AMALGAMATION AND CHARACTERIZATION OF FLY ASH BEDMADE BY USING GGBS AS ADMIXTURE

A thesis submitted in partial fulfilment of the requirements for the degree of

Master of Technology

in

Civil Engineering

Submitted by

Jitendra Kumar

(Roll No.: 1904790005007)

Under the Supervision of

Mr. Anuj Verma

(Assistant Professor & Head)

Department of Civil Engineering

Rajshree Institute of Management & Technology

Bareilly – 243001 (U.P.)

Affiliated to

Dr. A.P.J. Abdul Kalam Technical University, Lucknow

(Formerly Uttar Pradesh Technical University)

June 2023

D E C L A R A T I O N

I hereby declare that the work which is being presented in dissertation entitled, **"Amalgamation and Characterization of Fly Ash Bed Made by Using GGBS as Admixture"**, as a part of curriculum for award of the degree of **"Master of Technology in Civil Engineering** with specialization in **Civil Engineering"** and submitted in the Department of Civil Engineering of **Rajshree Institute of Management & Technology Bareilly**, is an authentic record of my own work carried out under the guidance of **Mr. Anuj Verma**, Assistant Professor, Department of Civil Engineering, Rajshree Institute of Management & Technology, Bareilly, U.P.

Place:

Date: **Jitendra Kumar**

C E R T I F I C A T E

Certified that Mr. **Jitendra Kumar**(1904790005007) has carried out the research work presented in this thesis entitled "**Amalgamation and Characterization of Fly Ash Bed Made by Using GGBS as Admixture**" for the award of **Master of Technology** from **Rajshree Institute of Management & Technology Bareilly** under my supervision. The thesis embodies results of original work, and studies are carried out by the student himself and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Signature
Mr. Anuj Verma
Assistant Professor& Head
Department of Civil Engineering

ABSTRACT

Flyash is a kind of by-product that is extremely fine and gets emerged from the combustion of coal inside thermal powerplants. The chunk of ash that settles at the surface of boiler is called bottom ash. Almost 80 percent of the total produced waste accounts for fly ash and the leftover 20 percent is bottom ash as per the weight of the substances.

Talking about production in India, about 184.14 metric tons was produced only in 2014-15. And in this number, the amount that was used was only about 102.59 metric tons which accounts of about 61 percent of the year 2015-2016, where the generated flyash accounted 176.74 metric tons. In this, only about 107.77 metric tons or about 60.97 percent was used. We can see that the flyash is getting increasingly produced and used but almost 40 percent of the substance comes put as waste. This unused flyash will either go down as a landfill and will cause ecological issues. Based on the landfills, a few heavy metals like boron, mercury and cadmium with finest particles of this substance get fileted into ground water and lead to contamination of ground water. Even air pollution is caused due to he flyash that emerges as a waste.

This study tries to make effective and efficient use of flyash that can be used as geo-engineering material. Products utilized in this study were flyash of F-class and emerged out Adhunik Metalics Limited in Sundergarh. Properties relating geo-techniques such as UCS strength, specific gravity, MDD, and OMC were found out for the flyash.

To augment flyash features, it was amalgamated with a slag and lime in distinct proportions. A quantity of line was added to flyash in different percentages such as 0 percentage, 5 percentage, 10 percentage, 15 percentage and 20 percentage. Also, quantities of amalgamations of slag, flyash and lime were mixed for the test. The process that too place was light compaction test and this brought forward MDD and OMC in distinct proportions of flyash mixed with GGBS and lime. The samples were then cured by keeping the average temperature at 28 degrees C and the models were wax-sealed with curing period varying between 0 days, 7, 14 days and 28 while the determination of UCS takes place.

While the samples were tested using a hydrometer, flyash was found to be graded consistently while the particles size was found to lie somewhere between silt and fine sand. At high OMC, the determined MDD was less. When the flyash was treated with slag and lime, MDD was enhanced and reduction of OMC took place. For virgin flyash, the value of UCS was too low but after getting lime treatment it enhanced quickly but in a bit. For flyash solution treated with lime, UCS was augmented while the curing period increased as well.

The value of UCS for flyash solution treated with slag was quite less when quick testing was done and while the enhancement in periods of curing took place, the value of UCS enhanced quite a bit. Flyash strength due to treatment with slag and lime tend to be the most when it was cured for about 28 days.

For unit period of curing, the solution flyash amalgamated with lime plus slag displayed a much high value of UCS against the flyash sample that was treated with similar percent of lime but not any slag. This pointed a great pro of mixing flyash with slag. Slag contains a high quantity of pozzolana such as alumina and silica and it also has a lot of lime. But against this, GGBS contains some distinct properties with water and these were initiated only in alkaline system. Under the circumstances, lime was utilized to offer an environment of alkalinity for pozzolanic reaction to occur.

List of Tables

Page No.

List of Figures

Table of Content

CHAPTER 1
INTRODUCTION

1.1 GENERAL

Coal is a very important resource for India where most of the industries such as thermal power plant, mineral industries are using coal for extracting energy. Production of this waste material is about 176.74 million tons in the year 2015-2016 and is expected to rise at 85.48 million tons till the mid of year 2017**(ENVIS 2017)**. The utilization of fly ash in the country has risen from 13 million tons to 51million tons and further 107.77 million tons in the recent years **(Shreya and Paul 2015; ENVIS 2017)**.

The inappropriate disposal of this waste material can cause various health problems such as silicosis, pneumoconiosis, etc. and it also effect the environment by forming a highly toxic liquid when mixed with water which can pollute the water table by contaminating with heavy metal **(Sikka and Kansal 1995)**. The Government of India has taken initiative on the fly ash mission with the help of Technology Information and Assessment Council (TIFAC) as its implementing agency for the sustainable utilization of fly ash.

Fly ash is using as a replacement of sand, gravel, limestone and clay for utilisation in dumping the low-land and making bricks and other civil engineering works. One of type ofutilization is pelletization by fly ash which could be further used for making buildings. Pelletized fly ash are light weight, ease to compaction, low specific gravity, good frictional property, alkaline nature, insensitive to change in moisture content etc. and therefore, can be good aggregate in concrete **(Sivakumar and Gomathi 2011; Pandian 2004)**.

Cement as a binder holds properties for using it as a pellet material. Cement also makes a cold bond which prevents pellets from collapsing. Thus it can provide very high strength to the pellets and further of these pellets can also be subjected to very high compressive strength. Geotechnical tests are conducted on the materials in the early stage of design for understanding the physical suitability of fly ash.

Flyash emerged due to the combustion of coal and is a kind of waste material which has features quite similar to ash emerging from volcanoes. While coal burs in thermal powerplants, the highest temperature can be recorded at 2800 degrees F. In the environment, the materials that are not combustible while emerging from burning or coal are flyash & bottom ash. Flyash emerged with the help of flue gasses and contained. Against this, the lighter bottom as is collected from boiler’s floor.

India’s generation of flyash accounts for about 176.74 metric tons or year 2015 and 2016 and in this only about 107.77 metric tons or about 60.97 percent was used. The leftover of this ash

was added to ground that led to ecological disbalances and would either pollute the air or could pollute the underground water.

Table 1: Characteristics of fly ash

Sl No.	PHYSICAL	CHEMICAL	BIOLOGICAL
1.	Spherical in shape, light weighted which cause bulk density, increasing in porosity.	Constituent element of fly ash are: Aluminium, iron, Calcium, Carbon, Magnesium, Potassium, Sodium, Sulphur and Manganese. Trace elements include Cadmium , and Zinc Inorganic ions are: Calcium, Carbon, Magnesium, Potassium, Sodium, and Sulphur.	It will stop soil erosion by working as a conditioner to soil
2.	It cause soil to porous in nature	This to provide the salt requirement of plant for the improvement of the growth of plants.	Provide favourable environment for the growth of various microorganism
3.	Flyash when mixed with soil improves the properties such as texture, bd,	With the improvement of soil properties such as soil cause improvement in the water retaining and mc properties	

1.2 PROPERTIES OF FLYASH

Powerplants produce a very fine powder known as flyash that emerges out due to burning or coal. You may also call it pulverized fuel ash. The size of its particles can be anywhere

between silt and fine sand. Apart from ferrous oxide and alumina, the major element that forms this is silica.

The activity of pozzolana that entails the Ca(OH)2 reaction with major elements of flyash sample. While Al2O3 and SiO2 are a part of the flyash, this includes Ca(OH)2 to give out CAH and CSH. Different pozzolanic reactions taking place with the reaction was also taken into account.

1.3 CLASSIFICATION OF FLYASH

When coal is combusted in a thermal powerplant, the minerals that do not get burned are assembled from air stream of the combustion and this is known as flyash.

Pozzolan is a kind of material that encompasses minerals such as aluminous and siliceous products that has very less or nil cementing features. However, when introduced to calcium hydroxide with temperature being normal, they result in compound that contain cementing features.

Flyash is often grouped in two heads: Flyash of Class F and Flyash of Class-C

Almost the entire flyash content resulting from the coal combustion process is known as flyash of class-F. It can contain products such as alumina, silica and iron with about the percentage of 70 and lime percentages is about 15 in most cases. Since flyash of class F will incorporate less lime quantity, in order to contain pozzolanic activity some extra lime may be needed.

Flyash of class C normally comes with high quantities of lime that can be over 30 percent. Therefore, pozzolanic activities can be natural even when no extra amount of lime is needed.

1.4 STRENGTH FEATURES OF FLYASH

In this testing, we used flyash of class F and it emerged out of Adhunik Metaliks Limited in Sundergarh. In order to ensure flyash suitability for construction, the features such as strength, the parameter for settlement and consistency were tested. In this test, an effort came to measure features of flyash that attained stability in presence of slag and lime with proper percentages to flyash. There were 2 phases of this study. The first phase encompassed chemical and physical flyash features determination using hydrometer analysis, UCS test and Proctor Test. The second phase saw mixing of flyash with slag and lime in different percentages while different combos were made. The combos underwent a light compaction test followed by MDD and OMC determination. UCS was performed with a time period of 0 days, 7, 14 days, and 28 delay for studying the efficacy of curing.

To be very clear that pollution cause due to industry is never limit to that particular area. Pollutants were traced in all living being and this shows that the pollutants particle can travel for a long distance by the cause of climatic effect and by this they effect the environment as well in very numerous ways **(Molecular genetics, 1994)**. The pollutants ejected from industries has very potential of creating huge pollution and producing imbalance in the environment.

1.5 INTRODUCTION OF LIME

Lime is kind of an alkaline product that resulted due to limestone heating. It is a form of inorganic product that encompasses hydroxides, oxides and carbonates as the main elements. While it gets heated to a substantially high temperature, it results in quicklime. When you add water to this quicklime, results to limestones. Here is the cycle of this formation:

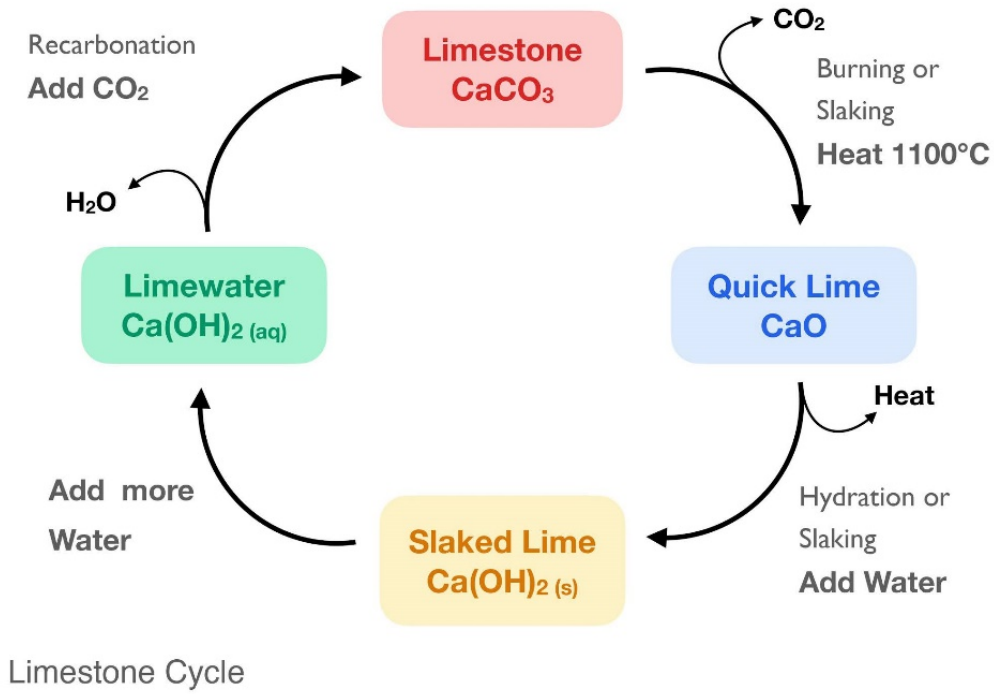

Fig 1 Lime Cycle

Lime is a very essential material used in construction whose history goes in a very ancient period. In fact, used in buildings. Besides, lime finds applications in lots of engineering works relating geotechnology and can be employed as a stabilizing agent for soil. It is

important as a stabilizing agent since it contains pozzolanic features. When employed as a stabilizer, a kind of pozzolanic reaction with occur. With the passing time, the soil would increase in strength. In his testing, we used lime as the major stabilizing agent for flyash but since it was really costly as well, we used distinct quantities of slag and line as stabilizing agent.

1.6 INTRODUCTION OF SLAG

Slag or GGBS is a waste product that emerges from iron production. When the melted blast furnace of iron is quenched, it leads to slag formation in water which is formed quickly. The product that forms on the stream is a kind of granular product that is glassy to touch and when dried and ground, a very fine powder is obtained. Slags can be obtained in three distinct types depending on distinct techniques of production:

- Slag emerging out of traditional ball mill
- Slag emerging out of roller press in high pressure
- Vertical roller press

The GGBS that is obtained from newest vertical mills contains amazing finess and the particle size is quite well distributed with immense activity index and low quantity variation if you match with the old mill of ball slag. The composition of minerals in this slag can vary depending on the raw material properties while the iron production takes place. Slag is a kind f product that has less viscosity and incorporates silicate and aluminate impurities from cokes and ores. GGBS contains products such as MgO, Al2O3, CaO and SiO2 as the major components. In this, if you increase the amount of CaO, the slag will see an enhance n its compressive strength.

Products like MgO and Al2O3 also offer some degree of strength. Just like cement, slag contains silica and lime as the major constituents in it and therefore you can use it to replace cement when while making concrete. Cement production leads to ecological issues and lime is still a major part of products that are used in cement manufacturing and we should remember that lime would go over some day. Therefore, slag can be a superior replacement option. However, the slag does not have as much ultimate strength like cement concrete and therefore it can take place of the cement only partially and this may lessen the amount of cement produced every day. As far as geo-technical projects are concerned, they use lime stabilization as a major technique. Slag contains a major portion of lime so it could really

replace lime but you cannot use GGBS as a direct stability agent since it has unnatural latent heat features which needs any alkaline substance to get activated. In this case study, flyash of class F that has been stabilized with lime and also contains GGBS in distinct amounts. Lime was considered an activator and distinct combos of GGBS and lime was studied to know the needed chemical and physical characteristics of the solution.

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

With the use of use of this literature review in the section, you get an overview of the processes that are needed in treatment and used as a stability agent for flyash as well as a distinct review when getting stabilized with lime. Not just this, it contains stability techniques for expansive soils that use lime and a few topics covered include study of slag and its role in construction.

2.2 LITERATURE REVIEW OF FLYASH

Al-Rawas et Al in 2003 studied this and told that industrial elements like cement furnace slag, lime and CBPD can be utilized as a stabilizing agent or flyash. Among all these, when you stabilize it with furnace slag, it needs lime to activate it.

Flyash is a kind of ash with fine particle of 4 micron to 10 micron of size. They were basically the flyash generated by thermal power plant when coal was burnt to heat boilers. These flyash are inorganic in nature and did not decay. It also occupy large land for its storage as it is very harmful for not only for human being but for environment also. Many researchers are working on its sustainable use in other things like recently flyash was started using in cement manufacturing and for dumping purpose etc.

Hardjito et al in 2004 studies geopolymer concrete and its compressive strength with the use of flyash. The tests which took place were dependent on features such as temperature for curing, time needed for curing, and the amount of super-plasticizer. The test states that in case the temperature is high and the curing time is long, the value of compressive strength was high and it also says that the working power of new geopolymer can be enhanced when you add a super-plasticizer based on naphthalene. It also says that that very less difference exists in the sample that was tested soon and the one that was tested almost an hour after curing it.

Flyash is very fine in size. Size of the particle varies depending on the source which commonly in the range from 2 to 10 µm and contains small percent of clay size of particle and glassy sphere, spherical in shape which allows the fly ash to flow freely. Fly ash has specific gravity in between 1.6 to 2.6 and it is non-plastic in nature and has a high shrinkage limit with bulk density in the range 0.9 to 1.3 g/cc it has a water holding capacity in between 40-60 percent **(ENVIS 2017).** Similar type of result also observed by other researchers and they found the whitish grey colour of fly ash with bulk density of 0.994 gm/cm^3, specific

gravity of 2.288, Moisture content 3.14% and average particle size is 6.92 µm **(Ismail et al. 2007).**

Kim et Al in 2005 employed industrial waste products such as flyash of class F and use of bottom ash in constructing. It can be a cost-effective measure to make use of the ancient product. The products are garnered from Indiana and studied for their properties such as stiffness, compaction, compressibility, strength and permeability. Flyash and bottom ash mixes are used in distinct ratios such as 50 units, 75 units and 100 units which is the weight of the flyash to the bottom ash. Post the test, you come to know that flyash and its specific gravity and bottom ash vary according to the plants they are derived from, and the max dry density appeared less than nominal value of geo-engineering material.

The fly ash is inorganic ash material generated by thermal industry and contains lots of chemical compound depending on the fly ash and their source. Generally fly ash consists of all the heavy metal which makes it toxic in nature. From previous studies, it was found that the chemical composition of fly ash such as SiO_2 (38% to 63%), Al_2O_3 (27% to 44%), TiO_2(0.4% to 1.8%), Fe_2O_3(3.3% to 6.4%), MgO(0.01% to 0.5%), CaO(0.2% to 8%), K_2O (0.04% to 0.9%), Na_2O (0.07% to 0.43%) and pH lies between 6 to 8 (ENVIS 2017). Bilir et al. 2015, also confirmed the compositions (as oxide) of fly ash like SiO_2(58.69%), Al_2O_3(25.10%), Fe_2O_3(5.80%), MgO(2.22%), CaO(1.49%), K_2O (4.04%), Na_2O (0.59%), SO_3(0.12%).

Phanikumar et al in 2007 studied the bulging characteristics of soils that expand and can turn to flyash. It may also bring an increasing change in the max dry density and lessen the OMC or optimum moisture content.

Gaurav and Reddy in 2011 studied the features like flyash's compressive strength and said that it could be enhanced when you use some additives like gypsum and lime. They also said that this strength can be enhanced when you cure it with steam rather than normal conditions of water curing.

Chithiraputhiran in 2012 replaced ordinary Portland cement with flyash and tried to make a geo-polymerizing material with an alkali that was activated with aluminosilicates. The paper showed that flyash that was activated by an alkali was the major topic of study. This paper saw an optimum value of n and binder that went selected according to the setting time. It said

that even at early and late ages a lot of compressive strength was produced, and this also saw a decrement when the flyash content saw an increment.

Rajesh et al in 2013 made a conclusion that slag that was activated by an alkali was capable of being used like cement and the only binding agent when concrete production takes place. To get the slag activated, we need an alkali activator which was about 4 percent of Na2O and about 4 percent of hydrated lime according to the sum weight of solid binding agent. This paper used 4 different mixtures for comparison, and these are 3 alkali activated slag and normal OPC with the same amount of binder, The features of delay were taken into account and even the measure of compressive strength was done at a period of a day, 7 days. studied in a period of 12 days. The slag activated by alkali saw a good workability achievement in comparison to old OPC.

Pani in 2014 studied flyash by taking it like a geo-engineering product for efficient utility. For study, flyash of class F was employed. In this the main stabilizing agent was lime and it went to the flyash in a quantity of 2 percent, 4 percent, 8 percent and 12 percent according to its weight. Distinct mixtures were taken into account by following UCS, standard proctor test, permeability test, modified proctor test and CBR test etc. The kind of effect that curing temperature had was also seen and UCS test took place for temperature ranging 10 degrees, 25 degrees, 45 degrees and 90 degrees while the curing period varied from 7 days, 15. 30 days and 60-days. Wax was used to coat the UCS specimen and when there was high temperature, highly resistant polyethylene was used to coat it, which also retained water. There was a comparative study carried out between unsealed and sealed samples. The value of OMC was 593kj per m3 and the value of MDD was 3483kJ per m3 of the compaction energy. This kind of capacitive energy and a period of curing which lasted 7 days and 30, after 4 soaking days period, it was the time for CBR test. The flyash that was treated with lime has higher UCS strength against virgin flyash.

Sharan and Singh in 2014 investigated and found the strength properties of flyash or pond ash that was compacted depending on energy of compaction and saturation point, Studied carried out on CBR values and UCS values depending on the energy that varies between 360 kJ/m3 and 3500 kJ/m3.Products like MgO and Al2O3 also offer some degree of strength. Just like cement, slag contains silica and lime as the major constituents in it and therefore you can use it to replace cement when while making concrete. Cement production leads to ecological

issues and lime is still a major part of products that are used in cement manufacturing and we should remember that lime would go over some day. Therefore, slag can be a superior replacement option. However, the slag does not have as much ultimate strength like cement concrete and therefore it can take place of the cement only partially and this may lessen the amount of cement produced every day. As far as geo-technical projects are concerned, they use lime stabilization as a major technique. Slag contains a major portion of lime so it could really replace lime but you cannot use GGBS as a direct stability agent since it has unnatural latent heat features which needs any alkaline substance to get activated. In this case study, flyash of class F that has been stabilized with lime and also contains GGBS in distinct amounts. Lime was considered an activator and distinct combos of GGBS and lime was studied to know the needed chemical and physical characteristics of the solution.

Chowdhury et al in 2015employed flyash like a substituting geo-product and published a paper to show the stability it can attain with alkalis such as Ca(OH)2, NaOH, and KOH etc. For the study purpose, flyash was amalgamated with 2-percent, 4-percent, 8-percent, 12-percent, 16-percent, and 20-percent alkali solution and this mixture underwent MPT or modified proctor test with MDD and OMC values found. This mixed product and the adjacent MDD, OMC and UCS specimen were prepared and rested for 0, 3 days, 7 and 28 days. For results, they discovered that the enhance in MDD and OMC with NaOH stability and KOH addition of CaOH2 does not offer any major enhancement in MDD values and OMC values. Even an enhance in UCS number with stability obtained from Ca(OH)2, NaOH and KH with augment in curing time and with an increment in content of alkali, decrement in content of alkali was found.

Hussain in 2015 made a study and said that effectively using waste products like materials in construction can put a check on greenhouse gases. This study used geo-polymer based on GGBS and bottom as source materials for the manufacture of geopolymer concrete used in paver blocks. In order to polymerize it, NaOH and a solution of Na2SiO3 was employed. These materials were sed to prepare paver blocks or grade M30 and M35. The content of bottom ash was 75 percent and that of GGBS was 25 percent while the ration between NaOH and Na2SiO3 being 2.5. When tested the grade M30 obtained or NaOH or 6M for a period of 3 days and of 8M for a period of a day. Against this, M35 obtained NaOH of 6M in 28 days and 8M in just a week.

Sivapullaiah and Sharma in 2015 studies the properties of waste from industries like flyash and even the GGBS that emerged out to denote that these could be used well enough as a stability agent when you add a little bit of activating agent. Lime is a very essential material used in construction whose history goes in a very ancient period. In fact, used in buildings. Besides, lime finds applications in lots of engineering works relating geotechnology and can be employed as a stabilizing agent for soil. It is important as a stabilizing agent since it contains pozzolanic features. When employed as a stabilizer, a kind of pozzolanic reaction with occur. With the passing time, the soil would increase in strength. In his testing, we used lime as the major stabilizing agent for flyash but since it was really costly as well, we used distinct quantities of slag and line as stabilizing agent.

Neupane in 2016 said that we can use geo-polymer to take it as a binding product. The used geo-polymer was normally prepared out of a mixture of alumina silicate in a powdered form that is a form of intense NaOH or solution of Sodium Silicate and this was normally known as geo-polymer that was activated with the help of liquid. This study used a couple of geo-polymer binders that were activated with the help of powder and had distinct features of slag and flyash. Just for the investigation, about 4 distinct strength variants such as 40 mega-pascal, 50 mega-pascal, 65 mega-pascal and 80 mega-pascal were employed with curing conditions being quite distinct and then you compared with concrete made from OPC of the similar grade. When contrasting with OPC, less quantity of water was needed for geo-polymer concrete for a period of 28 days in compressive strength against concrete of OPC. Geopolymer concrete showed about 15 percent to 20 percent high tensile strength and even flexural strength against same grade concrete of OPC.

Rios et Al in 2016 came up with a study that stated that binding agents such as flyash, geo-polymers and lime were employed to enhance the stability of the silty sand. A lot of samples were formed by just using the 3 binders as stated above and these specimen samples underwent unconfined compressive strength with tensile strength after curing was done for 63 days. They found hat strength and stiffness of samples prepared using the geopolymer as binding agent were considerably high against those produced with flyash or lime at the binding agent. They also said that the power of mixes prepared using flyash and lime as the binding agent was much more than when lime was used as a binding material.

2.3 OBJECTIVES

We have seen it in literature review that the most potent problem with flyash disposal is that it needs a huge land area as a dumping space and can lead to a lot of ecological issues. Flyash used in construction is perhaps one of the better ways to use a large amount of it and prevent harms. This project work has been done with the aim to use solid waste emerging from industries as a product in place of normal construction materials with the help of proper stability techniques.

The flyash of class F that emerged out of Adhunik Metaliks Ltd. in Sundergarh was stabilized using line that was the one the major stability products. Besides this, the earthy blast furnace slag that was in granulated form was employed to lessen lime usage that is quite costly in comparison to GGBS. This GGBS shows some latent hydraulic features, it cannot be employed as stability product without getting it activated with the help of an alkali. So for current study, lime is only employed as an activating agent to trigger pozzolanic reactions.

This project work mainly deals in:

- The process of adding lime and the period of curing on flyash's UCS.
- The process of adding slag and the period of curing on flyash's UCS.
- The process of adding slag and lime and the period of curing on flyash's unconfined compressive strength

CHAPTER 3
SAMPLING

3.1 FLY ASH

For this research, MPL or Maithon Power Limited was appointed as a station for sampling and this is situated in Dhanbad district in Jharkhand state with latitudes of the area being 23^0 49’ 38” N and longitudes being 86^0 45’ 41” E. MPL is one of the joint ventures of Damodar Valley Corporation and Tata power that brought 1050MW (about 2 x 525 MW units) in Dhanabad city, Jharkhand, India.

This is the first ever 525MW Project from India with the plants employing subcritical power and these thermal plants were based on coal and were credited to be the first ever PPP project or Public Private Power plants in India.

According to the bidding rules, the project ran on Indian coal and was anticipated to help about 16 million consumers at the domestic level in lieu with proving power that is cost-effective and great for the agriculture. This project was said to offer power to as many as 4 states in India which are Kerala, New Delhi, West Bengal and Jharkhand according to the everlasting PPA that are short of electric power currently. Not only does it offer viable power source, it also met the growing power needs of these states. Such dependable power derived from projects would enhance the effectiveness of service and manufacturing industry.

Fig1: Sampling location

3.2 LIME

Lime is a building material widely used in construction. It basically use as binder in construction. Is it composed of calcium and compounds of calcium and oxides obtained from burnet lime stone in underground mining coal fire in coal seam. It is inorganic in nature. The word lime derives from it use in initial time and its binding property. In the present research work it has been bought form commercial shop from the market of Lucknow as there is no availability of free lime in the research area due to inactive mining in the area.

Fig 2: Limestone Powder

3.3 GROUND GRANULATED BLAST FURNACE SLAG

Ground Granulated Blast furnace slag which is commonly known as GGBS is the slag emitted out of blast furnace employed in the heavy industries especially in steel industry and cement industry. In the present research work the sample collection for GGBS has been done at Bokaro Steel Plant Limited at Bokaro district, Jharkhand. This steel plant was establish in the year 1965 and it was operate under Steel Authority India Limited. Currently BSL is employed with five blast furnace with a total capacity of about 5.8 metric ton.

Fig 3: Ground Granulated Blast Furnace Slag

Fig 4: Ground Granulated Blast Furnace Slag Powder

CHAPTER 4
MATERIALS AND METHODOLOGY

4.1 INTRODUCTION

If flyash underwent some compaction, it could increase in strength a bit but when it turns saturated, it would at once lose all its strength. Therefore, proper stability methods are needed in order to employ this flyash as a material for construction. This project will see flyash being stabilized with the help of lime as the major material. But while it takes some extra cost for lime, we can use GGBS as a stability agent. However, we need to activate GGBS as well and this needed some lime addition. So this study deals in making the flyash a stable material with an increment in chemical and physical properties to employ it like a geo-engineering product by addition of GGBS and lime in regular composition. Distinct mixtures of slag, flyash and lime underwent some light compaction test in order to find strength of product with different mixing and the curing period was also different. This chapter sees quite some detail of used materials, preparation of the sample and procedure for testing.

4.2 EXPERIMENTAL ARRANGEMENTS

4.2.1 Materials Used

4.2.1.1 Flyash

This study saw the use of flyash of class F. As already stated, it emerged out of Maithon Power Limited in Maithon, Jharkhand. Prior to its use, the sample was tested through the 2mm IS sieve to keep away the vegetative materials and foreign samples. The received sample was garnered and mixed well and placed in the oven for a period of a day at temperature ranging between 105 degrees and 110 degrees. The sample was then placed in an airtight jar for future uses.

Fly ash is said to be an indispensable leftover product for the industries that is derived from coal burning and can be used to produce electricity. In India, only a meager proportion of it is employed in technical project construction and rest of it goes to waste that leads to a lot of issues with the environment. Stabilizing it with fly ash can enhance mechanical and engineering features of soil and this is a credible option to employ fly ash. Soil stabilization with coal and fly as in rising in popularity and has been seen a credible source by pavement engineers. “F” Grade fly ash is used in this experiment.

Figure4.1 Flyash

3.2.1.2 Lime

The lime employed in this test was a commercial product, that wascarriedout of Lucknow market and ensured to have cleared 150μ sieve test. Then it was maintained in somecontainer that was airtight for future uses.

Fig 4.2 Lime

4.2.1.3 Slag

The granulated blast in a ground form of furnace slag emerged out of Bokaro Steel Plant Limited at Bokaro district. Following this, it was trampled, dried in an oven, cleared a 300u sieve test and preserved in a container for future needs.

Fig 4.3 Powder of slag

4.2.2 Flyash: Physical Features

Physical features of flyash of classF flyash, that passes on 2 mm mesh are established and displayed below:

Table 4.1 Fly ash Properties

Physical Parameter	Values
Color	Grey
Shape	Rounded
Fine Sand	15
Silt & Clay	85
Coefficient of Curvature	1.38
Coefficient of Uniformity	5.23
Specific Gravity	2.17
Coarser Particle	0
Medium Particle	0
Plasticity	Non-Plastic

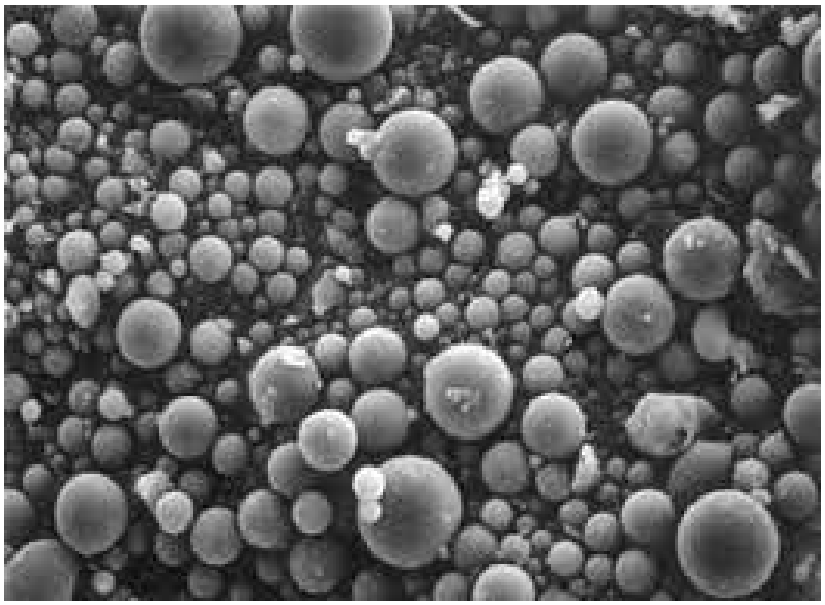

Fig 4.4 FESEM image of Fly ash

You can see fly ash's surface morphology in this figures that has been obtained with the use of SEM. You can see in the picture of particles that they are angular in size and are uniformly graded. For the highest level of morphology resolution, the acceleration voltage was taken as 20kV.

4.2.3 Composition of fly ash

Flyash of grade F has a chemical structure that was established as shown in the table below. The major elements that form this flyash were Al2O3 and SiO2. Besides, these. Parts of CaO, K2) and MgO are also found in it.

Table 4.2 Composition of Flyash

Element	Composition
MgO	1.8
Al_2O_3	27.6
SiO_2	52.23
K_2O	2.01
P_2O_3	1.89
CaO	2.72
Fe_2O_3	1.83
Na_2O_3	0.8
MnO	0.5
TiO_2	0.69
Loss on ignition	6.1

4.3 PROPERTY DETERMINATION

4.3.1 Specific Gravity

To determine the specific gravity of flyash of class F, the IS:2720 code of part 3 and section1 from 1980 was used..

In order to know specific gravity of fly-ash-mixed soil of fine grains, this test takes place with the help of density bottle procedure according to IS2720 (3rd Part/first section). Specific Gravity is defined as the proportion of weight of a certain amount of material at designated temperature to the similar amount of water in a distilled form at similar temperature.

Apparatus

- Three density bottles of 25ml capacity.
- Weighing balance.
- Spatula

Here is the procedure that you should follow:

1) Take the mass of vacant density bottle together with the stopper (W1)
2) Density bottle weight with fly ash is obtained (W2).
3) Add distilled water to the density bottle filling up till neck and place the stopper.
4) Weight the density bottle along with the fly ash and water (W3).
5) Empty the bottle, get it cleaned well enough and add distilled water to fill it completely.
6) Weight of this filled water is taken again (W4).
7) Obtain at least a couple of readings in this procedure for the samples.

Fig 4.5: Density bottle

Calculation

$$specific\ gravity = \frac{w_2 - w_1}{(w_4 - w_1) - (w_3 - w_2)}$$

With the use of density bottle testing, kerosene was used as solvent and the value was determined at 2.4

4.3.2 Grain Size Analysis

To ascertain the distribution of grain size, we passed the flyash through a sieve of 75 μ. To find coarse particle distribution, we conducted sieve analysis according to the IS 2720 4th part in 1975 and therefore for particles that were fine we conducted hydrometer analysis according to the IS 2720 part 4.

The purpose of this test is to know the percentage of distinct sizes of grains in a particular type or soil. Using sieve or mechanical analysis, you can govern the dispersal of particles that are coarse and large in size. Against this, you can determine the concentration of fine particles using hydrometer method. This distribution of distinct sixes of grains can affect the soil's engineering features. And with analysis of the sizes of grains, you can get their distribution value which is essential to classify the kind of soil. This test is done with the help pf sieve according to IS2720 (4th part – 1985).

Apparatus

- Balance
- Set of sieves
- Cleaning brush
- Sieve shaker

Procedure:

1. Obtain the weight of every sieve that you use with the pan at the bottom.

2. Weigh down the dry sample that you take.

3. Arrange the sieves in increasing order of their capability and also put the pan that was there in the bottom.

4. Add the dry sample to the sieve.

5. Use a mechanical shaker and place the stack of sieve on it. Shake it for about 30 minutes.

6. After 30 minutes, remove the stack of sieves from the shaker and note down the weight o dry sample retained in each of the sieves.

Fig 4.6: Sieve analysis test

Calculation:

- The amount of fly ash recovered from each of the sieves is derived according to the max mass of the taken sample of fly ash.

- Following this, we derive the cumulative proportion of fly ash that gets retained on the successive sieves.

Graph: You need to prepare a graph taking log sizes of the sieves on one and percentage finer on the other. We call this graph as the grading curve. Equivalent to 10 percent, 30 percent, and 60 percent fine, while the graph diameters are taken as D10, D30 and D60.

The flyash that passes in the 75 μ was about 87 percent. Therefore, flyash was kept under silt size to fine sand category. The uniformity coefficient or Cu was about 5.66 while the curvature coefficient was 1.26. This shows that flyash was uniformly graded.

4.4 ENGINEERING PROPERTIES DETERMINATION

4.4.1 Relationship of Dry Density and Moisture Content

We find content of moisture and its relationship with dry density with the use of Standard Proctor Test according to the IS code 2720 part 7 from 1980. In this, we mix lime with flyash at a percentage of 0 percent, 2 percent, 4 percent, 8 percent and 12 percent wit slag quantity varying according to the dry weight with different combos. To have this test, there was a good amount of water was transferred into the mix to stir it well enough and then it was compressed in the proctor mould in 3 distinct layers with the use of Proctor hammer that weighs 2.6kgs. With the use of this, we even determined the optimum moisture content and the max dry density. Like this, distinct combos were studied and similar procedure was employed adjacent to MDD and OMC determination. Compaction energy employed in this test was taken as 595kJ per m3.

Table 4.3 Ratio of Fly ash, Lime And GGBS

Lime	**Fly ash and Slag Ratio**				
0	100%	95:5	90:10	85:15	80:20
2	100%	95:5	90:10	85:15	80:20
4	100%	95:5	90:10	85:15	80:20
8	100%	95:5	90:10	85:15	80:20
12	100%	95:5	90:10	85:15	80:20

Results of test are displayed in tables below

Table 4.4. Variation of Dry Density with different ratio

Lime %	Maximum Dry Density				
	0% Slag	5% Slag	10% Slag	15% Slag	20% Slag
0	11.00	11.19	11.35	11.50	11.69
2	11.21	11.29	11.46	11.56	11.71
6	11.26	11.32	11.47	11.68	11.75
8	11.47	11.60	11.68	11.80	11.90
12	11.72	11.80	11.87	12.00	12.15

Table 4.5.Variation of Dry Density with different ratio

Slag	Maximum Dry Density				
	0% Lime	2% Lime	4% Lime	8% Lime	12% Lime
0	11.01	11.16	11.25	11.43	11.70
5	11.16	11.26	11.36	11.50	11.78
10	11.40	11.40	11.45	11.64	11.83
15	11.43	11.59	11.67	11.80	12.00
20	11.69	11.70	11.75	11.90	12.16

Table 4.6.Variation of Optimum Moisture Content with different ratio

Lime	OMC				
	0% Slag	5% Slag	10% Slag	15% Slag	20% Slag
0	42.19	38.60	38.30	38.09	37.99
2	40.36	38.30	38.19	37.95	37.36
4	38.29	37.90	37.59	36.86	36.01
8	36.90	36.19	35.82	35.26	34.98
12	34.20	33.89	33.23	33.00	32.33

Table 4.7.Variation of Optimum Moisture Content with different ratio

Slag	OMC				
	0% Lime	2% Lime	4% Lime	8% Lime	12% Lime
0	42.17	40.36	38.30	36.87	34.16
5	38.60	38.26	37.89	36.19	33.90
10	38.30	38.11	37.58	35.90	33.30
15	38.10	37.97	36.85	35.26	33.00
20	38.00	37.90	36.10	35.00	32.27

4.4.2 Determining Unconfined Compressive Strength

Value of unconfined compressive strength was determined by the test and it was done to find the values of this features for normal flyash and that which was stabilized using slag and line. To prepare the specimen of MDD we can determine the OMC with the help of standard proctor test with the value of energy taken as 595kJ per m3 in accordance with IS:2720 10^{th} part. The cylindrical sample was 76mm high and had a dia. Of 38mm. It also went through axial strain of the value 1.25mm per minute till we see a failure. These samples were coated with max so that the moisture could be retained and there could be a proper interaction amongst GGBS, lime and flyash. To determine the efficacy of curing, these specimen were preserved for 0, 7 days, 14 and 28 days according to the curing period. For every combo of GGBS, flyash and lime with distinct periods of curing, 3 similar test specimens were taken into account and their average value was determined.

Fig 4.7UCS arrangement

Fig 4.8UCS samples

The test outcomes are mentioned below:

Table 4.8Unconfined compressive strength at 0% slag.

Lime %	UCS			
	On day	7 Days	14 Days	28 Days
0	0.23	0.23	0.23	0.23
2	0.64	0.65	0.71	0.79
4	1.06	2.01	2.92	3.01
8	1.07	2.99	3.02	4.63
12	1.30	3.09	3.61	5.86

Table 4.9 Unconfined compressive strength at 5% slag.

Lime %	UCS			
	On day	7 Days	14 Days	28 Days
0	0.10	0.20	0.29	0.32
2	0.74	1.42	1.68	1.72
4	0.92	1.9	2.41	2.92
8	0.98	3.08	3.10	4.91
12	1.02	3.62	5.33	5.44

Table 4.10 Unconfined compressive strength at 10% slag.

Lime %	UCS			
	On day	7 Days	14 Days	28 Days
0	0.21	0.42	0.45	0.59
2	0.35	0.91	1.80	2.97
4	0.45	1.50	3.05	3.40
8	0.58	2.02	3.19	3.81
12	0.61	3.22	3.30	4.89

Table 4.11 Unconfined compressive strength at 15% slag.

Lime %	UCS			
	On day	7 Days	14 Days	28 Days
0	0.22	0.48	0.62	0.95
2	0.80	1.31	1.89	3.11
4	0.86	2.10	3.49	3.59
8	0.90	2.22	3.69	4.07
12	1.00	3.88	4.32	5.10

Table 4.12Unconfined compressive strength at 20% slag.

Lime	UCS			
	On day	7 Days	14 Days	28 Days
0	0.28	0.62	1.20	1.40
2	0.89	3.00	3.59	3.70
4	0.92	3.27	4.60	5.31
8	0.95	5.41	6.90	7.31
12	1.18	5.80	8.00	8.45

CHAPTER 5
RESULTS AND DISCUSSION

5.1 GENERAL

Coal ash is a kind of minute product that emerges out when the coal combustion process takes place. The by-product of the combustion mechanism is thrown in the earth and this leans to ecological and human health problems. Therefore, it is quite important to use the waste produced in this manner as much as we can. And even therefore, using it as a construction product is one of the best alternatives. In this method, flyash of Class F was used and we tried to bring it stable with the help of GGBS and lime. This specimen mix could have undergone a few test like UCS and Standard Proctor etc. This chapter deals in the same results that have been discussed as below.

5.2 PROPERTIES

5.2.1 Specific Gravity

According to IS Code 2720 Part 3, Section 1 from 1980, we establish specific gravity with the use of density bottle method while the value of this was 2.4. Specific gravity is considered an important property of the basic materials when we deal in any form of geo-technical work, Flyash's specific gravity was found to be very less than similar geo-technical products. It leads to immense cenospehers which are not even removed die to air microbubbles or it could be due to change in chemical structure of the content of iron. Generally, flyash's specific gravity lies in the range between 1.6 and 3.1, according to Pani in 2014, but can rely on parent material.

5.2.2 Distribution of Grain Size

This test determined that the grade of the particles found in flyash of class F were very uniform and the size of the particles lies mainly between silt and the size of fine sand. This test showed that about 86 percent of the flyash was passing in the 75μ IS sieve while the curvature coefficient Cc was lying around 1.26 and the Uniformity coefficient Cu tend to be 5.66. The distribution of gain size quiet relies on the amount of pulverization, presence of any type of foreign materials in flyash and the temperature of the boiler.

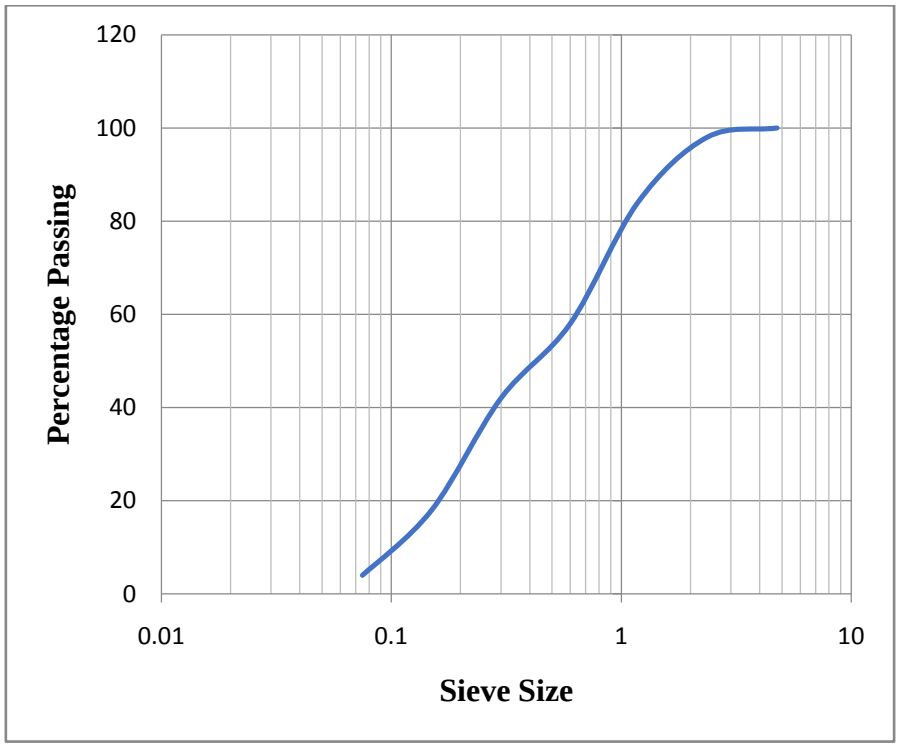

Fig 5.1 Distribution of Grain Size Curve in Flyash of Class-F

5.3 ENGINEERING PROPERTIES

5.3.1 Compaction Features

This project sees utilization of light compaction. The combinations that were taken were compressed in 3 different layers and received 25 blows each on one layer with hammers that had a weight of 2.6 kilograms.

Total energy for every compaction was about 595kJ per m3. MDD and OMC were established for each of these combos and the graph derived for distinct combos was portrayed. The diversion in the value of OMC and MDD with the diverging amount of lime and that of the value of slag was also seen in this.

5.3.2 Unconfined Compressive Strength Determination (UCS)

The UCS value or unconfined compressive strength was established with the UCS test. The specimen samples that was taken in this had a height of 76mm and a dia. of 38mm. There were 3 distinct samples prepared or distinct combos of GGBS, lime and flyash and with the use of MDD and OMC obtained out of SPT test, there was average of 3 was taken in this.

The value of relationship between stress and strain for the flyash that was treated was compared for a period of curing for 0, 7 days, 14 and 28 days. Varying UCS quantity with the vary in curing period for the aforementioned says with varying value of lime was established with the help of bar charts. Varying UCS with distinct content of lime and slag with distinct vary in curing time was also represented.

CHAPTER 6
CONCLUSIONS AND FUTURE WORK

6.1 CONCLUSION

In this study, we have tried to make use of by-product like flyash like a geo-engineering product. We tried to stabilize the flyash with the help of slag and line and then it was tested with light compaction. After compaction, the MDD and the OMC value of the products were determined with the help of SPTand it was verified for UCS. The value of UCS were checked against the needs of the sub-base and base of pavements in highways. Through this, the conclusions that have been made are as follows:

- Talking about gradation analysis, we found that flyash that passed out of 75μwas about 86 percent and the size of the particles varied between silt size and fine sand. The curvature coefficient and uniformity coefficient were determined and their value was 1.26 & 5.66 that indicated that the materials were well-graded according to the range of the size.

- Standard Proctor test was employed to establish the MDD and OMC values with energy taken as 595kJ per m3. The value of OMC for flyash was 10kN per m3 and the value of MDD was found to be 42.12 percent. It truly states that the virgin flyash contains less MDD with more OMC value.

- Flyash was adulterated with 0 per-cent, 2 per-cent, 4 per-cent, 8 per-cent, and 12 per-cent lime content and the highest value of MDD turned out to be 11.68kN per M3 while the OMC of the products varied from 34.12 per-cent with 12 per-cent of lime. The above results found the conclusion that adding lime in the solution can lessen the value of OMC while the value of MDD was enhanced.

- Flyash was added to 0 per-cent, 5 per-cent, 10 per-cent, 15 per-cent and 20 per-cent slag where the most value of MDD turned out to be 11.66kN per m3 while the OMC being 34.16 percent at about 20 percent of slag. The value of MDD increased while that of OMC lessened.

- A mix of lime and slag using even the flyash was prepared and the value of MDD and OMC were established for each comb. It was found that mix with 20 per-cent of slag and 12 per-cent of lime in association with flyash contains the most MDD at 12.12 kN per m3 and the least OMC at 32.23 per-cent. It can be concluded that adding slag and lime in flyash enhances the MDD value while it lessens the OMC.

- UCS was performed by taking a sample size that was 76mm high and a dia of 38mm, which was compressed to adjacent MDD and OMC that were established with the use of compaction. The value of UCS in flyash was about 0.34MPa.

- The value of UCS for flyash that was mixed with lime at varying percentage of 0 per-cent, 2 per-cent, 4 per-cent, 8 per-cent and 12 per-cent was established and it was also known that max value of UCS was somewhere about 1.22MPa using 12 per-cent of lime.

- Curing period effect was also taken into account and these samples took curing for about 0, 7 days, 14 and 28 days. In this, the max value of UCS turned out to be 5.75MPa with the use of 12 percent lime after 18 days of curing.

- The value of UCS for flyash that was mixed with slag at varying percentages such as 0 per-cent, 5 per-cent, 10 per-cent, 15 per-cent and 20 per-cent was established and it was known that max value of UC was about 0.25MPa at 20 per-cent of slag taken at once. The samples took curing or 7, 14 days, and 28 and the max value of UCS that was established after 28 days was 1.39MPa, which shows a great enhance in value of UCS with the help of virgin flyash and while adding just the slag.

- The value of UCS for different combos of slag, flyash and lime were established for different periods of curing. And it was known that flyash that contained about 12 per-cent of lime and 20 percent of slag contains max strength after it was cured for 28 days with 8.44MPa strength.

- As per :Guidelines for Flexible Pavements Design" from IRC 37-2012, the value of UCS in sub-base was between1.5 and 3MPa and for the base course, the value of UCS

varied between 4.5 and 7MPa. The result got out of this project was considered more than needed. So in upcoming period, you can use it as a pavement base or sub-base.

6.2 FUTURE SCOPE

Some review that is imperative to effectively use lime and GGBS with flyash are as follows:

- How these materials performed in constant loading condition was to be checked
- Varying temperature of curing to define the impact of temperature of curing on UCS
- CBR values of the mix. Checked through CBR test
- Checking the permeability of the mix through permeability test
- Durability aspects to be checked with the use of durability test
- Check the consolidation features with the help of odometer test
- The efficacy of flyash that was activated with the help of lime while GGBS leachate quality was established.

References

- Al-Rawas, Amer Ali, et al. "A coMParative evaluation of various additives used in the stabilization of expansive soils." (2002): 199-209.

- Hardjito, Djwantoro, et al. "Factors influencing the compressive strength of flyash-based geopolymer concrete." civil engineering dimension 6.2 (2004): pp-88.

- Kim, Bumjoo, Monica Prezzi, and Rodrigo Salgado. "Geotechnical properties of fly and bottom ash mixtures for use in highway embankments." Journal of Geotechnical and Geoenvironmental Engineering 131.7 (2005): 914-924.

- Phanikumar, B. R., and Radhey S. Sharma. "Volume change behavior of flyash-stabilized clays." Journal of materials in Civil Engineering 19.1 (2007): 67-74.

- Reddy, BV Venkatarama, and K. Gourav. "Strength of lime–flyash coMPacts using different curing techniques and gypsum additive." Materials and structures 44.10 (2011): 1793-1808.

- Chithiraputhiran, Sundara Raman. Kinetics of Alkaline Activation of Slag and Flyash-Slag Systems. Arizona State University, 2012.

- Rajesh, D. V. S. P., et al. "Performance of alkali activated slag with various alkali activators." International Journal of Innovative Research in Science, Engineering and Technology 2 (2013): 378-386.

- Saride, Sireesh, Anand J. Puppala, and Srujan R. Chikyala. "Swell-shrink and strength behaviors of lime and cement stabilized expansive organic clays." Applied Clay Science 85 (2013): 39-45.

- Pani, Aparupa. Effect of Curing Temperature on the Strength of Lime Stabilized Flyash. Diss. NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA, 2014.

- Singh, S. P., and A. Sharan. "Strength characteristics of coMPacted pond ash." Geomechanics and Geoengineering 9.1 (2014): 9-17.

- Chatterjee, A.K., 2011.Indian fly ashes: their characteristics and potential for mechano-chemical activation for enhanced usability. J. Mater. Civil.Eng. 23 (6), 783–788.

- Chen, L., Lin,D.-F.,2009.Stabilization treatment of soft subgrades oil by sewage sludge as hand cement.J.Hazard.Mater.162(1),321–327.

- Xuan jing ke xue (2005), Bioleaching of fly ash from municipal solid waste incinerator using sewage sludge and pig manure as culture media. PubMed, vol.26 (6):180-5.

- Ashok Bankar, Mark Winey, et.al (2012) , Bioleaching of Fly Ash by the Tropical Marine Yeast, *Yarrowia lipolytica*. Applied biochemistry and Biotechnology, Volume 168, Issue 8: 2205-2217.

- Seidel A, Zimmels Y and Armon R (2001), Mechanism of bioleaching of coal fly ash by Thiobacillus thiooxidans. Chemical, Volume 83:123-130.

- Yang Songrong et.al (2002), Research and application of Bioleaching and Biooxidation technologies in China. Minerals Engineering, vol 15, issue 5: 361-363

- Klaus Bosecker (1997) Bioleaching: metal solubilisation by microorganisms. FEMS Reviews 20: 591-604.

- Mittra B.N, S. Karmakar et.al (2003) Fly ash- a potential Source of Soil Amendment and a Component of Integrated Plant Nutrient Supply System, International Symposium, Paper 28.

- R.D. Tripathi , S. Dwivedib, et.al(2008) Role of blue green algae biofertillizer in ameliorating the nitrogen demand and fly-ash stress to the growth and yield of rice (Oryza sativa L.) plants. Chemosphere, volume. 70: 1919–1929.

- S. Aggarwal, G.R. Singh and B.R. Yadav (2009) Utilization of Fly ash for Crop Production: Effect on the Growth of Wheat and Sorghum Crops and Soil Properties. Journal of Agricultural Physics, Vol. 9, pp. 20-23.

- Hrishikesh N Vitekari1, Ashish P Talele et.al (2012) Fly Ash Based Biopesticides: A Comprehensive Review.Biological Sciences, Volume 2, Issue 1: 76-82.

- Bilir, T., Gencel, O., & Topcu, I. B. (2015). Properties of mortars with fly ash as fine aggregate. *Construction and Building Materials*, *93*, 782-789.

- ENVIS (2017) Centre on Fly ash; CSIR-Central Building Research Institute Roorkee ;Ministry of Environment, Forests & Climate Change, Govt of India;http://cbrienvis.nic.in/summaryoflfyash.html. Accessed on 08-08-2017

- IS:1489(PART 1):1991, Bureau of Indian Standard, New Delhi, India, Specification of Portland pozzolana cement.

- IS:2386:1963,Bureau of Indian standards, New Delhi, India, Methods of testing of aggregates.

- IS:2720:1983,Bureau of Indian standards, New Delhi, India, Methods of testing of soil.


International Journal for Research Trends and Innovation
IJRTI | IJRTI.ORG | ISSN: 2456-3315
An International Open Access, Peer-reviewed, Refereed Journal
Certificate of Publication
The Board of
International Journal for Research Trends and Innovation
Is hereby awarding this certificate to
Jitendra Kumar
In recognition of the publication of the paper entitled
PREPARATION AND CHARACTERIZATION OF LIME ACTIVATED FLYASH WITH BLAST FURNANCE SLAG
Published in Volume 7 Issue 8, August-2022
Co-Authors - Anuj Verma
Paper ID - IJRTI2208067
ISSN 2456-3315
Editor-In Chief
INTERNATIONAL JOURNAL FOR RESEARCH TRENDS AND INNOVATION | IJRTI
An International Scholarly, Open Access, Multi-disciplinary, Indexed Journal
Website: www.ijrti.org | Email: editor@ijrti.org | ESTD: 2016
Manage By: IJPUBLICATION Website: www.ijrti.org | Email ID: editor@ijrti.org