Utilization of Cementitious Material from Ground granulated blast furnace slag, Metakaolin and Silica Fume in Stabilized Soil Blocks

K.Srinivasan[1],M. Kaarmugilan[2],V. Karthikeyan[3],S. Dinesh Kumar[4],P. Santhosh[5]

[1]Assistant Professor, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Puducherry.
[2,3,4,5]UG Students, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Puducherry.

Abstract -A Brick is a most important material for the construction of building, walls, pavement and the most important element in masonry construction. The Egpytians made the first brick at 2500 BC. The first brick were made up of a mixed clay and straw after the growth of civilization there are more than thousand varieties of brick in different size and made with different materials . The red brick are the mostly used for the construction purpose and the red brick are burned to attain the strength. In our project we are using the expansive soil for making the brick. the soil will swell on absorption of the water and the soil will shrink on removal of water hence to enchance the properties of the soil the stabilize of soil were done for that cement were used and to enchance the properties GGBS, metakaolin , silica fume the three types of bricks with various proportion were made then the strength of the bricks are attained and the stabilized soil block are the unburned and the strength is found without burning the brick.

Key Words:Silica fume, Metakolin, Expansive soil, Cement, GGBS.

1. INTRODUCTION

Expansive soil, rich in strong hydrophilic mineral like montmorillonite and illite, is a special kind of clay soil formed in natural geological process. Expansive soil is characterized by expansion, shrinkage, and super-consolidability [1]. volume of expansive soil varies with water content. Change in volume will result in swelling pressure or contraction stress, consequently causing cracking and breaking up of foundations, pavements, rail-ways, roadways, and channels [2]. At the same time, hazards of expansive soil are often accompanied by recurrent and long-term latent features, so expansive soil is well known as “engineering cancer” [3]. How to stabilize expansive soil has become one of the global engineering problems in the field of engineering geology and geotechnical engineering today.Expansive soil of Central India, commonly known as Black Cotton soils such soil exhibits the extreme consistency hence the stabilization is done to enchane the physical properties of the soil , stabilization will increase the shear strength of the soil and increase the strength of the sub bases, The National Society of Professional Engineers (NPSE) has explored some of new types of soil stabilization technology for stabilization of soil properties but we are using various cementitious material to stabilize the soil and the brick were made without burning hence it is called as stabilized soil block.

In order to reduce damage caused by expansive soil, it is necessary to take certain treatments for expansive soil during construction. Are many stabilized measures for expansive soil, commonly involving soil replacement, chemical modifi-cation, humidity controlling, and special foundation systems [5]. Due to significant improvement effect and low engineering cost, the chemical modification is favored by engineers. Traditional chemical binders in soil stabilization are lime, cement, or lime/cement (i.e., a mixture of lime and cement) [6, 7]. Due to robustness and easy adaptability, incorporation of these traditional binders has gained pop-ularity [8–10]. Lime is the most usual modification material in expansive soil. Soil stabilization using lime is achieved through cation exchange, flocculation and agglomeration, lime carbonation, and pozzolanic reactions [11].

However, the traditional binders in soil stabilization are controversial, not only for their negative environmental effects during manufacture but also for their costs. In recent years, as environmental protection issues have drawn increasing attention, scholars have started to use various types of solid wastes as additives for expansive soil stabilization [12], such as fly ash [13], blast furnace slag [14, 15], cement kiln dust [16, 17], waste foam particle [18], alkali residue [19], and so on. Sometimes, some wastes can also be mixed with cementitious material during stabiliza-tion of expansive soil, for example, fly ash and lime [20, 21], bagasse ash and lime [22], natural volcanic ash and lime [23], phosphogypsum and lime [24], ground granulated blast-furnace slag and lime [25], iron tailing sands, and calcium carbide slag [26]. Mixtures can achieve better results than cementitious material alone.

Ordinary Portland Cement (OPC) is one of the most common stabilizers used for soil stabilization [29, 30]. However, it is well-known fact that manufacture of OPC contributes to a lot of CO_2 emissions which cannot augur well for a low cost green material. Earlier research in the manufacture of stabilized soil blocks have mostly concentrated on cement and lime stabilization of blocks. Studied the strength, durability, and shrinkage characteristics of cement stabilized soil blocks and tried to establish empirical guidelines for cement content required for a wide range of soils [28]. An investigated the effect of combination of lime and cement on the long-term durability of compressed stabilized earth blocks [31]. An investigated coal ash stabilized earth blocks and the effect of addition of cassava peels on their strength and performance [29]. The studied the performance of phosphogypsum stabilized adobe blocks and compared its performance with blocks stabilized with natural gypsum [32]. The studied the valorisation of Tunisian phosphogypsum in clay bricks [33]. A probed the performance of stabilized adobe blocks with cement and lime and their combinations [34]. Examined the durability of lime stabilized earth blocks [35], in a later study, investigated the performance of stabilized earth concrete in both labora-tory and field conditions [36].

2. Materials

2.1.1 Cement

Cement is a binder, a substance used for construction that sets, hardens, and adheres to other materials to bind them together. Ordinary Portland cement is generally manufactured by burning calcareous and argillaceous material at clinkering temperature and grinding it down with addition of little gypsum. Ordinary Portland cement has three grade 33, 43, 53.Ordinary Portland cement 53 grade is used for the stabilizing the expansive soil.

Table 1 Properties of Ordinary Portland cement

S.No	Properties	Obtained Results
1	Specific Gravity	3.15

2.1.2 Expansive Soil

Expansive soil is a soil that is prone to large volume changes that are directly related to changes in water content. Expansive soil has a shrink-swell property when soil has high water content then the soil will swell and can form deep cracks on the other hand if there is a low water content the shrink property will be occur . The continuous change in soil can cause uneven settlement to building hence the expansive soil are stabilized. The expansive soil is collected from the construction site and the soil sieved in 75micron sieved then the required sample is collected for our project .The geo-technical properties of the soil were tested in the laboratory in accordance with the Bureau of Indian Standards (BIS) codes and are tabulated.

Table 2 Properties of expansive soil

Characteristics	Value
In-situ Moisture Content %	37.5
Liquid Limit LL %	39.5
Plasticity Index PI	18.37
Sand %	12.07
Silt %	75.03
Clay %	12.9
Specific Gravity (SG)	2.67
γ d max Mg/m^3	1.59
Optimum moisture content OMC %	22
pH	7.78
Organic Matter Content %	7.95
Unconfined Compressive Strength qu (kPa)	134

2.1.3Water

Portable tap water was used in the work for both mixing and curing. Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into carefully. It is necessary to provide pure and good quality water. Normal portable water is used in this project.

2.1.4Ground Granular Blast Furnace Slag

Ground granular blast furnace slag is obtained from quenching molten iron slag, by product of The iron from blast furnace from water and it is dried and made as powder . GGBS cement can be added to concrete in the concrete manufacturer's batching plant, along with Portland cement, aggregates and water.GGBS is a by-product obtained in the manufacture of pig iron in the blast furnace and is formed by the combination of iron ore with limestone flux. If the molten slag is cooled and solidified by rapid water quenching to a glassy state, little or no crystallization occurs. The physical structure and gradation of granulated slag depend on the chemical composition of the slag, its temperature at the time of water quenching and the method of production. For our project we used the locally available ground granular blast furnace blast slag is used at specified proportion.

Table 3 Properties of Ground Granular Blast Furnace Slag

S. No	Properties	Obtained Values
1	Specific Gravity	2.9
2	Fineness Modulus	$>350m^2/kg$
3	Bulk density	$1800kg/ m^3$

Table 4 The chemical characteristics of GGBS used in this study.

Items	CaO	SiO	Al2O3	MgO	Fe2O3	SO3	K2O	TiO2	pH
GGBS	40.13	37.73	5.75	4.26	0.01	0.0	0.61	0.65	8.5

2.1.5 Metakaolin

Metakaolin is the anhydrous calcined form of the clay mineral kaolinite. Minerals that are rich in kaolinite are known as china clay or kaolin, traditionally used in the manufacture of porcelain. The particle size of metakaolin is smaller than cement particles. Metakaolin is manufactured byheating the china clay between600 and 800°C. When used in concrete, metakaolin undergoes a pozzolanic reaction and refines the microstructure of the hydrated cement paste. Metakaolingives more compressive and flexural strength and it is used for the light weight. In our projectwe used metakaolin for the light weight and for the compressive strength.

Table 5 Properties of Metakaolin

S.No	Properties	Obtained Values
1	Specific Gravity	2.3
2	Fineness Modulus	$700m^2/kg$
3	Bulk density	$350kg/ m^3$

2.1.6 Silica Fume

Silica fume, also known as microsilica, is an amorphous polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm silica fume is a very effective pozzolanic material.

Silica fume is added to Portland cement to improve its properties, in particular its compressive strength, bond strength, and abrasion strength. In our project silica fume is replaced at required proportion in to check the compressive strength.

Table 6 Properties of Silica Fume

S.No	Properties	Obtained Values
1	Specific Gravity	2.2
2	Specific Surface	370m^2/kg
3	Bulk density	576kg/ m^3

3.0 Dimension of the mould

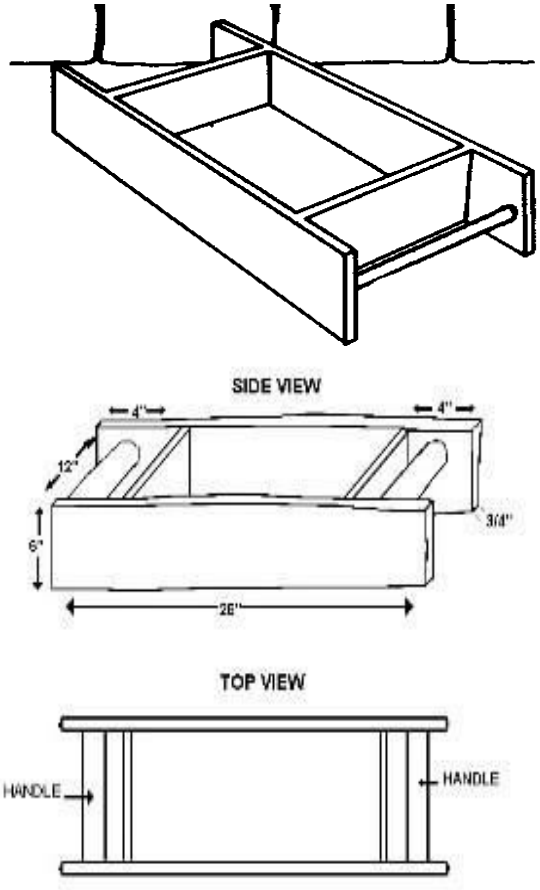

Fig 1 Dimension of Mould

3.1. Mix compositions, sample preparation and testing

3.1.1 Deciding of Percentage

The sample specimen brick size of (190*90*90)mm were casted with 8% of cement in bricks ,then addition of 2% , 4%, 6%, 8% of metakaolin in each brick(CM) ,the compressive strength of brick is tested after the curing of 7 days . The appropriate percentage of silica fume is found by same procedure by addition of 2%, 4%, 6%, 8% of silica fume in each brick (SC) with 8% of cement then compressive strength is tested after curing of bricks. Hence by this process with found that 4%, 8% of silica fumes and metakaolin gives better result. In our project we used a 4%, 8% of silica fume and metakaolin in alternate proportion.

3.1.2 CASTING OF BRICK

BRICK 1

The Standard brick size of (190*90*90)mm were casted. To Stabilize the expansive soil we used ground granular blast furnace slag is used .For the brick 53 grade ordinary Portland cement (8%), Expansive soil sieved in 75micron, Ground Granular Blast Furnace Slag(12%),is added with the specified proportion .

BATCHING AND MIXING

At first the raw materials such as Ground Granular Blast furnace slag ,clay, cement , water is taken of specified below given quantity, at next stage 12% of Ground Granular Blast Furnace Slag and 8% of cement which is to be replaced and is added to Clay and mixed thoroughly.At next stage the water is poured at appropriate rate and mixed with the mixture which is shown then mixed slowly and thoroughly tills it attains the consistency then mixture is poured in the mould , the bricks is casted.

Table 7 Mix Proportioning for Brick 1

SL. NO	MATERIALS	QUANTITY
1	Cement	151.6 kg/m ^{3}
2	Water	189 l/m ^{3}
3	Clay	1516.5 kg/m ^{3}
4	Ground Granular Blast Furnace Slag	227.5 kg/rn^3

BRICK 2

The Standard brick size of (190*90*90) mm was casted. To stabilize the expansive soil we used metakaolin and silica fume is used. For the brick 53 grade ordinary Portland cement (8%), Expansive soil sieved in 75micron, metakaolin (8%) and silica fume (4%), is added with the specified proportion .

BATCHING AND MIXING

At first the raw materials such as Metakaolin, Silica fume , clay, cement , water is taken of specified below given quantity, at next stage 8% Metakaolin, 4% Silica fume and 8% of cement which is to be replaced and is added to Clay and mixed thoroughly.The proportion of the material used in the brick are given in the below table, the metakaolin and silica fume are used with same percentage and compressive strength is found. At next stage the water is poured at appropriate rate and mixed with the mixture which is shown then mixed slowly and thoroughly tills it attains the consistency then mixture is poured in the mould , the bricks is casted.

Table 8 Mix Proportioning for Brick 2

SL. NO	MATERIALS	QUANTITY
1	Cement	151.6 kg/m ^{3}
2	Water	189 l/m ^{3}
3	Clay	1516.5 kg/m ^{3}
4	Metakaolin	151.6 kg/rn^3
5	Silica fume	75.83 kg/rn^3

BRICK 3

The Standard brick size of (190*90*90) mm was casted. To stabilize the expansive soil we used metakaolin and silica fume is used. For the brick 53 grade ordinary Portland cement (8%), Expansive soil sieved in 75micron, metakaolin (4%) and silica fume (8%), is added with the specified proportion .

BATCHING AND MIXING

At first the raw materials such as Metakaolin, Silica fume , clay, cement , water is taken of specified below given quantity, at next stage 8% Metakaolin, 4% Silica fume and 8% of cement which is to be replaced and is added to Clay and mixed thoroughly. At next stage the water is poured at appropriate rate and mixed with the mixture which is shown then mixed slowly and thoroughly tills it attains the consistency then mixture is poured in the mould , the bricks is casted.

Table9 Mix Proportioning for Brick 3

SL. NO	MATERIALS	QUANTITY
1	Cement	151.6 kg/m ^{3}
2	Water	189 l/m ^{3}
3	Clay	1516.5kg/m ^{3}
4	Metakaolin	75.83kg/rn^3
5	Silica fume	151.6kg/rn^3

Fig 2 Casting of bricks 3

3.1.3 CURING PROCESS

Thus the strength of the brick not only depends upon the mix proportions thus to prevent the loss of moisture and to maintain the temperature, curing is carried out all the specimens that we have casted are demoulded with care and the bricks are cured by gunny bags curing.

3.1.4 NUMBER OF BRICKS CASTED

For deciding the percentage 3 bricks were casted at each percentage, totally 24 bricks then for compressive strength 12 bricks and for the water absorption 12 bricks. All bricks were casted in Standard size of (190*90*90) mm then normal fired brick.

4. RESULTS AND DISCUSSION

4.1 COMPRESSIVE STRENGTH

About 12 cubes were casted and it is allowed for 7 days curing. After completing the drying process these cubes were tested in Compression Testing machine to determine maximum stress. Thus all cubes mix with 2% , 4%, 6%, 8% replacement of metakaolinwere tested at 7 days and tabulated below.

Table 10 Compressive Strength for Metakaolin at 7 Days in (Mpa)

Metakaolin%	Specimen	Compression Strength Value (N/mm^2)	Average Compressive Strength (N/mm^2)
2%	1	2.33	2.33
	2	2.37	
	3	2.31	
4%	1	2.43	2.45
	2	2.45	
	3	2.47	
6%	1	2.55	2.53
	2	2.55	
	3	2.53	
8%	1	2.63	2.65
	2	2.68	
	3	2.65	

Table 11 Compressive Strength for Silica Fume at 7 Days in (Mpa)

Silica Fume%	Specimen	Compression Strength Value (N/mm^2)	Average Compressive Strength (N/mm^2)
2%	1	3.15	3.11
	2	3.12	
	3	3.08	
4%	1	3.25	3.26
	2	3.29	
	3	3.24	
6%	1	3.39	3.41
	2	3.42	
	3	3.43	
8%	1	3.57	3.55
	2	3.54	
	3	3.54	

About 12 cubes were casted and it is allowed for 7 days curing. After completing the drying process these cubes were tested in Compression Testing machine to determine maximum stress. Thus all cubes Standard fried brick, Brick 1, Brick 2, Brick 3 were tested at 7 days and tabulated below.

Table 12 Compressive Strength For All bricks at 7 Days In (Mpa)

SL No	Specimen	Compression Strength Value (N/mm^2)			Average Compressive Strength (N/mm^2)
1	Standard brick	3.2	3.21	3.19	3.21
2	Brick 1	3.63	3.64	3.6	3.62
3	Brick 2	2.65	2.68	2.7	2.68
4	Brick 3	3.99	4.0	3.97	3.99

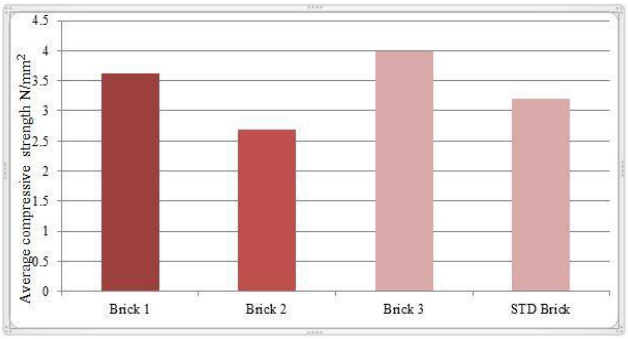

Chart 1 Compressive Strength for All bricks

4.3 WATER ABSORPTION TEST

Water absorption is the amount of water absorbed by the specimen generally expressed in percentage. For the water absorption test we have casted six 100mm cubes for water absorption the sample is oven dried at 110^0C and the weight is now taken as w1 for more than 2 hrs and then completely immersed in water for 24hours after the soaking period thus the surface of the cube is gently wiped and the weight is noted as w2 and for both M10 and M30 the water absorption value is tabulated below.

Water absorption = (Wet weight- Dry weight/Dry weight)*100

Fig 3 Water Absorption Test

Table 13 Water Absorption Test

SI NO	SPECIMEN	WATER ABSORPTON (%)			Average Water Absorpton(%)
1	Standard brick	9.8	9.5	9.4	9.5
2	Brick 1	7.3	6.8	7.4	7.16
3	Brick 2	9.8	10.4	9.9	10
4	Brick 3	10.9	11.2	11.4	11.1

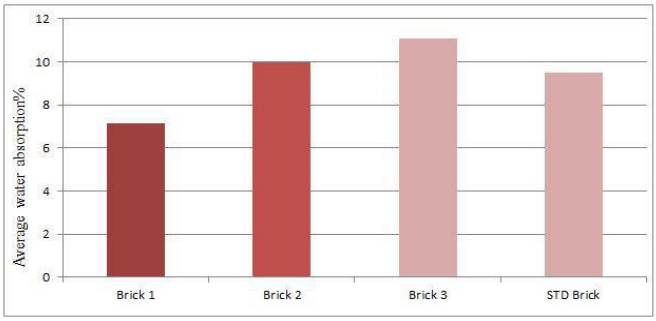

Chart 2 Water Absorption Test

5. CONCLUSIONS

This project is focused on the review of performance of the unfired brick with the addition of metakaolin and silica fume. The study suggests that the proper combination of metakaolin and Silica fume can be used as a brick for the construction .On the basis of this project the following results were obtained.

1. The addition of metakaolin (4%) and silica fume (8%) to the expansive clayey soil it increases the compressive strength at the same there increases in water absorption.
2. The compressive strength of brick 3 is 21.7% greater than the standard fired brick. The addition of silica fumes increases the water absorption also increases.
3. The combination of metakaolin and silica fume are very effective in stabilizing the expansive soil hence it may be new technique to stabilize the expansive soil.
4. In brick 2 increasing the percentage of metakaolin, compressive strength of the brick of decreases.
5. The unfired brick with addition of Ground Granular Blast Furnace Slag had done already but the addition of silica fume 8% and metakaolin 4% had better compressive strength.
6. The Brick 3 (Metakaolin 4%, Silica fume 8%) has equal performance compared to standard fired brick hence it used as replacement of fired brick, also it reduce emission of carbon dioxide.

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BIOGRAPHIES

K.Srinivasan. M,Tech., Assistant Professor, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry – 605107.

M.Kaarmugilan. UG Student, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry – 605107.

V.Karthikeyan. UG Student, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry – 605107.

S.Dinesh Kumar. UG Student, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry – 605107

P.Santhosh. UG Student, Department of Civil Engineering, Sri Manakula Vinayagar Engineering College, Madagadipet, Puducherry – 605107.