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Shear Strength and CBR improvement of Lacustrine Soil mixed with Waste Brick Powder

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Abstract: The Lacustrine soil is a post glacial deposit with sand and/or silt seems and thin layers in between and it is highly compressible, possesses very low shear strength as well as it is very sensitive. The poor strength of Lacustrine soils comes as a hindrance to construction of infrastructure in the lacustrine plains of state of Jammu & Kashmir, India. This research hence aims at improving the strength characteristics of lacustrine soils by utilization of waste material - brick powder which needs vast land for dumping. Hence this research aims at two objectives – first is to improve strength properties of Lacustrine soils and second is to use waste material which would otherwise need landfill area and create environmental degradation. The addition to strength of soil after mixing will be due to presence of Silica and Alumina in brick powder. This research studied shear strength and CBR properties of Lacustrine soil in natural state and after replacement of the soil by waste brick powder 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 maximum unconfined compressive strength gain of 150% and maximum Tri-axial compressive strength gain of 165% for mix with 30% replacement of soil by brick powder with respect to natural soil. CBR Value also showed sufficient increase from 1.34 % to 11.5% for mixture with 30% of brick powder.
Keywords: Shear Strength, CBR, Waste Brick Powder, Sustainability, Stabilization.

I. INTRODUCTION

Certain types of soils are very weak and they cannot be used as foundation layers or as a construction material. Different methods are adopted to stabilize these types of soils to suit the specifications of construction industry, which incurs more effort and money. In order to reduce the expenditure towards stabilization, studies using industrial wastes are being carried out to reduce the pollution by dumping and save the environment. The weak foundation due to presence of weak soil beneath 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]. Literature reference on these studies indicates the potential use of industrial wastes for stabilization of soils. The addition to strength of soil after mixing will be due to presence of Silica and Alumina in brick powder [5]. In this paper an attempt has been made to stabilize the soil using brick powder. Brick powder being an industrial waste product provides a better option [6]. This will be effective in terms of cost and a good approach to the environment to preserve and minimize accumulation of industrial waste. A.Heidari and B.Hasanpour [7] have reported in Asian journal of Civil Engineering that brick powder being a pozzolanic material can be used in soil stabilization.

The Lacustrine soil being weak in nature has low strength and the brick powder being non useful waste has got disposal problems. The study of using brick powder 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 brick powder generated from various brick kilns pose increasingly difficult problems for the municipalities. A practicable solution to the disposal problems would be the reuse of solid waste brick powder for civil engineering applications.

This paper presents a summary of research project investigating the use of brick powder 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. India is the second largest producer of clay fired bricks [8], accounting for more than 10 percent of global production. India is estimated to have more than 100,000 brick kilns, producing about 150-200 billion bricks annually, employing about 10 million workers and consuming about 25 million tons of coal annually. India's brick sector is characterized by traditional firing technologies; environmental pollution; reliance on manual labor and low mechanization rate; dominance of small-scale brick kilns with limited financial, technical and managerial capacity; dominance of single raw material (clay) and product (solid clay brick); and lack of institutional capacity for the development of the sector.

II. LITERATURE REVIEW

H.N.Ramesh, A.J.Krishnaiah and S.Shilpa shet [9] from Department of Civil Engineering, UVCE, Bangalore University, Bangalore-56, India in april-2013 conducted tests on lime treated black cotton soil by adding mine tailing mixtures as a stabilizing agent. Liquid limit, plastic limit and shrinkage limit of Black cotton soil and mine tailings (MT) mixtures treated with lime are investigated and are presented in this paper. In the present investigation an attempt has been made to utilize the mine tailings in geotechnical applications and to evaluate the index properties of black cotton soil and mine tailings mixture treated with lime. The test results indicate that the progressive decrease in liquid limit, decrease in plastic limit and increase in shrinkage limit with curing time. Liquid limit is used for the estimation of compression index which is useful for the settlement analysis of soils.

Effect of Fly ash on expansive soil was studied by Erdal Cokca [10], There are two major classes of fly ash, class C & F. He carried out investigations using Soma Fly-ash and Tuncbilek fly-ash and added it to expansive soil at 0-25%. Specimens with fly-ash were cured for 7 & 28 days after which they were subjected to oedometer free swell tests. And his experimental findings confirmed that the plasticity index, activity and swelling potential of the samples decreased with increasing percent stabilizer and curing time and the optimum content of fly ash in decreasing the swell potential was found to be 20%. The changes in the physical properties and swelling potential are a result of additional silt size particles to some extent. He concluded that both high – calcium and low calcium class C fly ashes can be recommended as effective stabilizing agents for improvement of expansive soils.

Mahasneh [11] studied the effect of aluminum residue on the expansive clayey soil and concluded that the addition of aluminum residue and recycled asphalt materials to a silty clay soil with proper compaction would lead to an increase in the bearing capacity and dry density. In addition, an increase in the unconfined shear strength and a decrease in swelling and the shrinkage potential of the silty clay soil were also observed. Hainin et al. [12] investigated the use of steel slag as an aggregate in the design of asphalt concrete for road construction. The best management option for this by-product is recycling. This leads to reduction of landfills reserved for its disposal, saving natural resources and attaining a cleaner environment. Sachin and Ankit [13] studied the influence of brick dust. Brick dust is a waste material that is widely available in large quantity. To resolve the problem of swelling, they replaced the soil with a stabilizing agent that was 50 % of its dry weight. For the analysis of stabilizer effect on soil, a comparison was done of the properties of 100 % black cotton soil and the combination of 50 % clack cotton soil + 50 % brick dust. The comparison included all properties by carrying out a compaction test, atterberg limit test, and linear and swelling tests on both normal and stabilized soil. The abovementioned tests show a great decrement in soil swelling.

Agarwal [14] presented the effect of stone dust, which is a kind of solid waste material that is generated from the stone crushing industry. This material is abundantly available; it is estimated that 15 % to 20 % of each crusher unit's product is stone dust. Adding 50 % of stone dust is effective in decreasing optimum moisture content of soils, which is advantageous in decreasing quantity of water required during compaction. The study also reveals the fact that with an increase in the percentage of stone dust, maximum dry density (MDD) of the soil increases. Mixing soil with stone dust was also found to improve its CBR. Adding only 30 % of stone dust was found to increase the CBR of soil by nearly 50 %.

III. MATERIALS USED

The materials used for the laboratory experimental research program include brick powder and soil sample. These are described below.

A. Brick Powder

Bricks powder may come from two sources. The first source is the bricks industry and the second source is associated with construction and demolition activity, and constitutes a significant fraction of construction and demolition waste. Therefore, the use of brick powder with soil has the advantage of solving several environmental problems. Besides this it gives Long-term mechanical strength, stable resistance to expansion due to the presence of free lime, sulphates and aggregate-alkali reactions, durable resistance to the action of pure and acid water, impermeability, reducing porosity and increasing compactness.

Brick powder was pulverized manually and then sieved through 1.18mm IS Sieve. The chemical composition of brick powder is presented in Table.1. Fig.1.1 shows SEM image of waste brick powder. Fig.1.2 shows waste brick powder sieved through 1.1mm IS sieve.

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Table.1. Chemical composition of brick powder

Mineral composition	Percentage(%)
Silica(SiO_2)	46.52
Alumina(Al_2O_3)	10.06
Calcium oxide(CaO)	24.48
Magnesium Oxide(MgO)	8.56
Iron oxide(Fe_2O_3)	4.29
Sodium Oxide(Na_2O)	1.02
Potassium Oxide(K_2O)	1.08
(TiO_2)	0.514
(P_2O_5)	0.199
(SO_3)	0.895
(MnO)	0.079
LOI(Loss on ignition)	0 .66

B. Soil

The soil used for experimental investigations was 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 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.2 shows soil sample under unconfined compressive test. Fig.3 shows particle size distribution curve and Fig.4 shows moisture-density relationship of soil. Table 2. Shows particle size distribution data.

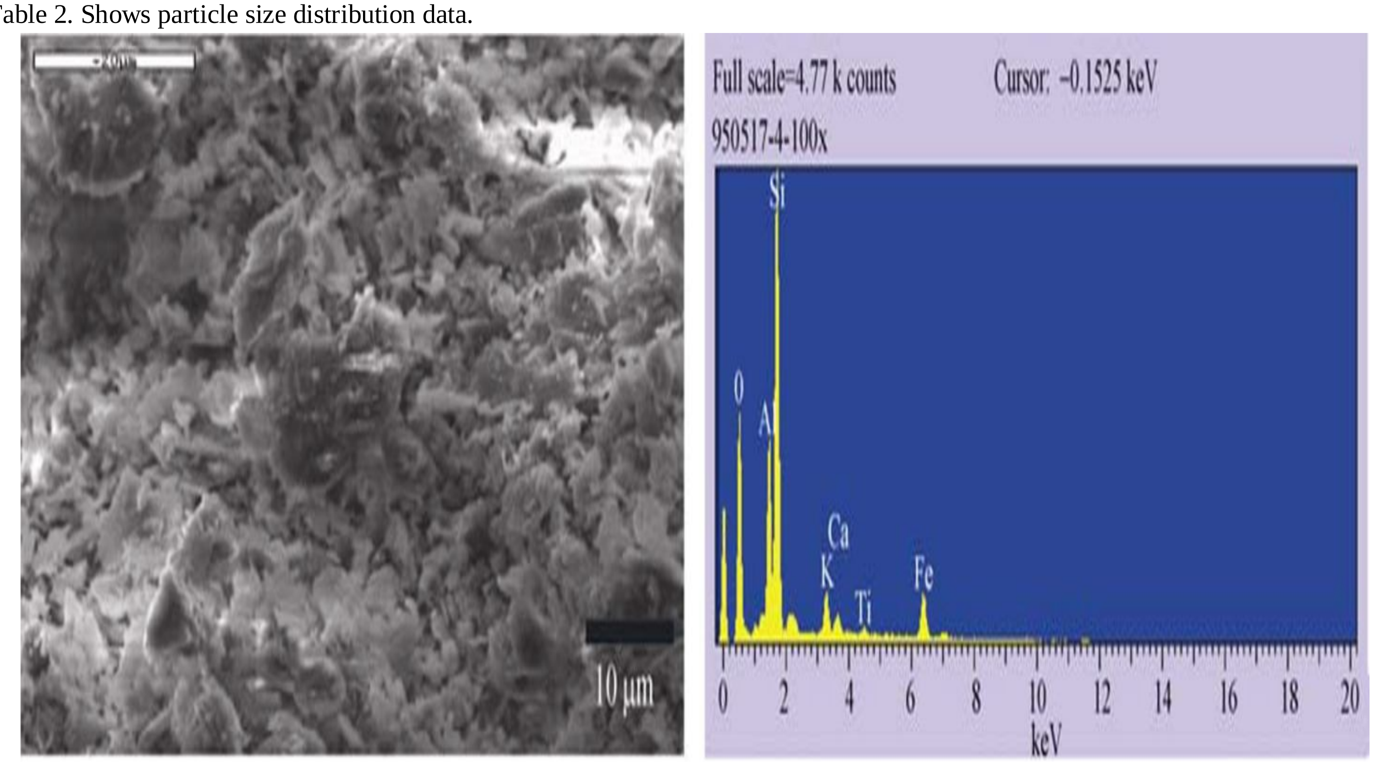

Fig.1.1. SEM micrographs and EDX composition analysis of brick powder (Tsai, Fang, Lin and Tsai 2009).

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Fig.1.2 Waste brick powder after being sieved through 1.1mm IS Sieve.

Fig. 2. Soil Sample under Unconfined Compression Testing Machine showing start of failure.

Table 2. Particle Size Distribution

Sieve Size (mm)	Retained (g)	Retained (%)	Cumulative Retained (%)	Cumulative Finer (%)
4.750	000	0.00	0	100
2.360	574	11.48	11.48	88.52
1.180	1224	24.48	35.96	64.04
0.600	766	15.32	51.28	48.72
0.300	1430	26.0	77.28	22.72
0.150	482	9.64	86.92	13.08
0.075	361	7.22	94.14	5.86
<0.075	285	5.70	99.84	0.16

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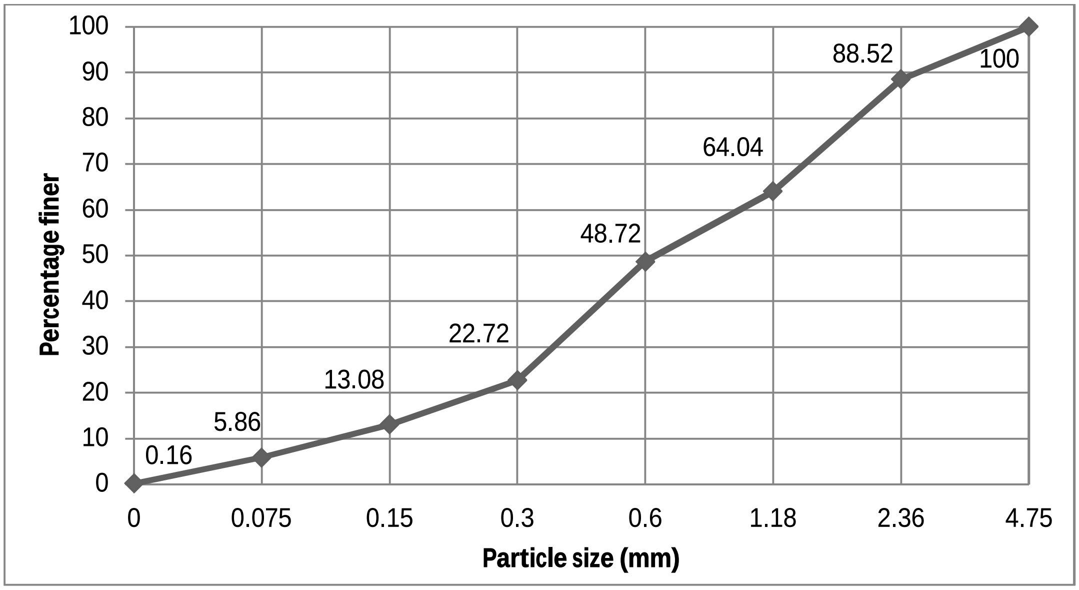
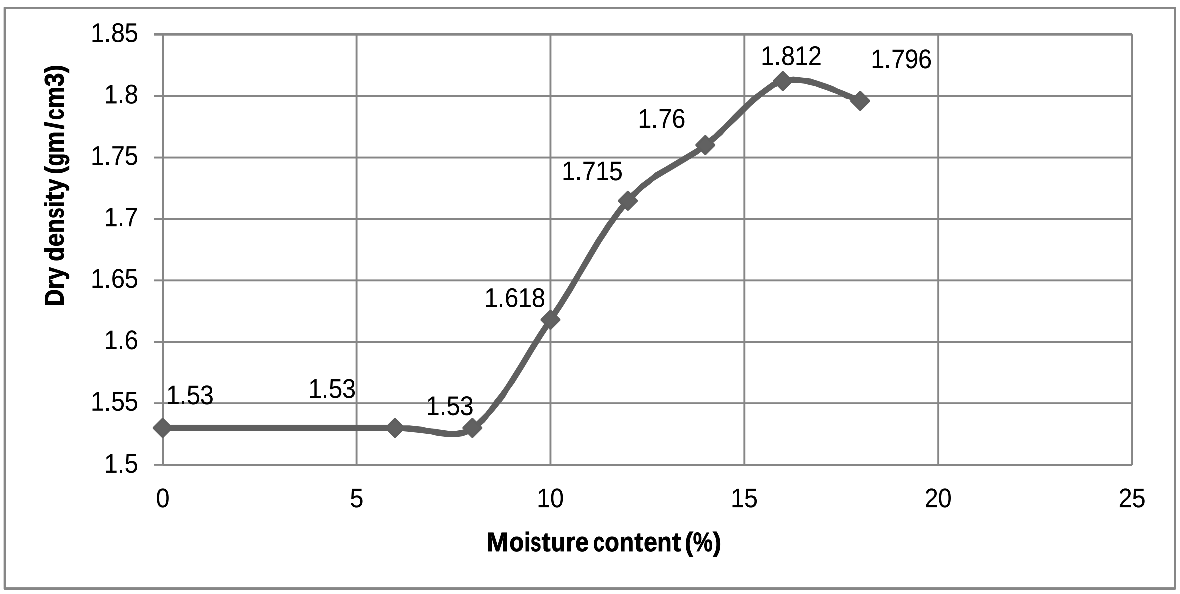


C. Moisture – Density relationship.

Fig. 3. Particle size distribution curve.



IV. 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.

A. 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), Tri-axial Compression Strength (TCS) and California Bearing Ratio (CBR).

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B. Tests on Soil Mixed with Brick Powder

Soil samples treated with brick powder were prepared at four soil- brick powder ratio i.e. 10%, 20%, 30% and 40% of brick powder 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).

V. RESULTS AND DISCUSSION

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

The samples both untreated and treated with brick powder 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. 5 and Fig. 6 represent Unconfined Compressive strength values immediately after compaction and after 7 days respectively. Maximum U.C.S value at t=0 was 138KN/m^2 and at 7 days was 280KN/m^{2}corresponding to soil sample containing 30% brick powder by weight. U.C.S values for various mixes are given in Table 3.

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

The samples both untreated and treated with brick powder 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. 7 and Fig. 8 represent Tri-Axial Compressive strength values immediately after compaction and after 7 days respectively. Maximum T.C.S value at t=0 was 217KN/m^2 and at 7 days was 434KN/m^2 corresponding to soil sample containing 30% brick powder by weight. T.C.S values for various mixes are given in Table 3.

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

The samples both untreated and treated with brick powder 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.9 and Fig.10 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% brick powder by weight. C.B.R values of various mixes are given in Table 3.

Table – 3. UCS, TCS and CBR Values for various mixes at 0 and 7 days

Sample	U.C.S value (KN/m^3) (t=0 days)	U.C.S value (KN/m^3) (t=7 days)	T.C.S value (KN/m^3) (t=0 days)	T.C.S value (KN/m^3) (t=7 days)	C.B.R value (%) (t=0days)	C.B.R value (%) (t=7 days)
Natural soil	65	112	92	164	0.985%	1.34%
Soil with 10% brick powder	85	144	118	210	1.34%	4.43%
Soil with 20% brick powder	92	164	131	236	1.7%	6.96%
Soil with 30% brick powder	**138**	**280**	**217**	**434**	**2.17%**	**11.5%**
Soil with 40% brick powder	117	169	151	223	1.75%	8.7.%

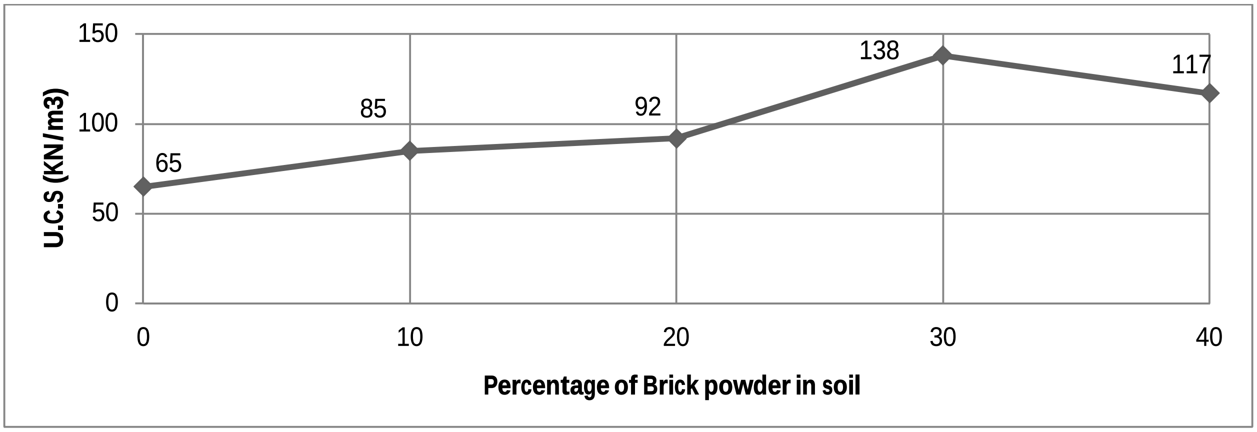

Fig.5- Unconfined Compressive strength immediately after compaction (t=0)

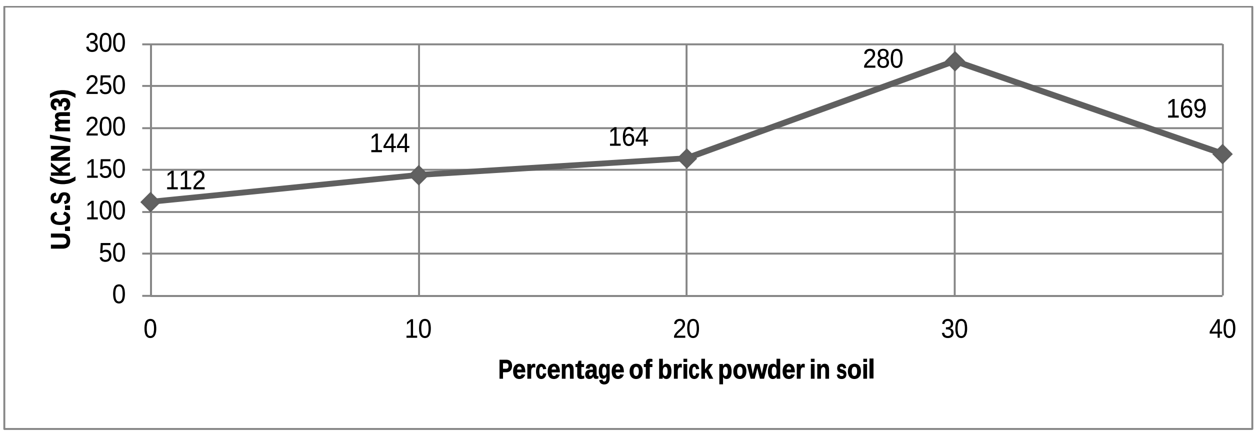

Fig.6 – Unconfined Compressive strength after 7 days

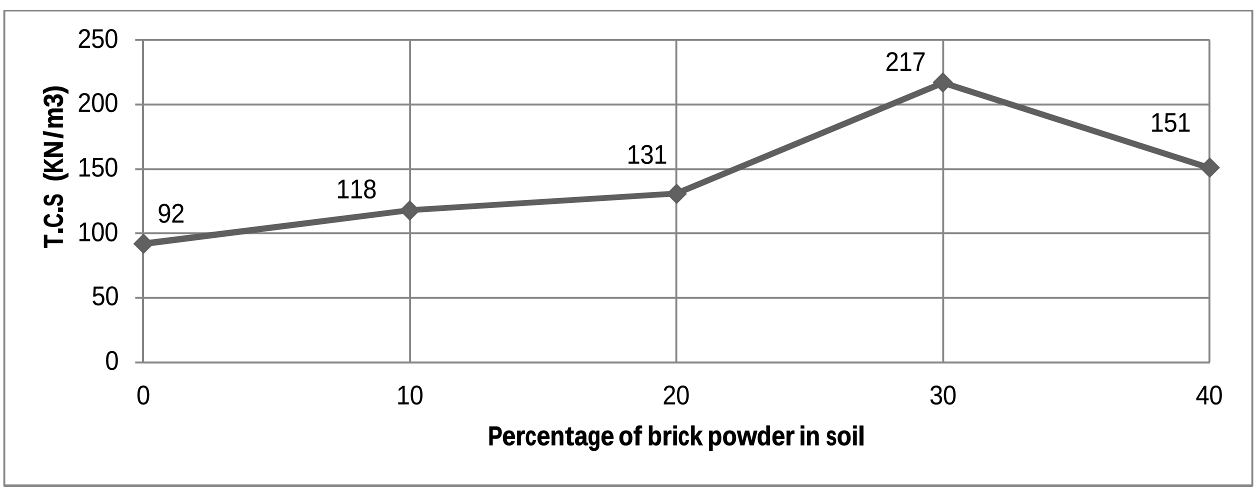

Fig.7 – Tri-axial Compressive strength immediately after compaction (t=0)

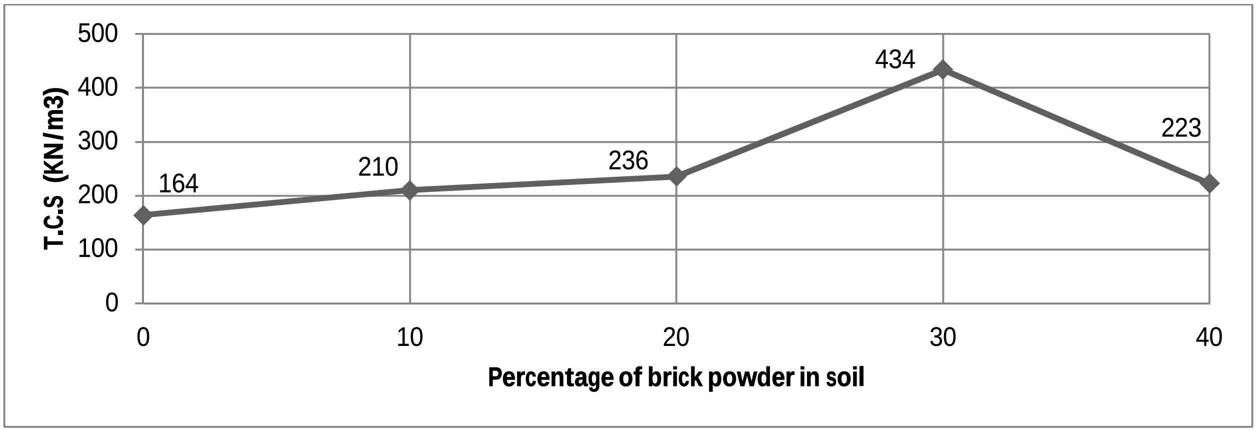

Fig.8 –Tri-axial Compressive strength after 7 days

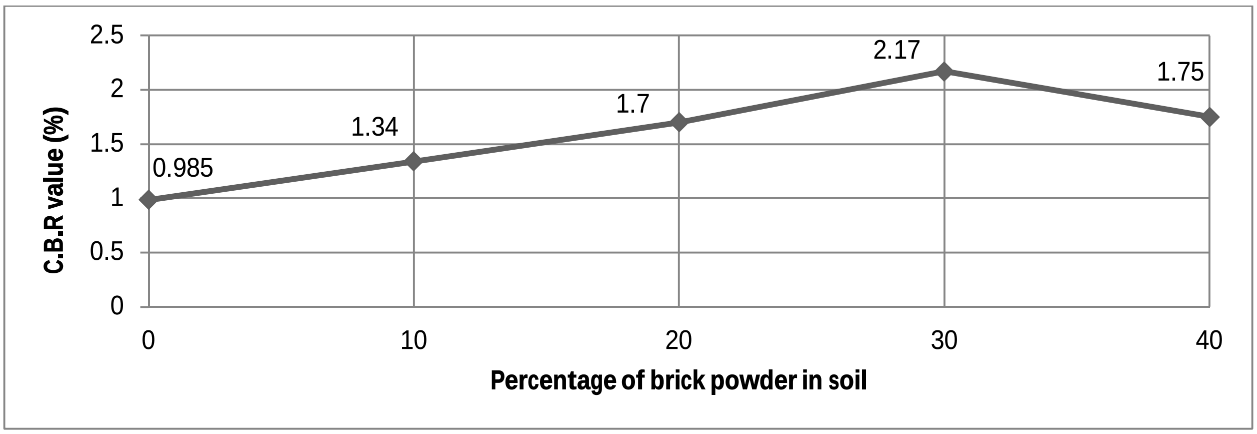

Fig.9 – CBR value (%) immediately after compaction

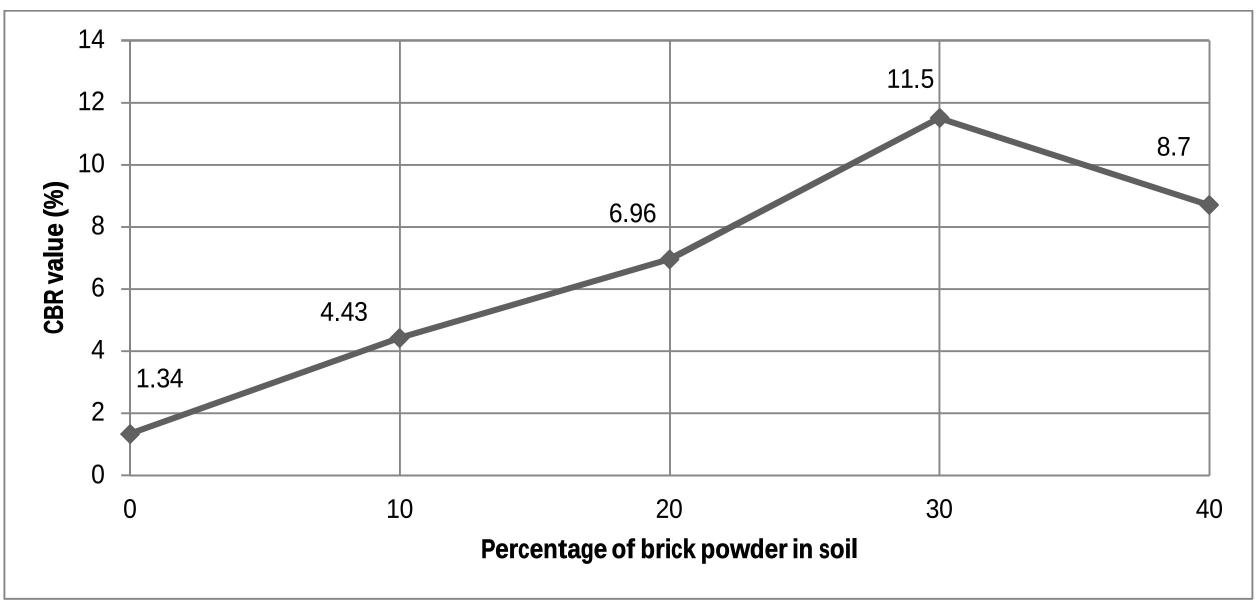

Fig.10 –CBR value (%) after 7 days

VI. CONCLUSION

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

A. Annually millions of tons of brick powder is produced globally as a waste product from different brick kilns and due to construction and demolition activity, 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.
B. Results showed maximum unconfined compressive strength gain of 150% and maximum Tri-axial compressive strength gain of 165% for mix with 30% replacement of soil by brick powder with respect to natural soil.
C. CBR Value showed sufficient increase from 1.34 % to 11.5% for mixture with 30% of Brick powder, thus it can be utilized successfully and economically in the pavement layers of road construction.
D. The problem of disposal of brick powder as a waste is addressed and hence avoiding landfill.

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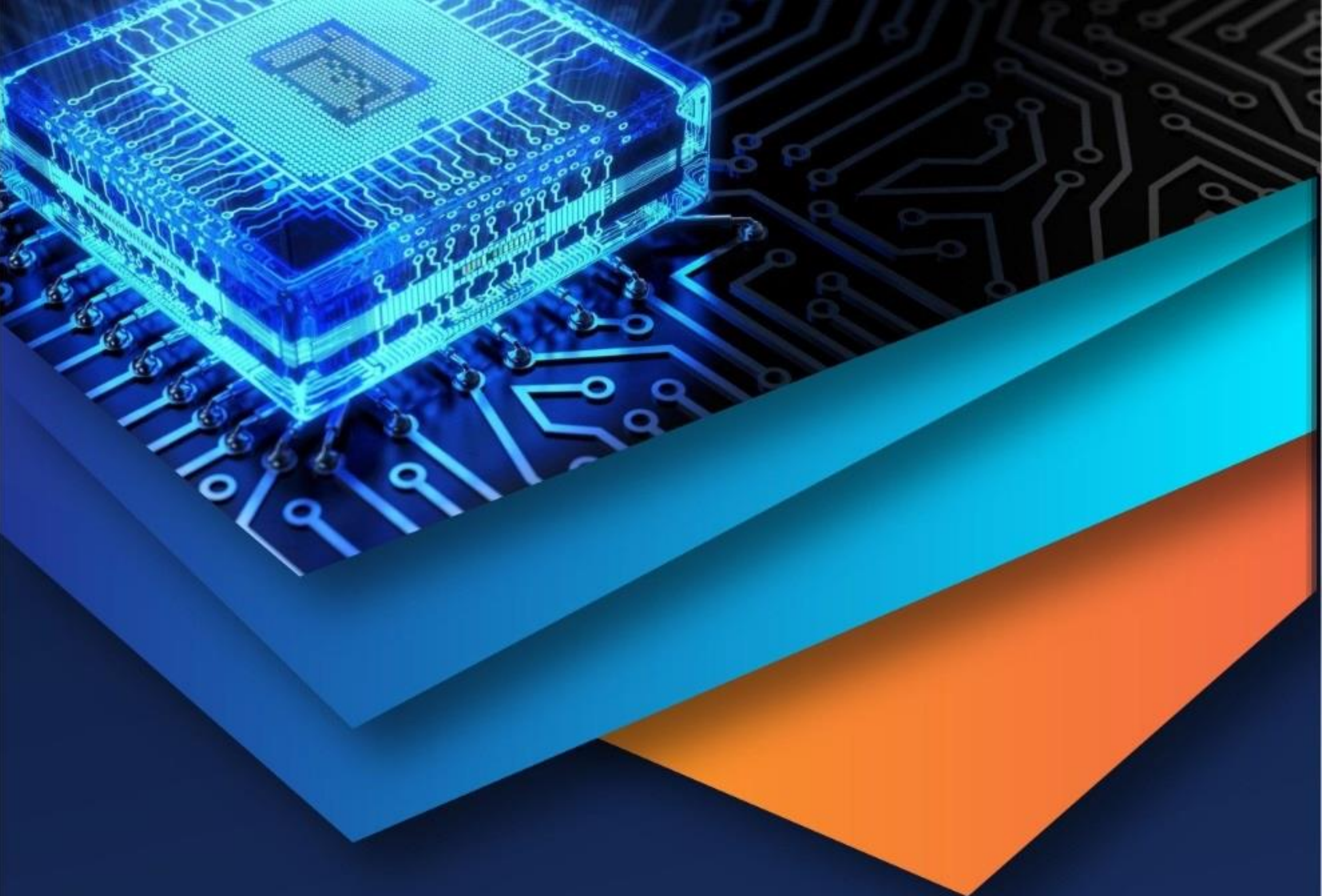

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