Effect of Coal Ash on Strength and CBR Properties of Lacustrine Soil

Mohammad Iqbal Malik[1], Aasif Iqbal[2], Jansher Manzoor[3], Hamid Nazir[4], Towseef Iqbal[5]
[1]Assistant Professor, Department of Civil Engineering, IUST, Awantipora
[2, 3, 4, 5] Civil Engineering Graduate Student, IUST, Awantipora.

***Abstract:*-In various countries of the world like India, after 1990, the shortage of land for construction purpose has become a problematic issue, particularly in Jammu and Kashmir, where horizontal growth has reached its peak level. Now days the new construction is mostly done on weak soil. Thus it became necessity to improve the strength of the soil at the construction site. This paper describes the suitability of using coal ash with lacustrine soil for increasing its shear strength and CBR properties, and to utilize the coal ash being a waste product which otherwise needs to be disposed to the environment causing environmental pollution. Several civil engineering laboratory tests were conducted to study the strength gain when coal ash was mixed with local soil sample. The soil was replaced by coal ash as 10%, 20%, 30%, and 40% by weight. These soil specimens were tested for compressive strength and CBR value for 7 days of age and were compared with normal soil sample without mix. The tests indicate an improved strength and better CBR properties of soil sample when stabilized.**

Keywords: - Unconfined Compressive Strength, Tri-axial Compressive Strength, CBR value, Coal ash, Weak soil.

1. INTRODUCTION

The whole structure or any other construction related things directly or indirectly depend upon the soil stability. The soil bed should bear all the generated stresses due to foundation and the superstructure. Thus for any structure, the foundation has the priority importance. The weak foundation due to presence of weak soil beneath it means the susceptibility of the structure to failure. In this regard, it is necessary to reinforce or to stabilize the soil. Civil engineering projects located in areas with soft or weak soils have traditionally incorporated improvement of soil properties by using cement [1][2] and lime[3][4] . However the use of these materials with soil is an uneconomical approach. We must opt for a waste product unlike using cement or lime with soil. Coal Ash [5] being an industrial waste product provides a better option. This will be effective in terms of cost and a good approach to the environment to preserve and minimize accumulation of industrial waste. Besides this, it can also make the poorly-graded types of soil usable for construction purpose.

Coal ash is produced in various coal-fired power plants all over the world, which totals about 480 million tones according to a report submitted in 2001 [5]. India is ranked 4th in world with a total coal ash production of 80 million tones. The Karewas (Cultivable land for Saffron) cover a vast area of Kashmir Valley. The lacustrine soil being weak in nature has low strength and the coal ash being non useful waste has got disposal problems. The study of using coal ash with lacustrine soil is carried out to observe the effectiveness of its addition on shear strength and CBR properties of weak soil. This is one of the approaches to overcome the increasing amount of solid waste generated by the population. As land is a very valuable commodity and landfills are fast diminishing, the disposal of the coal ash generated from solid waste incineration poses increasingly difficult problems for the municipalities. A practicable solution to the disposal problems would be the reuse of solid waste ash for civil engineering applications.

This paper presents a summary of research project investigating the use of coal ash with soil. The soil was partially replaced as 10%, 20%, 30% and 40% by weight. Several tests were performed on these soil specimens to determine the shear strength and CBR value for 7 days of age which were compared with normal soil sample without mix. The final results indicate an improved shear strength and CBR value. This paper thus hopes to contribute new geo-technique related to soil engineering problems.

2. MATERIALS USED

The materials used for the laboratory experimental research program include coal ash and soil sample.

2.1. Coal Ash

Coal ash was collected from Islamic University campus, Awantipora, Jammu and Kashmir. It is produced as a residue from different coal scuttles being used in class rooms during chilly winters for heating purposes. Coal ash was pulverized manually and then sieved through 1.18mm IS Sieve. The chemical composition of coal ash is presented in

Table.1.

Table.1. Chemical composition of coal ash

Mineral composition	Fly ash (%)	Bottom ash (%)
Silica(SiO_2)	50.03	63.67
Alumina(Al_2O_3)	3.68	13.43
Calcium oxide(CaO)	3.80	5.46
Magnesium Oxide(MgO)	4.01	2.46
Iron oxide(Fe_2O_3)	32.88	11.41
Potassium Oxide(K_2O)	0.32	1.03
LOI(Loss on ignition)	3.99	0.84

2.2. Soil

The soil used for experimental investigations was also obtained from University Campus area which is predominantly organic soil and of Lacustrine origin. The soil was retrieved from the base of an excavation approximately 1m deep. Its specific Gravity was found to be 1.535. Prior to soil treatment, the soil was air dried for 1 week and then crushed using crushing equipment. The maximum particle size was restricted to 4.75mm which corresponds to opening of IS sieve. A particle size distribution analysis was carried out indicating well graded soil with Uniformity Coefficient [7] of 11. The result obtained from Standard Proctor test showed that the maximum dry density of soil is 1812 kg/m^3 at Optimum Moisture Content (OMC) of 16%. Fig. 1 shows soil sample under unconfined compressive test. Fig. 2 shows particle size distribution curve and Fig. 3 shows moisture-density relationship of soil.

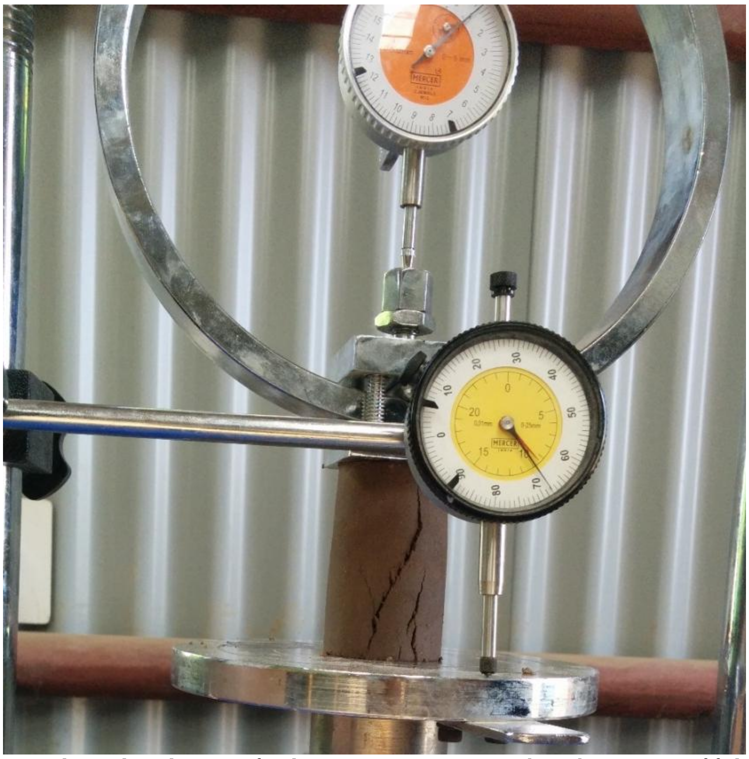

Fig. 1. Soil Sample under Unconfined Compression Testing Machine showing start of failure.

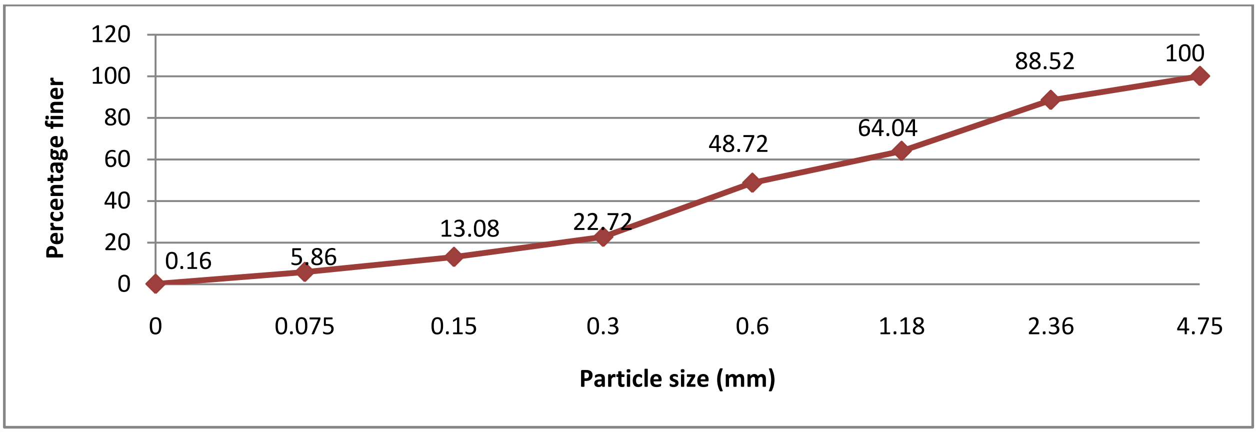

Fig. 2. Particle size distribution curve.

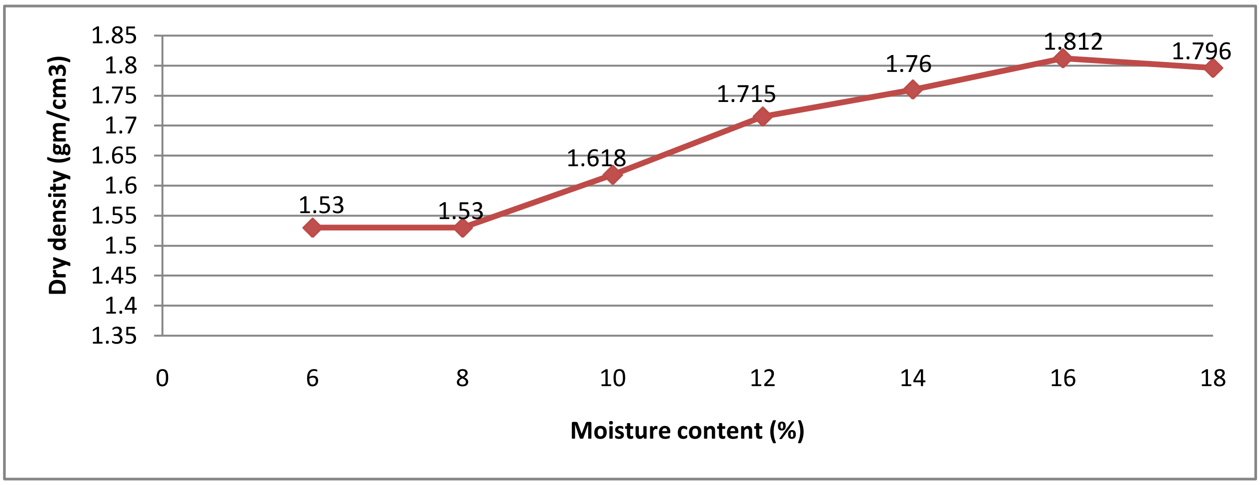

Fig. 3. Moisture – Density relationship.

3. EXPERIMENTAL INVESTIGATION

The experimental tests were conducted in the laboratory, Department of Civil Engineering at Islamic University of Science and Technology, Awantipora, J&K. Testing samples were prepared after compaction, with moisture content equal to optimum moisture content obtained from standard Proctor compaction test.

3.1.Tests on natural soil

The air dried soil was sieved through 1.18mm IS sieve and then compacted at Optimum Moisture Content (OMC). Samples were tested immediately after compaction (t=0), as well as after 7 days. These soil samples were tested for following strength parameters: Unconfined Compression strength (UCS) [8], Tri-axial Compression Strength (TCS) and California Bearing Ratio (CBR).

3.2. Tests on soil mixed with coal ash

Soil samples treated with coal ash were prepared at four soil- coal ash ratio i.e. 10%, 20%, 30% and 40% of coal ash by weight. After Addition of water (water quantity obtained as per Optimum Moisture Content), the mixtures were compacted without delay. These samples were tested immediately after compaction (t=0), as well as after 7 days for same Unconfined Compression strength (UCS), Tri-axial Compression Strength (TCS) and California Bearing Ratio (CBR).

4. RESULTS AND DISCUSSION

4.1.Unconfined Compressive Strength (U.C.S.) Test

The samples both untreated and treated with coal ash were tested for Unconfined Compressive strength (U.C.S) immediately after compaction as well as after 7 days. These tests were carried out at strain rate of 1.25%/minute. Fig. 4 and Fig. 5 represent Unconfined Compressive strength values immediately after compaction and after 7 days
respectively. Maximum U.C.S value at t=0 was 157 KN/m^2 and at 7 days was 506 KN/m^2 corresponding to soil sample containing 30% coal ash by weight. U.C.S values for various mixes are given in Table 2.

4.2.Tri-Axial Compressive Strength (T.C.S.) Test

The samples both untreated and treated with coal ash were tested for Tri-Axial Compressive strength (T.C.S) immediately after compaction as well as after 7 days. These tests were carried out at strain rate of 1.25%/minute.

Fig. 6 and Fig. 7 represent Tri-Axial Compressive strength values immediately after compaction and after 7 days respectively. Maximum T.C.S value at t=0 was 217 KN/m^2 and at 7 days was 710 KN/m^2 corresponding to soil sample containing 30% coal ash by weight. T.C.S values for various mixes are given in Table 2.

4.3.California Bearing Ratio (C.B.R.) Test

The samples both untreated and treated with coal ash were tested for California Bearing Ratio (C.B.R.) immediately after compaction as well as after 7 days. These tests were carried out at strain rate of 1.25%/minute. Fig. 8 and Fig. 9 represent California Bearing Ratio values immediately after compaction and after 7 days respectively. Maximum C.B.R value at t=0 was 19% and at 7 days was 28.5% corresponding to soil sample containing 30% coal ash by weight. C.B.R values of various mixes are given in Table 2.

Table – 2. UCS, TCS and CBR Values for various mixes at 0 and 7 days

Sample	U.C.S value (KN/m^2) (t=0 days)	U.C.S value (KN/m^2) (t=7 days)	T.C.S value (KN/m^2) (t=0 days)	T.C.S value (KN/m^2) (t=7 days)	C.B.R value (%) (KN/m^2) (t=0days)	C.B.R value (%) (KN/m^2) (t=7 days)
Natural soil	65	112	92	164	0.985%	1.34%
Soil with 10% coal ash	72	184	105	276	1.8%	4.43%
Soil with 20% coal ash	118	309	171	493	5.87%	13.96%
Soil with 30% coal ash	**157**	**506**	**217**	**710**	**19%**	**28.5%**
Soil with 40% coal ash	131	302	203	664	11%	12.50%

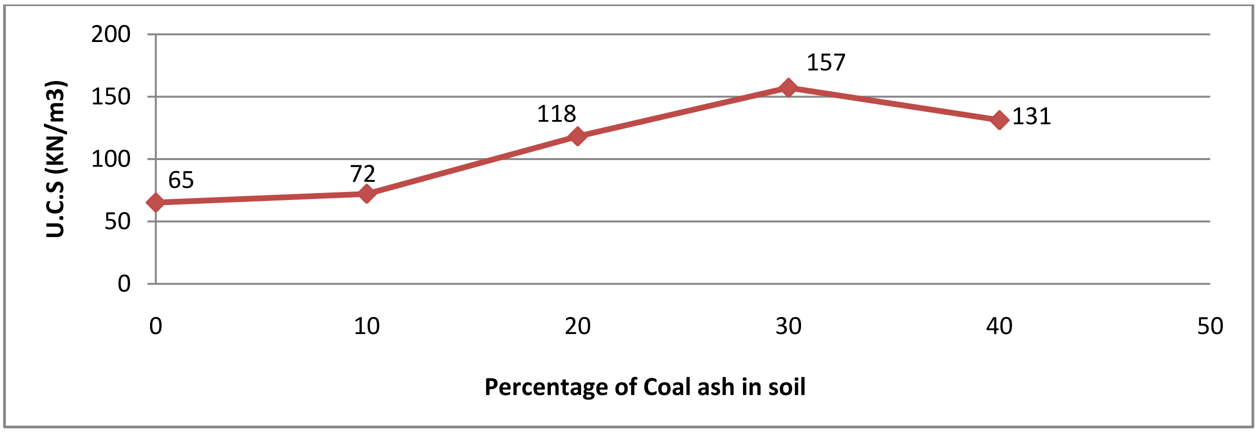

Fig.4- Unconfined Compressive strength immediately after compaction (t=0)

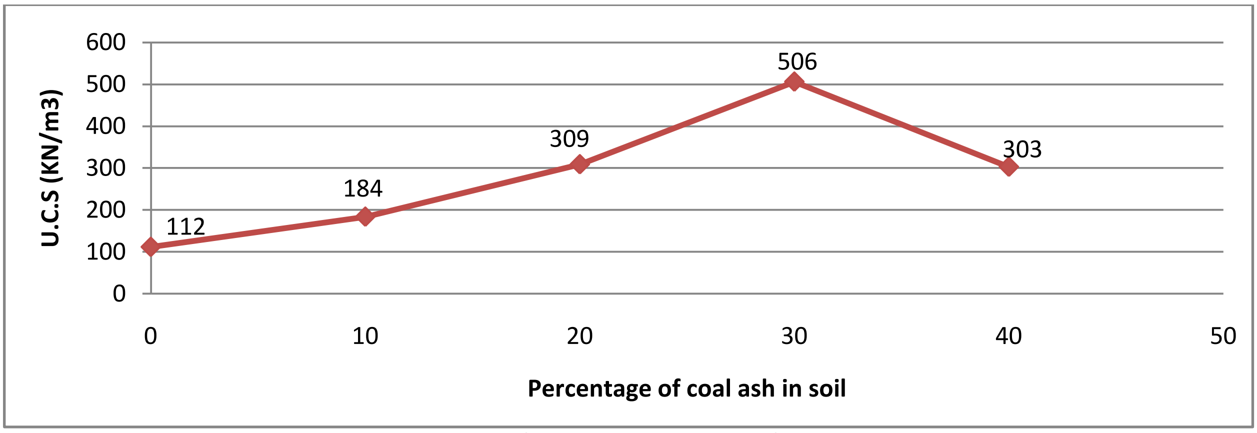

Fig.5 – Unconfined Compressive strength after 7 days

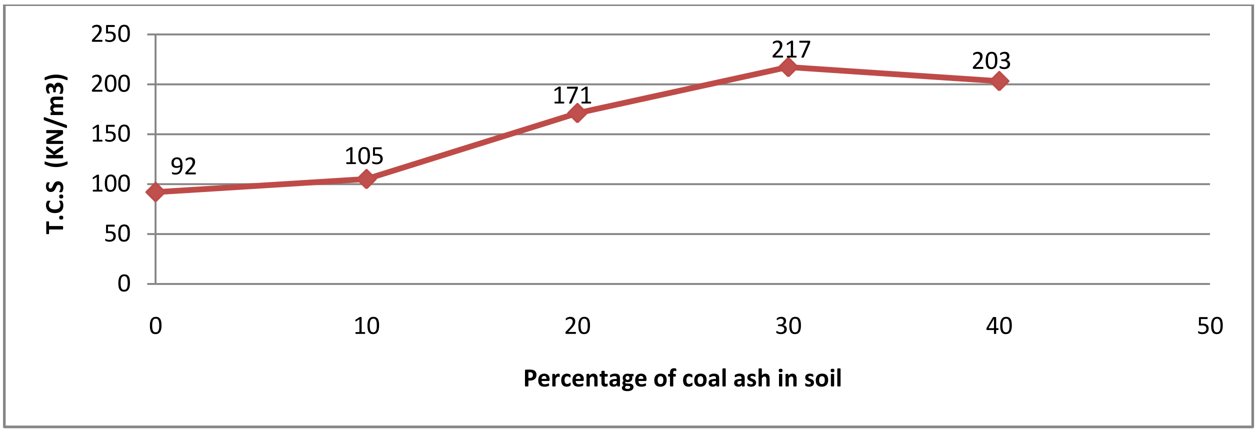

Fig.6 – Tri-axial Compressive strength immediately after compaction

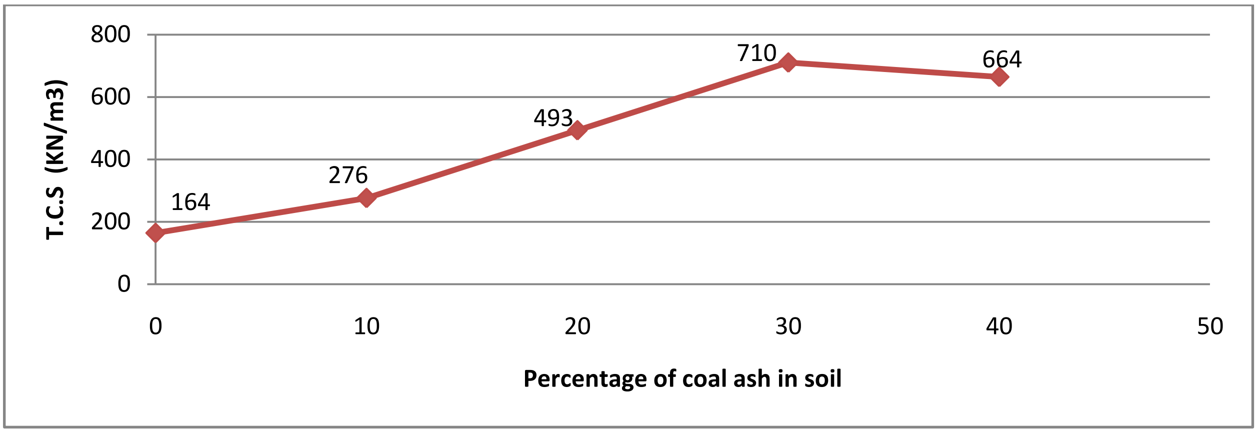

Fig.7 –Tri-axial Compressive strength after 7 days

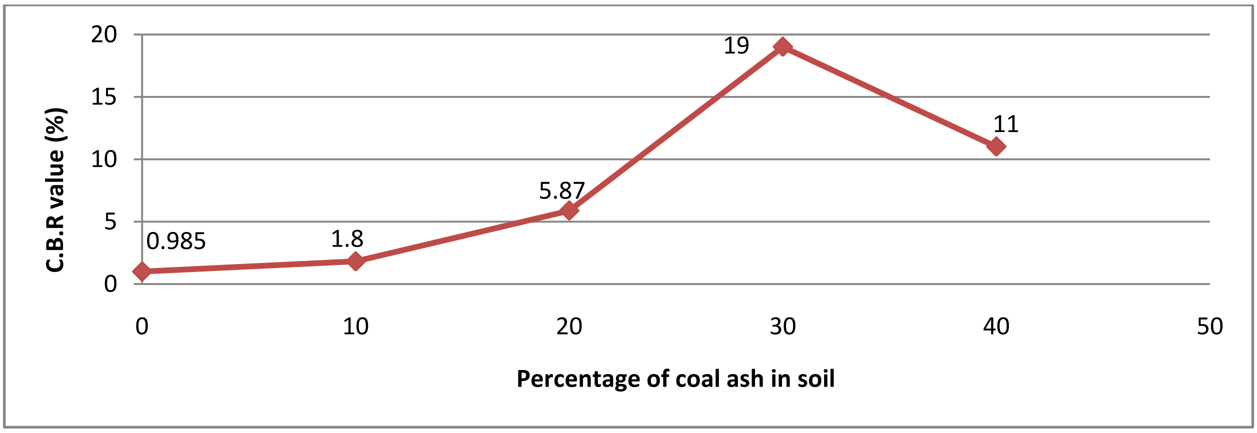

Fig.8 – CBR value (%) immediately after compaction

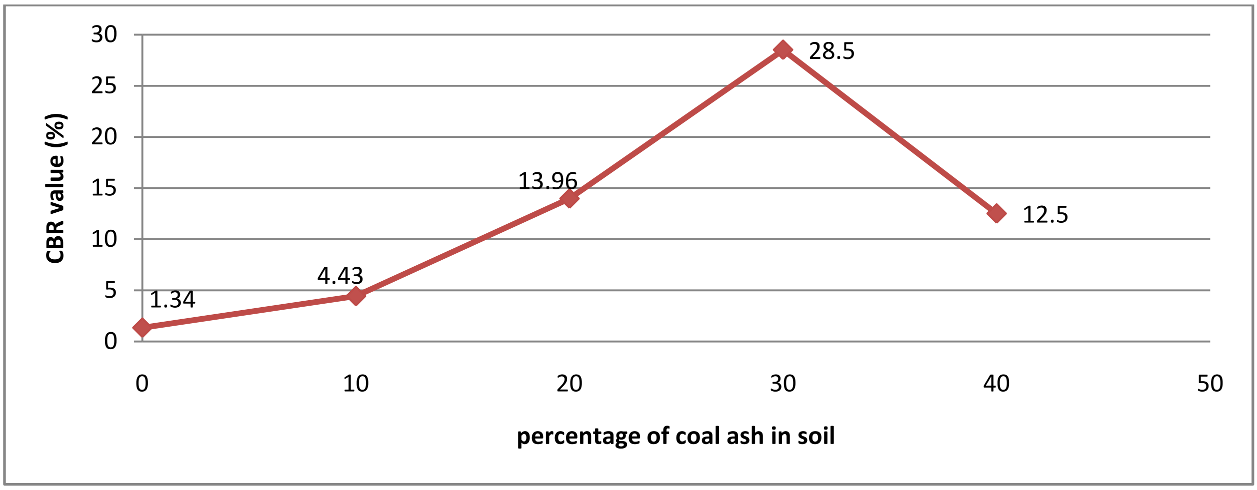

Fig.9 –CBR value (%) after 7 days

5. CONCLUSION

On the basis of results obtained, following conclusions can be drawn:

1. Annually millions of tons of coal ash is produced globally as a waste product from different Coal-fired power plants, the research concluded that it can be used to increase the strength parameters of soil in a way to minimize the amount of waste to be disposed to the environment causing environmental pollution.
2. Results showed maximum unconfined compressive strength gain of 350% and maximum Tri-axial compressive strength gain of 330% for mix with 30% replacement of soil by coal ash with respect to natural soil.
3. CBR Value showed sufficient increase from 1.34 % to 28.5% for mixture with 30% of Coal ash, thus it can be utilized successfully and economically in the pavement layers of road construction.
4. The problem of disposal of coal ash as a waste is addressed and hence avoiding landfill.

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