Utilization of fly ash along with additive for better compressive strength as compared to traditional practice in mine haulage roads

Manvendra Shekhar Pandey[1],Sindhu J.Nair[2]

[1]*M.Tech. Scholar (Environmental Science & Engineering), Bhilai Institute of Technology, Durg, Chhattisgarh, India,*

[2]*Professor & M.Tech.Coordinator,Department of Civil Engineering, Bhilai Institute of Technology, Durg, Chhattisgarh, India*

Abstract: In India, power generation is one of the biggest sectors. Also most of the power generated is thermal power. The thermal power generation is mostly based on coal. Also this process involves combustion of coal which generates fly ash as by-product. This fly ash requires serious disposal. There are various methods adopted for this in India. One method which is not very well popular is using this fly ash along with a little amount of additives in the construction of mine haul roads. The material which is used currently for mine haul road construction is locally available mine refuse. The current practice poses some serious problems, the solution of which can be found from the fly ash composites. Thus compressive strength of fly ash composites was tested. For this, additive selected for strength gain was lime. Thus composites having different compositions were tested for their compaction characteristics and at their Optimum Moisture Content, the samples were cured for different periods and their compressive strength was tested. The results are analyzed. All of the samples developed were suitable for use in mine haul road.

Keywords: Fly ash, Mine reject, Cement, Maximum Dry Density, Optimum Moisture Content, Compressive strength, and fly ash composites.

I. INTRODUCTION

Fly ash is a waste product from coal based thermal power plant. In India major source of power generation is coal based thermal power plants. As of July 2020, India has total installed power generation capacity 379 GW, out of which 231.45 GW installed capacity is of thermal power plants. Out of which almost 86 percent of thermal power generation is from coal and rest is from Lignite, Diesel and Gas. Class F or low-lime fly ash fly ash is the predominant type of fly ash found in India, other type which can also be found in smaller amounts across India is Class C or high-lime fly ash. The disposal of this fly ash can pose serious problems if not disposed properly. There are many areas of utilization of this fly ash, such as cement manufacturing, brick manufacturing, agricultural uses, land filling, ash dyke construction, road construction backfilling of mines, , etc. One of such options is use of this fly ash in mine haulage roads. A field survey of the mines located near Arang, Raipur area shows that almost all the mines located in this area are limestone mines. Also the material used for haul road construction in almost all the mines, were locally available mine rejects or refuse. These haulage roads in mines are subjected to heavy compressive loads. Heavy vehicles generally run with excavated materials on these roads and thus road maintenance is an important criterion in mine economy. Also huge accidental chances can arise if the construction material used in roads does not possess sufficient load bearing capacity. There have been sufficient research papers showing that there has been increase in the strength of fly ash if lime is added. This research paper is an investigation step to determine if the developed experimental composites have sufficient compressive strength to bear heavy truck loads and is better than the currently used materials in terms of strength.

II. LITERATURE REVIEW

The Indian coal is low grade and has high ash content (30-45%) as compared to imported coals (10-15%), so large quantities of fly ash are generated, 217.04 Million tons in 2018-19. The generated fly ash requires large areas for disposal as well as remains a source of environmental pollution. In India an area of 65000 acres of land is being occupied by ash ponds and is its generation is expected to cross 225 million tones by the year 2020. FA disposal in an unscientific way affects the local ecosystems due to the heavy metal pollution through erosion and leachate generation. Apart from occupying large areas, fly ash, if not managed well, by virtue of its weightlessness can become airborne. Dumped FA contaminates surface and groundwater, soils and vegetation by mobilization of its hazardous metals. (Aadil Yousuf et al, 2020)

Soil stabilization with fly ash can reduce environmental pollution, and costs of materials are relatively inexpensive. Soil stabilization with fly ash has been proposed as an effective alternative for strength and stiffness improvement through chemical reactions, because certain types of fly ash contain lime (CaO) and pozzolan consisting of, for example silica (SiO_2) and alumina (Al_2O_3) When fly ash is mixed with soil in the presence of water, chemical reactions occur. These chemical reactions dissociate the lime (CaO) in the fly ash and establish cementitious and pozzolanic gels consisting of calcium silicate hydrate (CSH) gel and calcium aluminate hydrate (CAH) as gel. (Minson Simatupang et al, 2020)

Class F type of fly ash contain less than 20 % of lime, while class C type of fly ash contain more than 20 % of lime.(Radharani and Manish Kumar Jain, 2015)

According to Pandian et al. (1998) the range of specific gravity varies from 1.46 to 2.66 for Indian fly ashes.

Das and Prakashi (1990) reported optimum moisture content (OMC) of 40% and maximum dry density (MDD) of 10.1 kN/m3 for Titlagarh fly ash by performing Standard Proctor Compaction test.

Now, manufacturers of haul trucks are planning for gross weights of more than 500mt (payload of more than 300mt). Correspondingly, the load per tire has increased to more than 85 tonnes. Tire pressure has also gone up to 827kPa (120psi) from 551kPa (80psi) during last five years. However, the new low profile truck tires (55/80R63, low profile) have an inflation pressure of 600kPa (87psi).

Two important elements of tires that affect haul road design are foot print area and tire pressure. Tire pressure has gone up to 690kPa (100psi) from 551kPa (80psi) during last five years. Although the new low profile truck tires (55/80R63) have an inflation pressure of 600kPa (87 psi). The increase in tire pressure has placed greater stresses on the road surface. The bearing capacity of materials used for the surface layer should be greater than the tire pressure. So, any material having a bearing capacity less than roughly 1MPa (equivalent to compressive strength of soft rock) cannot be used for the surface layer. (Dwayne D. Tannant and Bruce Regensburg, 2001)

While lime-alone works well to stabilize clay soils, a combination of lime and fly ash is beneficial for lower plasticity, higher silt content soils. The fly ash provides the pozzolanic reactants, silica and alumina, lacking in such soils. (Joel H. Beeghly, 2003)

The unconfined compressive strength of fly ash- soil mixtures increases with the increase of fly ash content. The pure fly ash samples can attain a UCS of 9365 kN/m2. The effect of longer curing time(from 14 days to 28 days) has greater effect on the 20 % fly ash content mixture. (Fabio Santos et al, 2011).

III. MATERIALS AND METHODOLOGY

***Materials used*:**

Fly ash was collected from ESP (Electrostatic Precipitator) of local power plant. The mine reject/mine refuse were collected from a nearby limestone mine of this plant, while lime was bought from local market of Raipur. Since the investigation was majorly about utilization of fly ash and at the same lime should also be used in small amounts to increase strength, therefore four different types of samples were prepared having compositions :-

a) 100 % Mine refuse (for reference)

b) 97 % Fly ash + 3 % Lime, abbreviated as 97% F and 3% L in later parts.

b) 94 % Fly ash + 6 % Lime, abbreviated as 94% F and 6% L in later parts.

c) 91 % Fly ash + 9 % Lime, abbreviated as 91% F and 9% L in later parts.

***Methodology*:**

First of all the compaction characteristics i.e., maximum dry density and Optimum Moisture Content (OMC) of all the above four sample types were found following the procedures following the procedures given in IS 2720 Part VII -1980. In this Standard Proctor mould with standard capacity of 944 cc was taken which had internal diameter of 10.2 cm and height of 11.6 cm. Samples of all the above discussed compositions were prepared in the mould with different moisture contents. The moisture contents selected for mine refuse sample were 2 %, 4 %, 6 %, 8 % and 10 %, while the moisture contents selected for fly ash composites were taken as 12 %, 14 %, 16 %, 18 % and 20 %. Then with the help of a standard 2.5 kg rammer having a free fall of 30 cm, compaction was performed for samples. In this 25 blows of hammers were given for one layer each and in this way three layers were compacted and then excess soil was trimmed off. Different weights were taken and bulk density calculations were then done as per IS 2720 Part VII-1980. The graph between Dry density and moisture/water added is plotted in graph and Optimum

Moisture Content (OMC) corresponding to Maximum Dry Density (MDD) was found out.

After finding out OMC and MDD for all the samples, unconfined compressive strength tests were performed on all the samples. These tests are performed to check the compressive strength of the samples and to assess if they are suitable for haulage roads. IS 2720 Part-10(1991) is followed in the test and samples having 3.8 cm diameter and 7.6 cm length were prepared. For this the samples were first oven dried and the dry weight of all the samples required for tests were found out by multiplying their maximum dry density as calculated in Standard Proctor Test with the volume/dimensions of the sample to be prepared and then Optimum amount of water as found out by Standard Proctor Test is added and cylindrical specimen is prepared for testing. Four different types of specimens were prepared for each combinations as tests were to be performed after 7 days, 14 days, 28 days and 56 days of curing. After attaching probing ring and fixing bearing plates and dial gauge, the gear was adjusted to 1.25 mm/ minute and readings were noted on dial gauge and probing ring for every 30 seconds till the failure of the specimen. The readings were noted and unconfined compressive strength was found out accordingly.

IV.OBSERVATIONS AND RESULTS

The values of Optimum Moisture Content and Maximum Dry Density for all the sample types found are shown in figures 1, 2, 3 and 4.

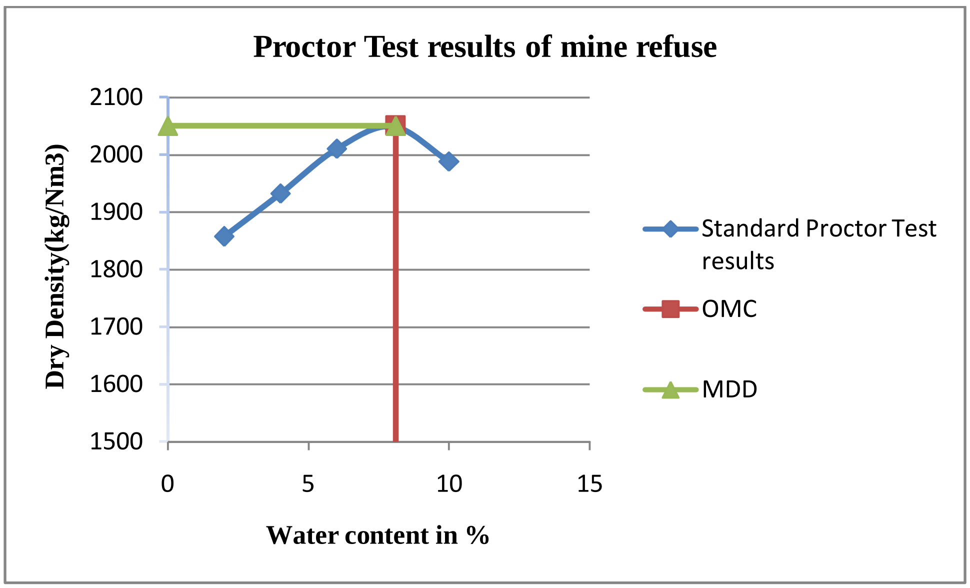

Figure 1

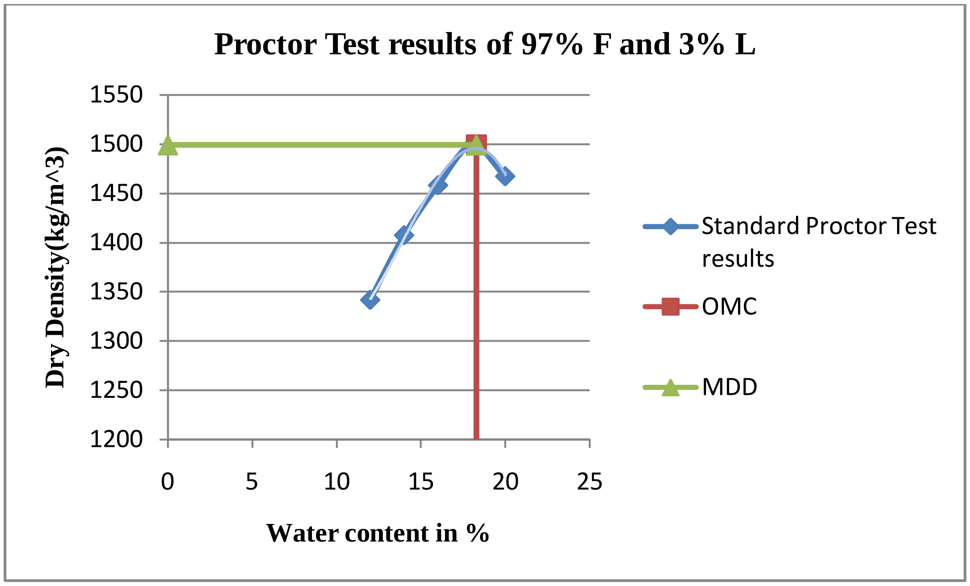

Figure 2

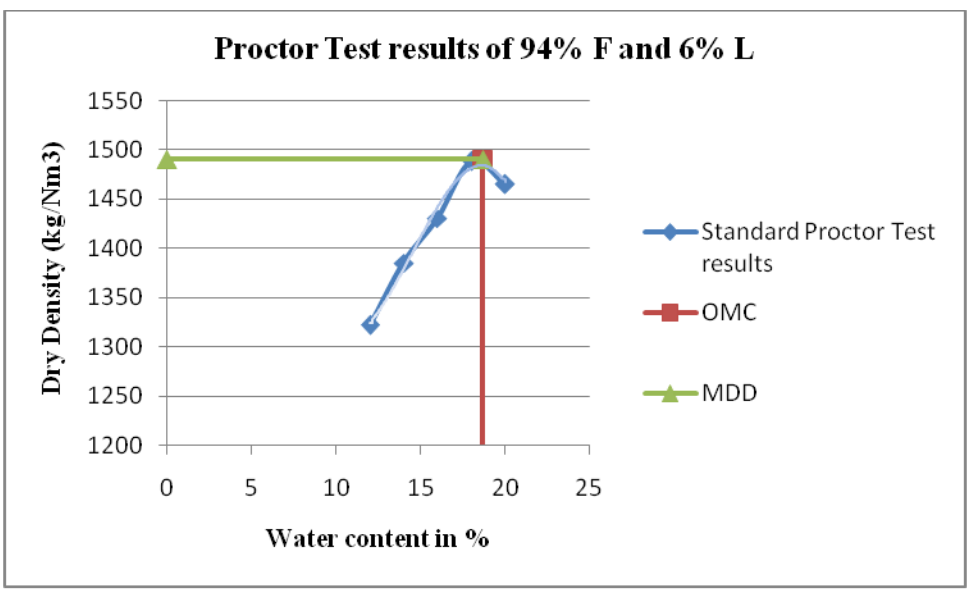

Figure 3

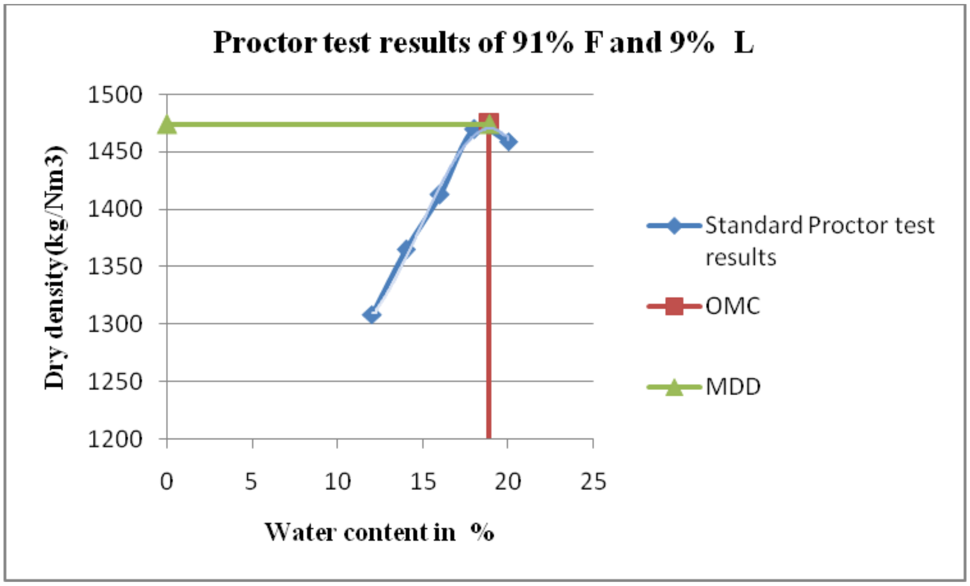

Figure 4

The value of OMC for Fly ash composites were much larger than mine refuse sample. This was mainly due to the presence of cenospheres as reported by Das and Yudhbir (2006). On the contrary, the values of MDD for fly ash composites were much lower than that of mine refuse. Maximum OMC of 18.9 and minimum OMC of 18.3 while maximum MDD of 1498.86 kg/Nm3 and minimum OMC of 1474.13 kg/Nm3 were reported for fly ash composites.

In the unconfined compressive strength test, all the test samples failed by shearing as shown in figure 5. However there has not been much increase in the UCS value of the mine refuse sample when the curing period has increased. Significant axial load was not required for the specimen's failure of mine refuse. The UCS values for mine refuse after 7 days, 14 days, 28 days and 56 days curing are shown in figure 6. None of the values exceeded 0.2 MPa or 200 kPa.

Figure 5 : Failure of a specimen by shearing

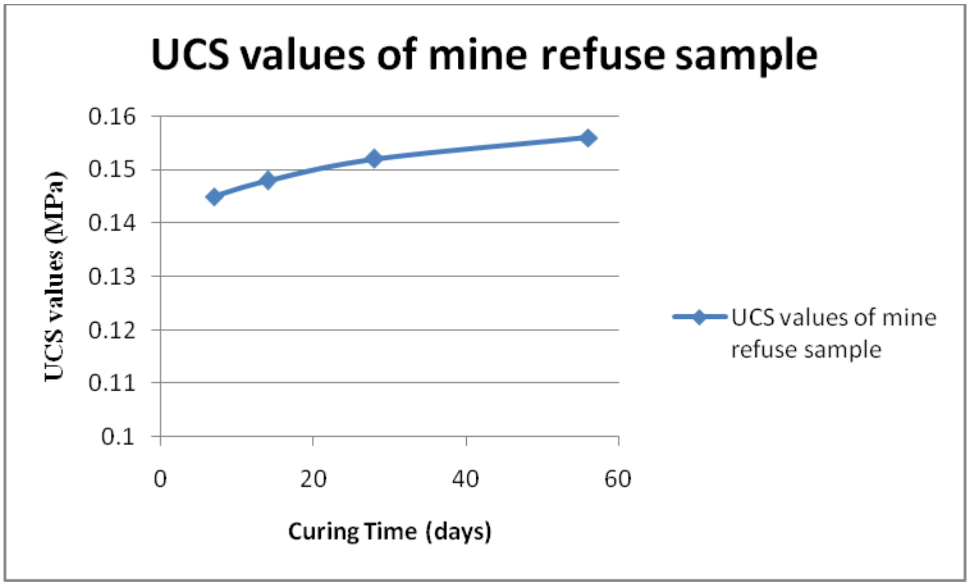

Figure 6

However the test results for fly ash-lime composites were mostly encouraging. The minimum value of UCS was observed for 97% F + 3% L sample and was 0.726 MPa at 7 days curing period. While the maximum value of UCS was observed for 91% F + 9% L at 28 days curing period and was calculated as 2.874 MPa. This shows that the compressive strength of the composites increased with increase in the lime content as well with increase in the curing time. Also it can be seen from figures 7, 8, 9 and 10 below, that if more lime is available in the composite, the value of UCS will be more. All of these values are higher than the values of tire pressures as reported by Dwayne D. Tannant and Bruce Regensburg, 2001.

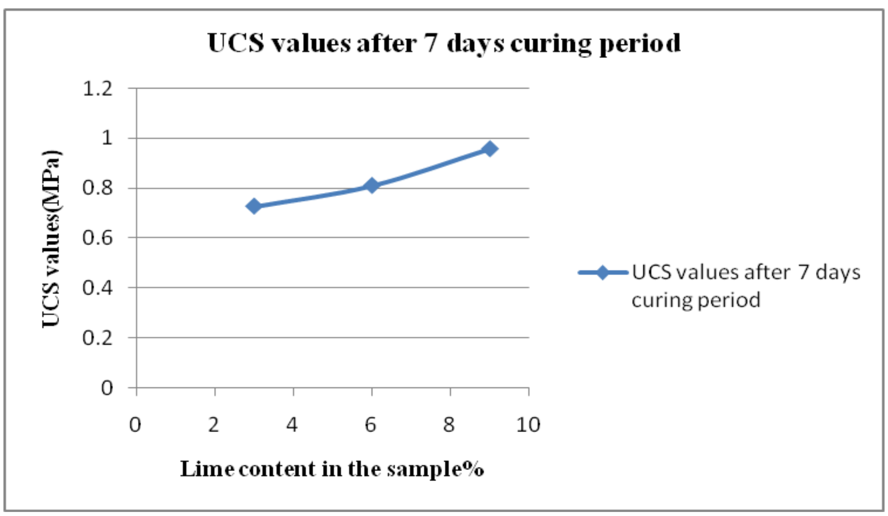

Figure 7

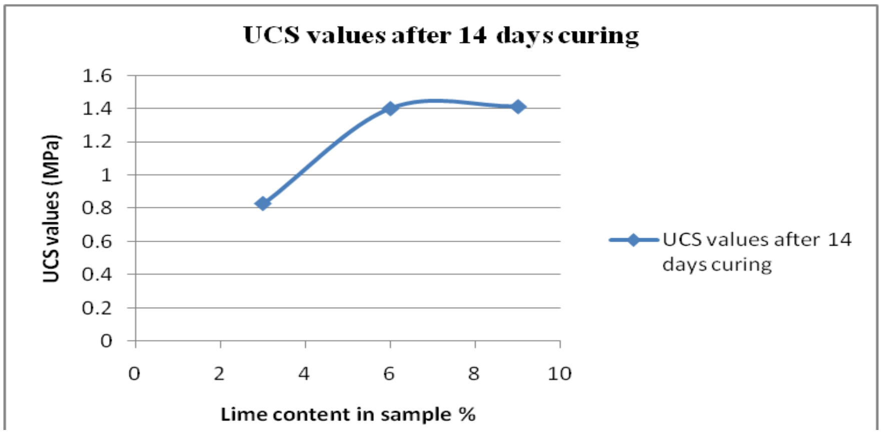

Figure 8

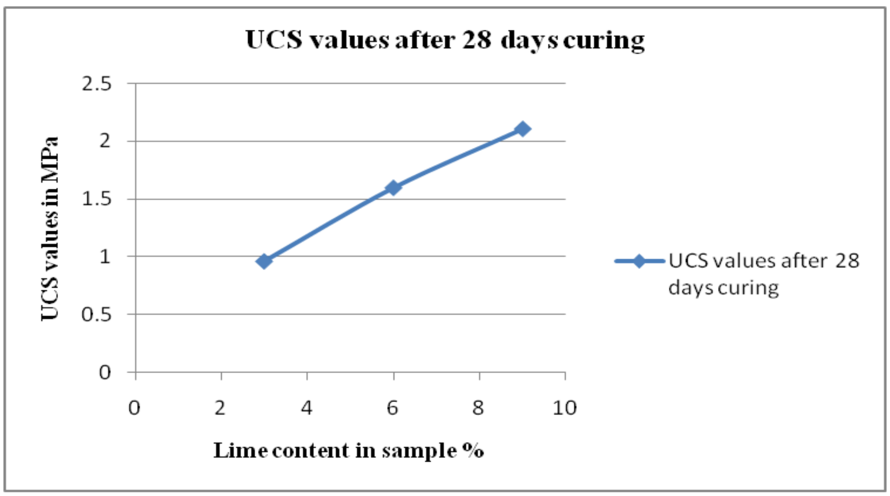

Figure 9

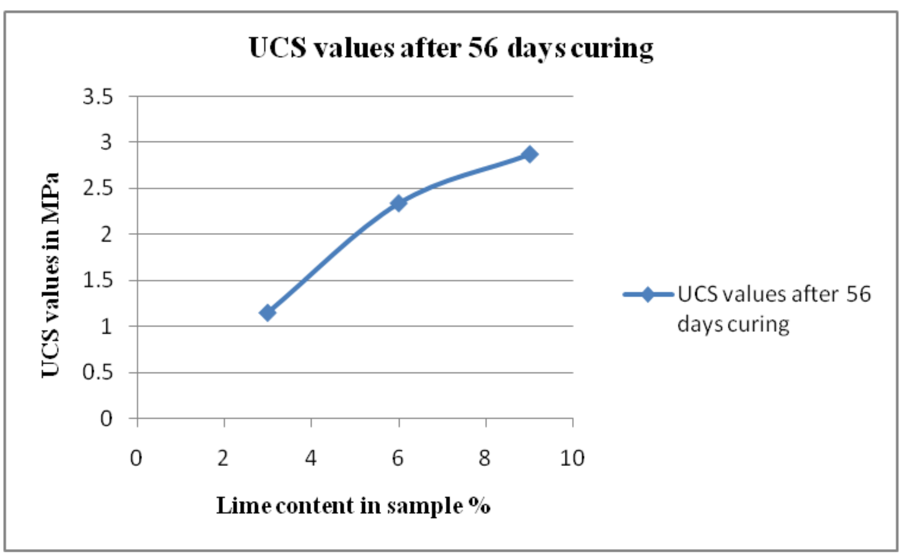

Figure 10

All the samples exhibited shear type failure. The axial strain and corresponding UCS values of different samples at different curing periods, is plotted in figures 11, 12 and 13.The axial strain corresponding to failure has increased with respect to both increase in the lime content as well as with respect to increase in the curing period.

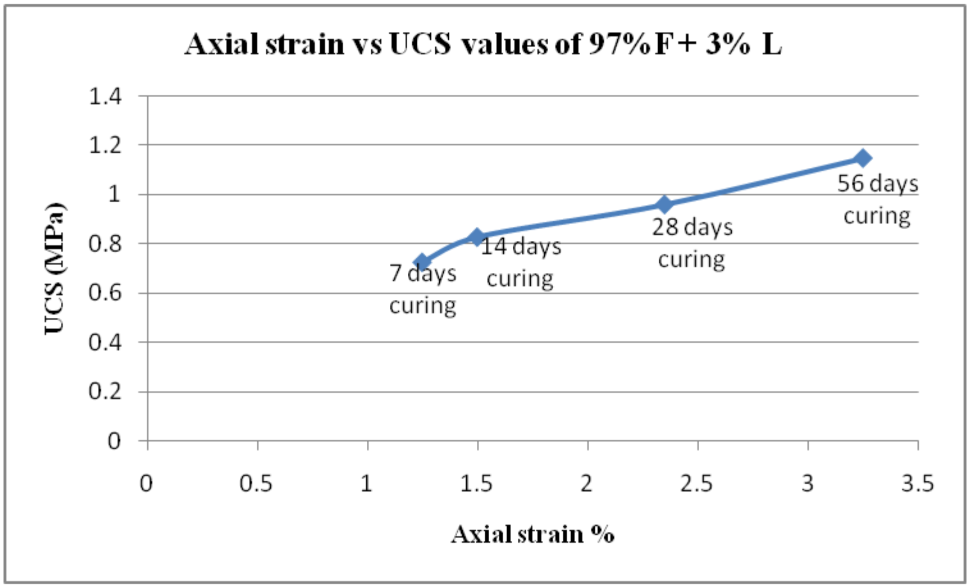

Figure 11

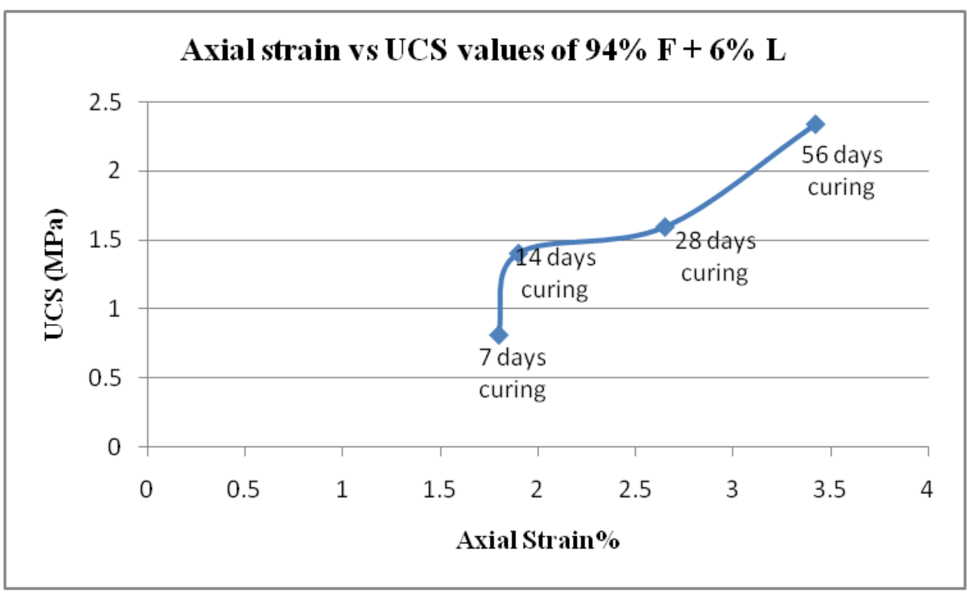

Figure 12

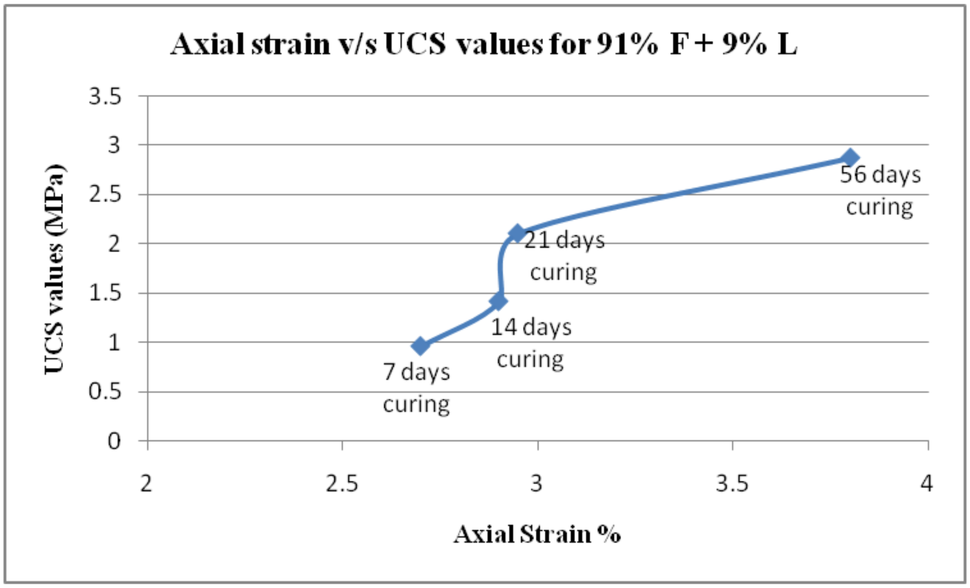

Figure 13

V. CONCLUSIONS

The following conclusions can be drawn from all the above :-

1. The fly ash composites have lower MDD than mine refuse, and the OMC of mine refuse is much lesser than fly ash composites. Also with increase in lime to fly ash composites, MDD decreased and OMC increased.
2. The traditional practice of using mine refuse for mine haul roads cannot be considered a safe and apt option because of very low UCS values as compared to the standards reported by Dwayne D. Tannant and Bruce Regensburg, 2001.
3. With the addition of lime, the compressive strength of the composites increases.
4. All the samples failed by shearing. The axial strain value corresponding to failure of the specimens, increases both with respect to increase in lime content as well as with respect to increase in curing period
5. All the developed fly ash composites were suitable for use in mine haul roads according to the tire pressures reported by Dwayne D. Tannant and Bruce Regensburg, 2001. However 94% F + 6% L sample and 91% F + 9% L samples at curing periods of 14 days or more, have better suitability for use in mine haul roads, as the compressive strength values were beyond 1 MPa.
6. The developed fly ash composites have better compressive strength as compared to the currently used mine haul road construction material.

REFERENCES

[1] https://www.investindia.gov.in/sector/thermal-power#:~:text=As%20of%20July%202020%2C%20India,27.9%25%20and%2025.3%25%20respectively.

[2] Anjan K. Chatterjee (2010,) “Indian Fly Ashes, Their Characteristics, and Potential for Mechano-Chemical Activation for Enhanced Usability”.

[3] Aadil Yousuf et al (2020,) “Fly Ash : Production and Utilization in India – An Oveview”.

[4] Minson Simatupang, Lukas Kano Mangalla, Romy Suryaningrat Edwin, Adris Ade Putra, Mohammad Tahir Azikin, Nini H. Aswas and Wayan Mustika (2020), “The Mechanical Properties of Fly-Ash Stabilised Sands”

[5] Radha Rani and Manish Kumar Jain (2015), “Physiochemical and Engineering characteristics of fly ash and its application in various field”.

[6] Pandian N.S., Rajashekhar C. and Sridharan A.(1998), “Studies on the specific gravity of some Indian coal ashes, journal of Testing and Evaluation, ASTM 26”.

[7] Joel H. Beeghly (2003), “Recent Experiences with Lime – Fly Ash Stabilization of Pavement Subgrade Soils, Base, and Recycled Asphalt”.

[8] Dwayne D. Tannant and Bruce Regensburg (2001), “Guidelines for mine haul road design” pp 90.

[9] Fabio Santos, Lin Li, Yadong li and Farshad Amini (2011), “Geotechnical Properties of Fly Ash and Soil Mixtures for Use in Highway Embankments”.

[9] IS 2720 Part VII – 1980.

[10] IS 2720 Part – 10 (1991).

♦♦♦