many advantages, the strength will be to low due to its low hydration at early stage, the fly ash comes out from power plant in larger quantity as waste product and store or stock it over fertile land or store rooms for further recycling purposes, it is necessary step for power plants that fly ash recycle quickly otherwise due to presence of sulphur content in fly ash the land where fly ash placed will barren that fertile lands. In this research paper, the experimental investigation was carried out to find the percentage of optimum mixture of fly ash building brick, so that we utilize and recycle as much as fly ash with optimum required building bricks strength. However the size of brick specimen is taken as 230mm x 100mm x 90mm according to Indian standard for different mixture percentage of Fly ash (10 to 30%), Gypsum (3%), Lime (25 to 35%) and Sandy (45 to 55%), with three different particle size of fly ash 425micron, 600micron, 825micron, compressive strength, Water absorption, Efflorescence test were studied for different mix proportions. The results shows the variations in compressive strength, Water absorption, and Efflorescence test for different mixture proportions of different materials mentioned earlier at three different curing temperature that is 1000^{o}C, 1100^{o}C, 1200^{o}C. From the present research based results it was evidently expected that, the maximum optimum compressive strength is obtained for optimum mixture percentage of Flyash-10% Lime-35% Gypsum-3% Quarry dust-52%.

Key words: Fly ash, Lime, Gypsum, Sandy, Compressive strength, Efflorescence and Water absorption**.**

I. INTRODUCTION

In the present trend in the construction industry, use of economic and eco friendly material is of a best concern. In present scenario one of the main materials used is cement. It is observed from various research studies that the heat which is emitting from cement shows a bigger percentage in global warming. An industry which deals in cements products account to a bigger emission of CO2 and they also use high levels of energy resources in the production of cement. In order to reduce these effects, change cement with some pozzolanic materials such as fly ash, which can have an better improve effect against these harmful factors. In this research work, we find the optimum mixture of fly ash (major ingredients) generated at Century Pulp and Paper Thermal Power Plant, sandy, hydrated lime and gypsum and also optimized the best pressure for forming building bricks. Fly ash- 55%, sand- 30% and hydrated lime – 15% with gypsum-14% was found to be the optimum mixture. For the optimum mix studied the compressive strength, tensile strength, Efflorescence, Initial rate of absorption, absorption capacity, Water absorption, shrinkage property, Flexural strength, unit volume weight, apparent porosity, microstructure open pore and impervious pore of the fly ash–sandy/clay–lime-gypsum building bricks manufactured with optimum composition under various building brick forming pressures, radio activity of the bricks made under optimum conditions were also investigated[1]. In this research paper, experimentally investigation is carried out for the fly ash brick mix proportions with different particle size and different material composition for strengthen purpose by Taguchi method (L9 Orthogonal Array Matrix). Minimum amount of lime and fly ash has been used as binding materials and considered the water binder ratio as control factor. So the effects of fly ash, water/binder ratio, sandy/clay, and gypsum on the performance characteristics are analyzed using mean response data and noise-to-signal ratios. Furthermore, the estimated optimum values of the process parameters are corresponding to binder/ water ratio of 0.4, fly ash of 10%, gypsum of 3%, lime of 35% and sandy/clay of 52% [2]. The addition of fly ash up to 30% at different temperature as 1000ºC and 1200^{0}C has no significant harmful effects on the brick quality. It was noticed that the fly ash added building bricks show reasonably best properties and may become competitive with the conventional building bricks. Applications of fly ash as a raw material for the building bricks production is not only capable alternative to clay but also a solution to difficult and expensive waste disposal problem[3]. In the present research work the attempt has made to find the optimum mixture percentage of different building brick material like, to obtain maximum compressive strength, tensile strength, Flexural strength, Efflorescence and Water absorption of fly ash brick admixed with lime, fly ash, clay/sandy and gypsum at various proportions. In present scenario composite are most successful materials used in various applications for latest works in the industry. Deepak Singla1, S.R. Mediratta presented research on composite material Al 7075 with fly ash as reinforcement are likely to overcome the cost barrier as well as the different mechanical and physical properties for application in the space craft and automotive industries. Composite material 7075-Fly

Ash Composites by using Stir Casting arrangement which was properly distributed the ash particles all over the required specimen and shows significantly improved properties which including toughness, hardness, high tensile strength, low density and good wear resistance as compared to other metals and alloy. On increasing the amount of fly ash strength in all test increases up to a certain level afterwards strength was decreases.[4]

II. OBJECTIVE

To find out the optimum mixture composition design for making building brick so as to achieve the maximum Compressive Strength, Efflorescence and Water absorption of fly ash building brick for three particle size 425, 600, 825micron of fly ash which further cure at different temperature 1000^{O}C 1100^{O}C and 1200^{O}C in furnance.

III.NEED FOR THE RESEARCH STUDY

1. To improve the engineering properties such as strength, workability, plasticity, water absorption tightness and Efflorescence of building bricks etc.
2. To increase the compressive strength to estimate the stability and durability of the brick.
3. To maintain the optimum Indian standard uniform size and shape of fly ash bricks and to reduce the plastering thickness.
5. To reduce the overall manufacturing cost of high strengthens building brick.
6. To minimize the consumption of fertile land soil in manufacturing of building bricks and finds the alternative for this problem.
7. To increase the utilization of fly ash in building brick so that we easily recycle the fly ash and protect our fertile land soil from sulphur which is present in fly ash and
8. To find the optimum material ratio composition of fly ash in building brick this satisfied the level of strength properties as well according to market demand and for specific situation like earth quack.

IV. MATERIALS AND METHODOLOGY

The following are the details regarding methods, methodology and properties of the materials used in this research study.

A. Materials Used

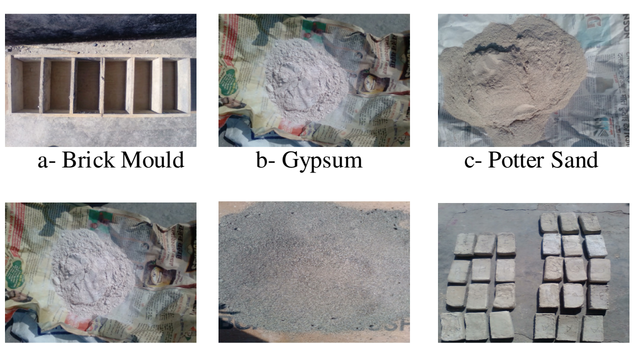
Sandy/Clay/Potter Sand
Gypsum
Lime
Fly Ash

Fly ash Fly Ash produced from Coal combustion in Thermal Power Plants is a main concern for environment. In today scenario, about 25 million tons of fly ash is produced from Thermal Power Plants in IGL, century paper and pulp plant, and Odisha. Fly ash is classified into three types: Pond ash stored in ash pond/mounds, Fly ash collected from ESP of Thermal Power Plants, and bottom ash – collected at bottom ash hopper of the boiler, which has largest carbon concentration. Fly ash is used in many sectors and areas such as, road making, construction materials, cement, dykes, asbestos, etc. Therefore, it is considered as a resource. At present around 1 million tons of fly ash is utilized in Brick making in Odisha, contributing to 4% use of total ash produced in the state. In order to encourage and inflate ash utilization in brick manufacturing, this guideline has been prepared by Fly Ash Resource Centre (FARC), State Pollution Control Board, Odisha. Fly Ash is a fine grey amorphous powder, which rich in Alumina and Silica. The properties of Fly Ash may vary both chemically and physically based on coal nature and the process of combustion. Fly Ash produced due to pulverized coal combustion. Its characteristics includes Spherical in shape, Fine particle size, Low carbon content, Better finish, Pozzolanic reaction, Reduced shrinkage, Cost saving and Increased long term strength. Pulverized fuel ash-lime bricks are manufacture from materials which includes fly ash in major quantity, lime and an accelerator which acts as a catalyst. Pulverized fuel ash-lime bricks are produced by blending above raw materials and then moulded into bricks form. For controlling the water absorption in the final product sand or crushed bottom fuel ash is also utilized in the composition as a coarse material. The major advantages of fly ash bricks are Lower water absorption, High compressive strength, Dimensional accuracy, Consumption of less mortar in construction High strength to weight ratio, Conservation of natural resources, like soil, sand etc. Now Fly ash bricks widely utilized in pavements, construction of buildings, boundary wall etc. For concern of quality assurance and market value, fly ash bricks require certification by **BIS. IS 12894:2002** for production of pulverized fuel ash lime bricks whose specification stipulates the various requirements.

Lime Lime is an important material for binding, now a day's which is used popularly in building construction. It is basically found as mixed form of Calcium oxide (CaO) and magnesium oxide (MgO) in nature. At ordinary temperature Lime reacts with fly ash and forms a compound possessing cementations characteristic or property. When fly ash, lime and calcium silicate hydrates are react with each other, they are responsible for the good strength of the compound.

Gypsum Gypsum is a soft crystalline rock which is an non-hydraulic binder occurring naturally as or sand. Gypsum have a precious property like incombustibility, small bulk density, good fire resistance, good sound absorbing capacity, hardening and rapid drying with, superior surface finish, and negligible shrinkage etc. In addition it can rise viscosity or improve material strength. It has 2.31 grams per cubic centimeter specific gravity. Gypsum powder has 2.8 to 3 grams per cubic centimeter density.

Potter Sand/Clay: We can break dirt into several sections: topsoil, clay, inelastic earth, and rock. Clays and inelastic earths are the results of decomposing rocks, in which the particle size is extremely small. Rocks include bedrock and boulders all the way down to fine sand. Most clay contain several different types of clay minerals with different amounts of metal oxides and organic matter, this is what sets the different types apart. Clay differs from the inelastic earths and fine sand because of its ability, when wet with the proper amount of water, to form a cohesive mass and to keep its shape when molded. This quality is called as plasticity of clay. When heated to high temperatures, clay also partially melts, resulting in the tight, hard rock-like substance known as ceramic material. There are many different types of clay bodies you can work with. Pick which is best for you. Clay can be divided into several classes, based on characteristics and at what temperature the clay fired so that it becomes mature, or reach its optimum hardness and durability. The three most commonly used clay bodies are mid-fire stoneware, high-fire stoneware, and earthenware. All three are available in moist commercially, ready-to-use form. Clay bodies can also be produced by mixing dry clays and additives with water to create your own desired clay body. Clay has very smallest particle size of any type of soil, with separate particles being so small that they can only be viewed by an electron microscope. This allows a large quantity of clay particles to prevail in a relatively minimum space, without the space that would usually be present between larger soil particles. This feature plays a large part in clay's smooth texture, because the separate particles are too small to produce a rough surface in the clay. Because of the small particle size of clay soils, the structure of clay-heavy soil tends to be very dense. Typically particles bond together, creating a mass of clay that can be tough for plant roots to penetrate. This density is responsible for clay-heavy soil being thicker and heavier than other clay soil, and soil types takes longer to heat up after periods of cold weather. This density also makes clay soils more resistant to erosion than sand or loam-based soils. Clay contains very minimum organic material; you often require to add amendments if you wish to grow plants in clay-heavy soil. Without added organic material, clay-heavy soil typically lacks the micronutrients and nutrients necessary for plant extension and photosynthesis. Mineral-heavy clay soils may be alkaline in nature, resulting in the need for auxiliary alteration to balance the soil's pH before planting anything that prefers a neutral pH. It's important to test clay-heavy soil before planting to determine both the soil's pH and whether it lacks important nutrients such as nitrogen, phosphorus and potassium. One of the problems with clay soil is its slow permeability resulting in a very large water-holding capacity. Because small and close soil particles are together, water takes much longer time to accelerate through clay soil than it does with other soil types. Clay particles then absorb this water, expanding as they do so and further slowing the water flow through the soil. This not only stop water from penetrating deep into the soil but can also damage and destroy plant roots as the soil particles expand.



a- Brick Mould b- Gypsum c- Potter Sand

d- Lime e-Fly Ash f- 9 Samples of Bricks

Figure 1: Different Material Composition used in Manufacturing of Fly Ash Bricks Pictures with Varying Samples and Mould.

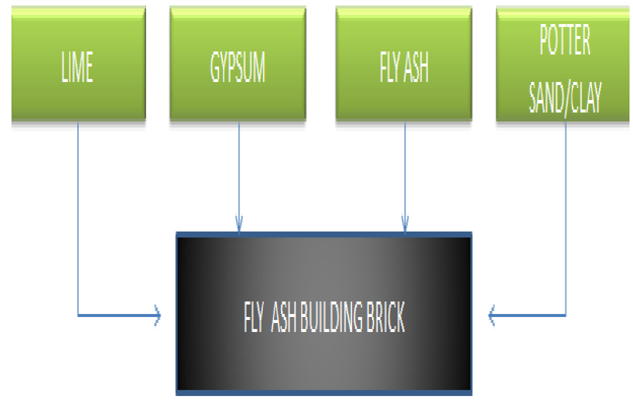


Figure2: Flow Diagram of Different Composite Material Used In Fly Ash Building Bricks

B. Methedology Used:

In this present research paper as a methodology we are using Taguchi method for finding the optimum mixture percentage with varying materials, material composition ratio and fly ash particle size for analyzing the compression strength, water absorption ratio and Efflorescence test. The material composition ratio percentage of different material with three different particle sizes is shown in table number 2 where gypsum percentage is taken constant throughout the samples.

Table Number 1: L9 Orthogonal Array Chart For Four Factors With Three Levels

EXPERIMENT NO.	P1	P2	P3	P4	LEVEL
1	1	1	1	1	L1
2	1	2	2	2	L1
3	1	3	3	3	L1
4	2	1	2	3	L2
5	2	2	3	1	L2
6	2	3	1	2	L2
7	3	1	3	2	L3
8	3	2	1	3	L3
9	3	3	2	1	L3

Table Number 2: Material Ratio Composition in Percentage.

LIME	FLY ASH	POTTER CLAY	GYPSUM	PARTICLE SIZE
25%	10%	42%	3%	425
25%	20%	47%	3%	600
25%	30%	52%	3%	825
30%	10%	47%	3%	825
30%	20%	52%	3%	425
30%	30%	42%	3%	600
35%	10%	52%	3%	600
35%	20%	42%	3%	825
35%	30%	47%	3%	425

In Taguchi method we are using L9 orthogonal array where we select 4 factors with three different levels as shown in table number 1. According to this L9 orthogonal array nine experiments were prepared for compression test. Out of which we find the best possible composition ratio with different particle size for the manufacturing of best fly ash building bricks for market concern.**Table Number 3**: Material Ratio Composition In Grams For Weight 1.175kg.

LIME	FLY ASH	POTTER CLAY	GYPSUM
1293.75	517.5	2173.5	155.25
1293.75	1035	2432.25	155.25
1293.75	1552.5	2691	155.25
1552.5	517.5	2432.25	155.25
1552.5	1035	2691	155.25
1552.5	517.5	2173.5	155.25
1811.25	1552.5	2691	155.25
1811.25	1035	2173.5	155.25
1811.25	1552.5	2432.25	155.25

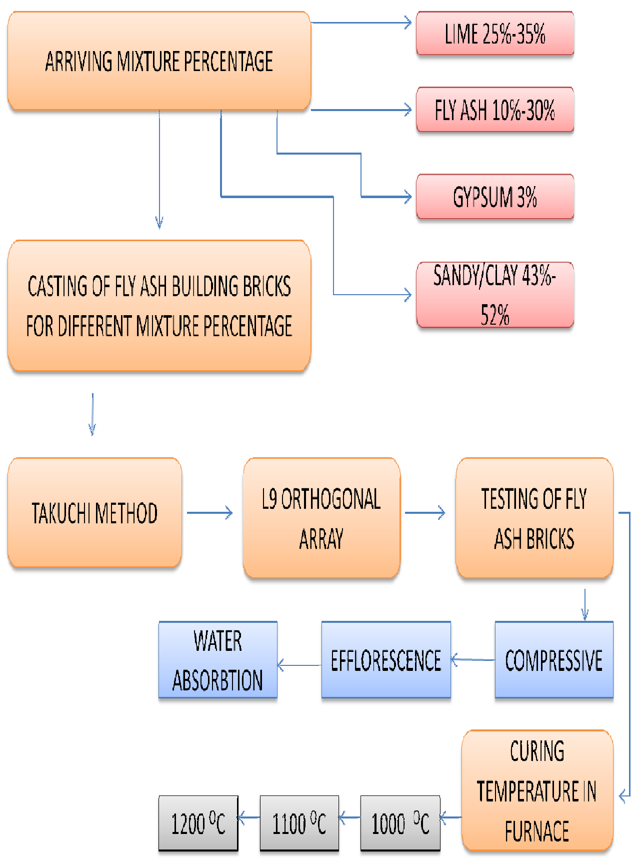


Figure3: Methodology Flow Chart

IV.Result And Discussion

The experimental based investigation was brought out to find the optimal mixture percentage with varying material composition fly ash building bricks of different particle size admixed with lime, gypsum, and potter sand and also to find the water absorption. Arriving set of experiments, Mixture samples are arrived by referring the latest articles and collection of data prepared the local manufacturing companies. For the various varying material compositions, fly ash building bricks are cast and several sets of experimental samples of building bricks according to L9 Orthogonal array was formed so that the following tests were conducted. Tests applied to bricks were as follows: Compressive Strength test, Water Absorption test, Efflorescence test.

A. Compressive Strength Test

The compressive strength of fly ash building brick is twice times greater than the normal clay brick. The minimum compressive strength of clay brick is 3.5 N/mm².So as the fly ash building brick has the compressive strength of 5-6 N/mm². Bricks to be used for different works should not have compressive strength less than as mentioned above. In our research paper, we used the digital universal testing machine for testing the compressive strength of bricks.

Table Number 4: Compression Strength of Different Samples.

EX. NO.	LIME	FLY ASH	POTTER CLAY	PARTICLE SIZE	COMPRESSION TEST
1	25%	10%	42%	425	5.48
2	25%	20%	47%	600	4.17
3	25%	30%	52%	825	4.02
4	30%	10%	47%	825	5.39
5	30%	20%	52%	425	4.22
6	30%	30%	42%	600	4.07
7	**35%**	**10%**	**52%**	**600**	**6.45**
8	35%	20%	42%	825	4.49
9	35%	30%	47%	425	4.14

Table Number 5: Compression Strength with Varying Curing Temperature.

Experiment No.	Temperature		
	1273 K (N/mm²)	1373 K (N/mm²)	1473 K (N/mm²)
1	0.81	2.43	5.48
2	0.34	1.67	4.17
3	0.12	1.23	4.02
4	0.68	2.36	5.39
5	0.22	1.43	4.22
6	0.21	1.62	4.07
7	**0.98**	**2.95**	**6.45**
8	0.44	2.08	4.49
9	0.03	0.97	4.14

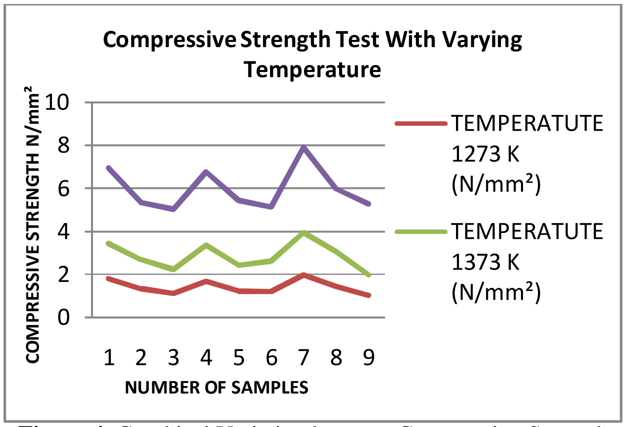


Figure 4: Graphical Variation between Compressive Strength with different Number of Samples

After the curing time gets over building bricks are placed for heating at three different temperatures in furnace i.e. 1473K, 1373K, and 1273K. After completion of combustion of building bricks in the furnace, brick samples prepared for testing. For testing the samples the building bricks are placed in the calibrated Compression testing machine of capacity 3000 KN, which applied a uniform load at the rate of 2.9 KN/min. The load of failure is the maximum load at which different sample fails which is recorded in the indicator reading on the testing machine, as shown in table number 4 and 5.

Taguchi Analysis: Compression Test of Fly Ash Bricks Prepared at Temperature1273 K versus Lime, Fly Ash, Potter Clay, Particle Size

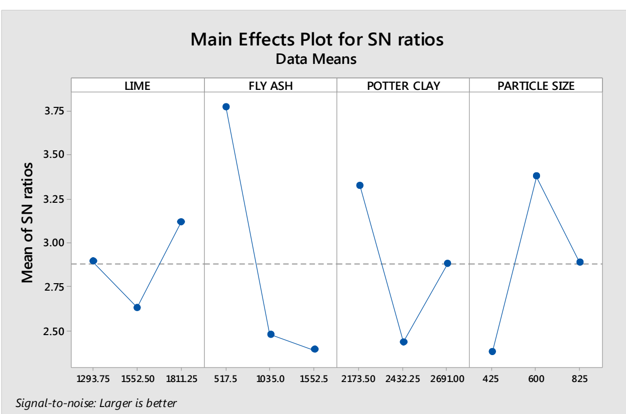


Figure 5: Main Effects Plot for SN ratios for Compressive Strength Test of Bricks Prepared at Temperature 1273K

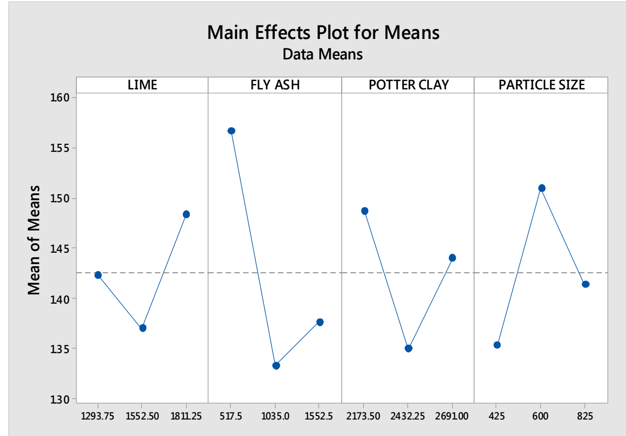


Figure 6: Main Effects Plot for Means for Compressive Strength Test of Bricks Prepared at Temperature 1273K

Table Number 6: Response Table for Signal to Noise Ratios Larger is better

			FLYASH	PARTICLE
Level	LIME	FLY ASH	CLAY	SIZE
1	2.893	3.772	3.326	2.379
2	2.630	2.479	2.435	3.377
3	3.119	2.391	2.882	2.886
Delta	0.489	1.380	0.891	0.998
Rank	4	1	3	2

Table Number 7: Response Table for Means

			FLYASH	PARTICLE
Level	LIME	FLY ASH	CLAY	SIZE
1	1.423	1.567	1.487	1.353
2	1.370	1.333	1.350	1.510
3	1.483	1.377	1.440	1.413
Delta	0.113	0.233	0.137	0.157
Rank	4	1	3	2

Taguchi Analysis: Compression Test of Fly Ash Bricks Prepared at Temperature1373 K versus Lime, Fly Ash, Potter Clay, Particle Size

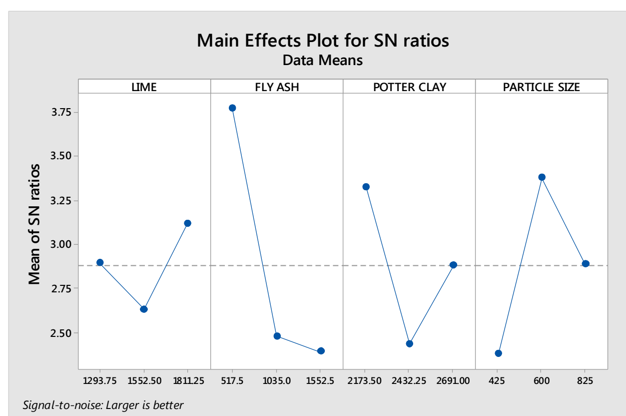


Figure 7: Main Effects Plot for SN ratios for Compressive Strength Test of Bricks Prepared at Temperature 1373K

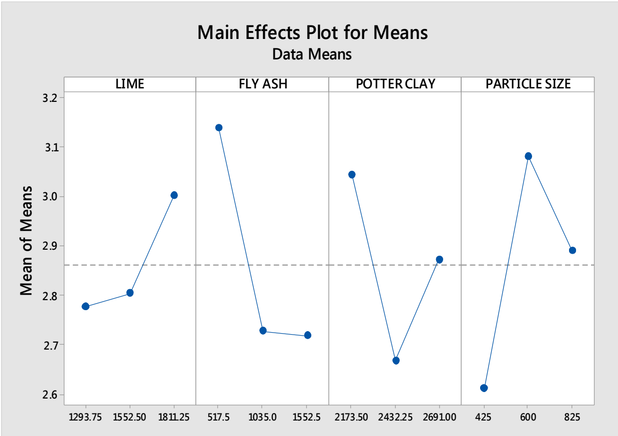


Figure 8: Main Effects Plot for Means for Compressive Strength Test of Bricks Prepared at Temperature 1373K

Table Number 8: Response Table for Signal to Noise Ratios Larger is better

			FLYASH	PARTICLE
Level	LIME	FLY ASH	CLAY	SIZE
1	8.734	9.866	9.614	8.102
2	8.868	8.671	8.315	9.609
3	9.197	8.262	8.870	9.088
Delta	0.463	1.604	1.299	1.507
Rank	4	1	3	2

Table Number 9: Response Table for Means

			FLYASH	PARTICLE
Level	LIME	FLY ASH	CLAY	SIZE
1	2.777	3.137	3.043	2.610
2	2.803	2.727	2.667	3.080
3	3.000	2.717	2.870	2.890
Delta	0.223	0.420	0.377	0.470
Rank	4	2	3	1

Taguchi Analysis: Compression Test of Fly Ash Bricks Prepared at Temperature1473 K versus Lime, Fly Ash, Potter Clay, Particle Size

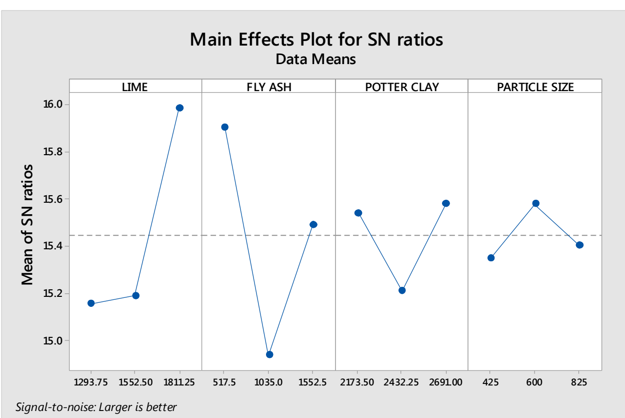


Figure 9: Main Effects Plot for SN ratios for Compressive Strength Test of Bricks Prepared at Temperature 1473k

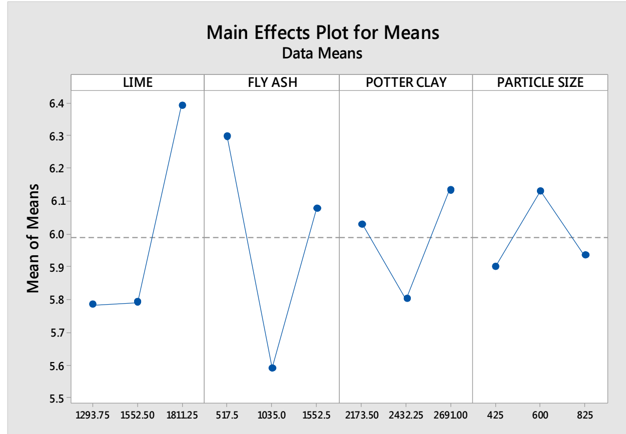


Figure 10: Main Effects Plot for Means for Compressive Strength Test of Bricks Prepared at Temperature 1473k

Table Number 10: Response Table for Signal to Noise Ratios Larger is better

			FLYASH	PARTICLE
Level	LIME	FLY ASH	CLAY	SIZE
1	15.15	15.90	15.54	15.35
2	15.19	14.94	15.21	15.58
3	15.98	15.49	15.58	15.40
Delta	0.83	0.97	0.37	0.23
Rank	2	1	3	4

Table Number 11: Response Table for Means

			FLYASH	PARTICLE
Level	LIME	FLY ASH	CLAY	SIZE
1	5.783	6.297	6.030	5.900
2	5.790	5.590	5.800	6.130
3	6.390	6.077	6.133	5.933
Delta	0.607	0.707	0.333	0.230
Rank	2	1	3	4

B. Water Absorption Test:

In water absorption test, firstly we weight all the samples before dipping into the water, after measuring the weight W1.

Table Number 12: Water Absorption Test Reading of Different Samples.

EX. NO .	W1 (kg)	W2 (kg)	(W2-W1)	(W2-W1)/W1	(W2-W1)/W1X100 %
1	1.69	2.15	0.46	0.272	27.2
2	1.71	2.29	0.58	0.339	33.9
3	1.73	2.36	0.63	0. 364	36.4
4	1.71	2.18	0.47	0. 401	40.1
5	1.69	2.25	0.56	0. 331	33.1
6	1.69	2.29	0.60	0. 355	35.5
7	1.75	2.16	0.41	0. 348	34.8
8	1.75	2.25	0.50	0. 425	42.5
9	1.75	2.34	0.59	0.808	80.8

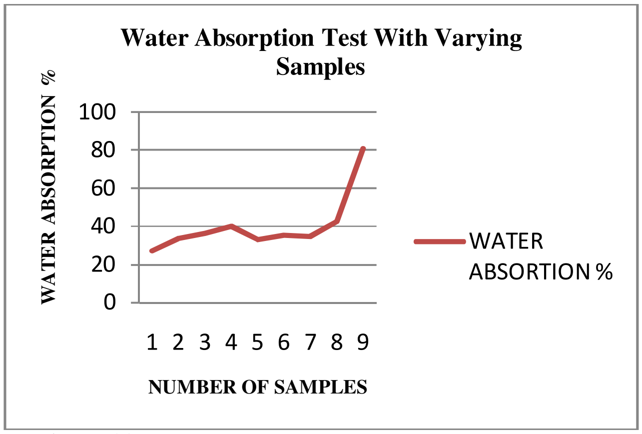


Figure 11: Graphical Variation between Water Absorption Percentages with Different Number of Samples

Taguchi Analysis: Water Absorption Test % versus Lime, Fly Ash, Potter Clay, Particle Size

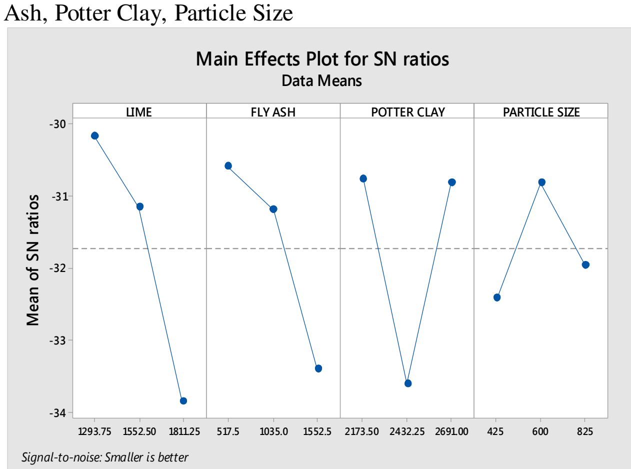


Figure 12: Main Effects Plot for SN ratios for Water Absorption Test of Fly Ash Building Bricks Prepared at Temperature 1473K

We dip all the samples into water for 24 hours, after 24 hours we take out all samples one by one and measure the weight as W2. After taking all short of reading we placed the entire sample in the oven at temperature of 105 to 115^{o} C till attains constant weight cool the bricks to room temperature and weight (W1). It is observed that the samples absorbed water not more than 11%. After removing all the bricks from oven, we calculate the Water absorption percentage by weight with formula W% = (W2 – W1/W1) x 100.

Figure13: Compressive Strength Testing Machine of 1000 N/mm capacity.

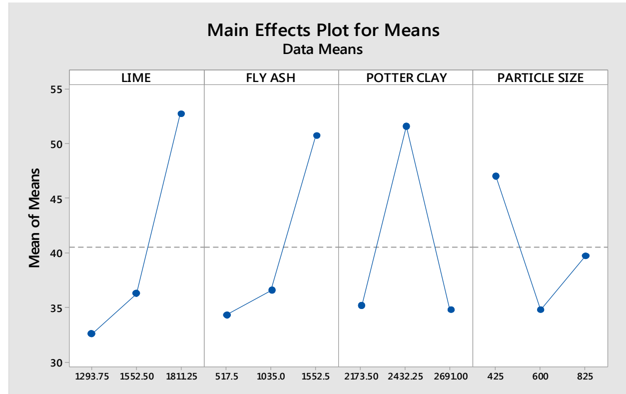


Figure 14: Main Effects Plot for Means for Water Absorption Test of Fly Ash Building Bricks Prepared at Temperature 1473k

Table Number 13: Response Table for Signal to Noise Ratios Smaller is better

Level	LIME	FLY ASH	POTTER CLAY	PARTICLE SIZE
1	-30.17	-30.59	-30.75	-32.41
2	-31.15	-31.19	-33.61	-30.81
3	-33.85	-33.40	-30.82	-31.95
Delta	3.68	2.81	2.85	1.60
Rank	1	3	2	4

Table Number 14: Response Table for Means

Level	LIME	FLY ASH	POTTER CLAY	PARTICLE SIZE
1	32.50	34.27	35.07	47.03
2	36.23	36.50	51.60	34.73
3	52.70	50.67	34.77	39.67
Delta	20.20	16.40	16.83	12.30
Rank	1	3	2	4

C. Efflorescence Test:

For efflorescence test, firstly we placed brick vertically in the water with one end immersed. The water immersion depth of fly ash building brick was 2.5 cm, and then all the arrangements placed in a well warm ventilated room at the temperature of 25-35 0C until all the water evaporates. The fly ash building brick absorbed and evaporates all the water present in the dish and place the similar quantity of water in the dish and allows it to absorb and evaporate as before. After this process, we examine all the samples of fly ash building bricks and we find the proper percentage of white spot on the surface area of fly ash building bricks. After observation, if any difference produces by the presence of salt deposit, then the report rated as 'effloresced', if there is no difference is occur, then the report rated as 'not effloresced'.

In our present research, it is being observed that the percentage of white spot in the fly ash building bricks= NIL.

VI. CONCLUSION

In our present research paper we are investigating to determine the optimum mixture percentage of fly ash building bricks for varying material composition with three different particle sizes of fly ash i.e. 425 micron, 600micron, and 825micron, which prepared at three different temperatures in furnance i.e. 1273K, 1373K, and 1473K, so that the optimum mixture percentage for fly ash building bricks of high compressive strength will further use for the different applications also. For the Compressive Strength Test and Water Absorption Test, sample 7 shows best results out of all samples i.e. $6.45 N/mm^2$ which is mention in table number 4. The best optimum mixture percentage for high compressive strength among all other samples is 10% Fly Ash, 35% Lime, 3% Gypsum and 52% Potter Sand for particle size 600 micron at temperature 1473K. From above result it is also concluded that as the particle size decreases, the compressive strength will also increase and the selected mixture composition shows and clearly proof that by using the above mixture composition percentage we minimize burning fuel cost because the temperature for preparing normal clay bricks is counted 1773K which is maintained five days continuously for manufacturing such bricks and we obtained twice better result as compared to that in which we provide only1473K temperature only for one day in electric furnance and we achieve twice better results for compressive strength test. Thus, we save the fuel also.

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