Study on The Use of Phospogypsum (Pg) And Crumb Waste Rubber (Cwr) In Improving of Expansive Soil Subgrades

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Abstract- *Expansive Soils, popularly known as Black cotton soils in India, are highly problematic because of their property of high degree of swelling and shrinkage. These soils when encountered as sub grade of Pavement constructions pose problems in the form of cracking and increased maintenance. Hence in order to improve the properties of such soils many methods are available like soil stabilization, soil replacement, moisture control, prewetting etc. In recent years, soil stabilization by using various industrial wastes was a most common practice. These solid wastes are day by day increasing in India, which is not environmental friendly hence they have to be recycled. Thus, a study is proposed to make use of one of these wastes in soil stabilization. In this present work, the study mainly focuses on stabilization of soil using Phospogypsum (PG), a waste from Fertilizer Industry. Also an attempt is made to utilize Crumb Waste Rubber (CWR) in combination with the above waste material. To understand the performance of stabilized soil, its properties like Atterberg's Limits, Compaction Parameters, Swell Parameters and Penetration Parameters were studied. Hence, in this project, the use of Phospogypsum (PG) and Crumb Waste Rubber (CWR) in different percentages as stabilizing materials for improving the problematic expansive will be tried by conducting various tests and the results will be analyzed to assess the efficiency of the materials used.*

Keywords- Expansive soil, Crumb waste rubber, Phosphogypsum, Atterberg's limit test, CBR test, Un confined compression test, maximum dry density and optimum moisture content test.

I. INTRODUCTION

Soil is the collection of natural bodies on earth‟s surface containing living matter and supporting, or capable of supporting plants. Its upper limit is the atmosphere (air) or water, and at its lateral margins it grades to deep water or barren areas of rock and ice. Its lower limit is normally considered to be the lower limit of the common rooting zone (root zone) of the native perennial plants, a boundary that is shallow in the deserts and tundra and deep in the humid tropics. Soil itself is very complex. It would be very wrong to think of soils as just a collection of fine mineral particles. Soil also contains air, water, dead organic matter, and mvarious types of living organisms. The formation of a soil is influenced by organisms, climate, topography, parent material, and time. For centuries mankind was wondering at the instability of earth materials, especially expansive soil. One day they are dry and hard, and the next day wet and soft. Swelling soil always create problem for lightly loaded structure, by consolidating under load and by volumetrically along with seasonal moisture variation. As a result the superstructures usually counter excessive settlement and differential movements, resulting in damage to foundation systems, structural elements and architectural features. In a significant number of cases the structure becomes unstable or uninhabitable.

Expansive soil deposits occur in the arid and semi arid regions of the world and are problematic to engineering structures because of their tendency to heave during wet season and shrink during dry season (Mishra et al. 2008). Expansive soils are a worldwide problem that poses several challenges for civil engineers. They are considered a potential natural hazard, which can cause extensive damage to structures if not adequately treated (Al-Rawas, 2002). During the last few decades damage due to swelling action has been observed clearly in the semi-arid regions in the form of cracking and breakup of pavements, roadways, building foundations, slab-on-grade members, and channel and reservoir linings, irrigation systems, water lines, and sewer lines (cokca, 2001). Various remedial measures like soil replacement, moisture control, pre-wetting, lime stabilization have been practiced with varying degrees of success. However, these techniques suffer from certain limitations with respect to their adaptability, like longer time periods required for pre-wetting the highly plastic clays, difficulty in constructing the ideal moisture barriers, pulverization and mixing problems in case of lime stabilization and high cost for hauling suitable refill material for soil replacement etc.

Stabilization of expansive soils is an alternative for geotechnical engineers considering the economics of construction with expansive clay soils. Mechanical stabilization, such as compaction, is an option; however many engineers have found it necessary to alter the physicochemical properties of clay soils in order to permanently stabilize them.

1. OBJECTIVES OF THE STUDY

The objectives of present experimental study are to develop correlations between engineering Characteristics of Expansive soil.

- To determine the characteristic of Expansive soil in particular the basic Properties, strength and compressive characteristics.
- To evaluate the performance of Expansive soil when stabilized with Phosphogypsum as an admixture and its suitability for the pavement sub grade.

To evaluate the performance of stabilized Expansive soil with an optimum of and Phosphogypsum and further addition of crumb waste rubber and their suitability for the pavements.

2. GENERAL

Transportation fulfills the basic need of humanity. For the time immemorial everyone travels either for food or leisure. There is a strong correlation between the quality of transportation facilities and development of country, because of which everyone places a great expectation from transportation facilities. Major challenges among civil engineers today is that transportation system must be analytically based, economically sound, eco-friendly, socially credible, sustainable and practically acceptable. In current scenario, conventional construction methods are unsuitable and driving interest in technologies like ground improvement. Among all transportation modes, economical road network plays a vital role for advancement in the economy of developing countries like India. In case of a highway, if the sub grade layer of the pavement is weak then they require greater thickness of pavement that results in increase of pavement construction cost.

II. LITERATURE REVIEW

Soil stabilization is a procedure where we improve engineering properties of soil with the use of natural or synthesized admixtures. In the past many researchers have carried out their research work for improving the strength of black cotton soil using different types of admixture at different percentages. A brief review of previous studies on black cotton soil is presented in this section and past efforts most closely related to the needs of present work.

Many researcher have done their research work on subgrade strength determination and used various types of materials such as waste materials, crushed stone, Geosynthetics etc. various scientists had different opinion to use those materials as stabilizing material.

PARIMAL JHA , NISHEET TIWARI (APRIL-MAY 2016) performed a research on black cotton soil & described that Black Cotton Soils exhibit high swelling and shrinking when exposed to changes in moisture content and hence have been found to be most troublesome from engineering considerations. This behaviour is attributed to the presence of a mineral montmorillonit. The wide spread of the black cotton soil has posed challenges and problems to the construction activities. To encounter with it, innovative and non traditional research on waste utilization is gaining importance now a days. Soil improvement using the waste material like Slags, Rice husk ash, Silica fume etc., in geotechnical engineering has been in practice from environmental point of view. The main objective of this study is to evaluate the feasibility of using Rice Husk Ash with lime as soil stabilization material. A series of laboratory experiment has been conducted on 0.5% lime mixed black cotton soil blended with Rice Husk Ash in 10%, 20% and 30% by weight of dry soil.

MANDEEP SINGH , ANUPAM MITTAL (29 MARCH 2014) observed that, solid waste materials such as rice husk ash and waste tyres are used for this intended purpose with or without lime or cement. Disposal of these waste materials is essential as these are causing hazardous effects on the environment. With the same intention literature review is undertaken on utilization of solid waste materials for the stabilization of soils and their performance is discussed. Soil stabilization means alteration of the soils properties to meet the specified engineering requirements. Methods for the stabilization are compaction and use of admixtures. Lime and Cement was commonly used as stabilizer for altering the properties of soils. Earth reinforcement techniques with commonly used with mild steel rods, geo synthetics etc.

TAPASH KUMAR ROY (APRIL 29-MAY 4TH 2013) investigated the benefits of using rice husk ash (RHA) with clayey soil as the subgrade material in flexible pavements with addition of small amount of lime. Four ratios of RHA of 5%, 10%, 15% and 20% mixed with the clayey soil by weight of soil sample. Further for getting the better performance, lime has been added in this study in the varying proportions from 1% to 3% by weight of soil. The compaction characteristics and unconfined compressive strength tests were conducted on these different mixed soils. The test results shows that the rice husk ash can be used advantageously with addition of clayey soil and lime as cost effective mix for construction of subgrade of the roadway pavement.

DR. D. KOTESWARA RAO , G.V.V. RAMESWARA RAO , P.R.T. PRANAV (APRIL 29-MAY 4TH 2013) reported that The soil found in the ocean bed is classified as marine soil. It can even be located onshore as well. The properties of marine soil depend significantly on its initial conditions. The properties of saturated marine soil differ significantly from moist soil and dry soil. Expansive soil is microcrystalline in nature and clay minerals like chlorite, kaolinite and illinite and non-clay minerals like quartz and feldspar are present in the soil. The soils have higher proportion of organic matters that acts as a cementing agent. Clay is an impermeable soil, meaning it holds water, as opposed to permeable soil that allows water to rapidly drain, like a gravel or sand. It is also an expansive soil, such as the Expansive soil which predominates in almost all countries of the world, which when shrinking or expanding, can damage foundations and structures. The shrink and swell movements are due to changes in soil moisture. Providing uniform soil moisture next to and under your foundation is the only best thing to reduce or minimize the damaging effects A s tudy on the use of Phospogypsum (PG) and Crumb waste rubber (CWR) in improving of Expansive soil subgrades.

III. METHODOLOGY

MATERIALS USED AND THEIR PROPERTIES

3.1 EXPANSIVE SOIL

The soil sample collected from ODDALAREVU‟ near Amalapuram, in East Godavari District, Andhra Pradesh State, India.‟ has been selected for the present study after having a visual inspection of it. When a lump of sample was cut with a knife it gave a shining surface hence, it was concluded that the sample is of clayey nature. Laboratory tests were carried out as per the IS Codal Provisions by pulverizing the lumps into individual particles to determine the properties of the selected soil sample as mentioned here under.

Fig 3.1: Expansive soil

TABLE 3.1 Properties of Expansive Soil

S. No.	Property	Value
1	Specific gravity	2.64
2	Differential free swell Index (%)	108
3	**Atterberg's Limits**	
	i) Liquid limit (%)	70.5
	ii) Plastic limit (%)	28.6
	iii) Plasticity index (%)	41.9
4	**Grain Size Distribution**	
	i) Sand Size Particles (%)	10
	ii) Silt & Clay Size Particles (%)	90
5	IS soil classification	CH
6	Compaction Parameters	
	i) Max. Dry Density (g/cc)	1.41
	ii) Optimum Moisture Content (%)	28.2
7	**Penetration Parameters**	
	i) CBR - UnSoaked (%)	3.3
	ii) CBR - Soaked (%)	1.7
8	**Shear Parameters at OMC & MDD**	

	i) Cohesion, Cu (kPa)	40
	ii) Angle of Internal Friction, Øu (Degrees)	0

3.2 CRUMB WASTE RUBBER

Solid waste management is one of the major environmental concerns worldwide. For the last 30 years many studies have been conducted in order to assess the feasibility of using industrial by-products and waste materials in civil engineering applications. The motives for such studies have been and still are:

- The high cost, the continuous reduction in supplies and the negative environmental impact from the use of natural aggregates;
- Legislation, which bans the disposal of wastes in landfills
- Recycling in general, as is demanded by the requirement for sustainable development. A steady stream of large volumes of waste tyres is generated annually owing to the continual increase in the numbers of all kinds of vehicles.For the present study Waste tyre rubber is collected from V.Maruthy retrading company in Kakinada. The Mixing of waste tyre rubber in soil not only reduces the waste in the environment but also Increases the strength of the soil.

TABLE 3.2 Physical properties of waste tyre rubber

Properties of CWTR		
S. No.	Property	Value
1	Specific gravity	2.4
2	Grain Size Distribution	
	i) Gravel Size Particles (%)	4
	ii) Coarse Sand Size Particles (%)	84
	iii) Medium & Fine Sand Size Particles (%)	12

FIG 3.2 waste tyre rubber

3.3 PHOSPHOGYPSUM

The production of phosphoric acid from natural phosphate rock by means of the wet process gives rise to an industrial by-product named phosphogypsum (PG). About 5 tonnes of PG are generated per tonne of phosphoric acid production, and worldwide PG generation is estimated to be around 100-280 Mt per year. Most of this by-product is disposed of without any treatment, usually by dumping in large stockpiles. These are generally located in coastal areas close to phosphoric acid plants, where they occupy large land areas and cause serious environmental damage. PG is mainly composed of gypsum but also contains a high level of impurities such as phosphates, fluorides and sulphates, naturally occurring radionuclides, heavy metals, and other trace elements. All of this adds up to a negative environmental impact and many restrictions on PG.

LABORATORY EXPERIMENTATION:-

The soil was initially air dried prior to the testing. The tests were conducted in the laboratory on the marine clay to find the properties of virgin marine clay.

The following tests were conducted as per IS codes of practice.

- Grain size distribution
- Specific gravity
- Index properties –liquid limit, plastic limit
- Compaction tests
- Penetration tests-California bearing ratio test.
- Unconfined Compression Test-Triaxial

Fig 3.3 Conducting liquid limit test

Fig 3.4 Preparation of soil sample for compaction test

Fig 3.5 conducting CBR test

IV. RESULTS AND DISCUSSIONS

In the laboratory, various experiments were conducted by replacing different percentages of Phospogypsum in the Expansive soil and also further stabilizing it with Crumb waste rubber. Liquid Limit, Plastic Limit and Compaction, CBR and UCS tests were conducted with a view to determine the optimum combination of Phospogypsum and Crumb waste rubber as Addition in Expansive soil , CBR and UCS are conducted for durability studies. The influence of the above said materials on the Index, Compaction and Strength properties were discussed in following sections. In the laboratory, all the tests were conducted per IS codes of practice.

4.1 EFFECT OF % PHOSPOGYPSUM AS ADDITION ON THE PROPERTIES OF EXPANSIVE SOIL

The individual influence of Phosphogypsum on the Index, Compaction and Strength properties of Expansive soil are clearly presented in Table 4.1and Figures 6.1, 6.2, 6.3, 6.4, and 6.5 respectively. The percentage of Phosphogypsum was varied from 0%, to 9% with an increment of 3%. From the above graphs, it was observed that the treatment as individually with 6% Phosphogypsum has moderately improved the Expansive soil. It can be inferred from the graphs, that there is a gradual improvement in the Plasticity index with an increment in % addition of Phosphogypsum up to 9% with an improvement of about 3%. Also maximum dry density is improved by an amount of 2.12% and it was about 33.75% for UCS and 87.8%, 123.5% for Unsoaked, Soaked CBRrespectively

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4.1 Results of the tests conducted on EXPANSIVE SOIL with different % of Phospogypsum

PG (%)	DFSI (%)	LL (%)	PL (%)	PI (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0	108	70.5	28.6	41.9	1.41	28.2	3.3	1.7	80
3	90	67.8	29.7	38.1	1.42	28	4.8	2.6	96
6	71	64.6	31.4	33.2	1.44	27.7	6.2	3.8	107
9	54	62.2	33.5	28.7	1.43	27.5	5.6	3.2	99

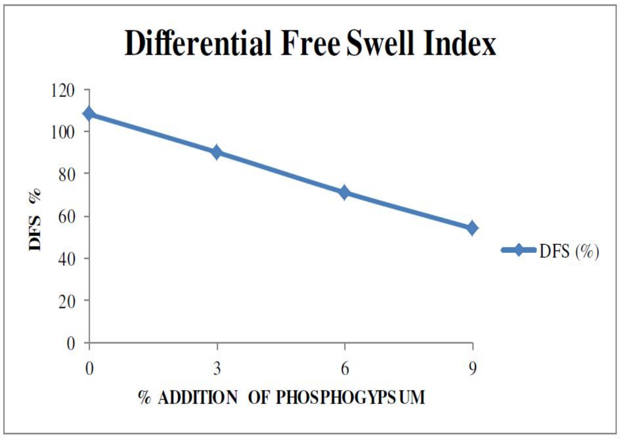

Fig 6.1 Plot showing the Variation in differential free swell index with different % of Phospogypsum

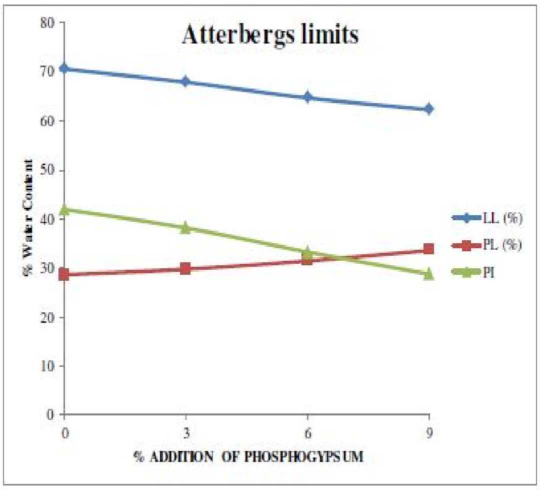

Fig 6.2 Plot showing the Variation in atterberg's limits with % addition of Phospogypsum

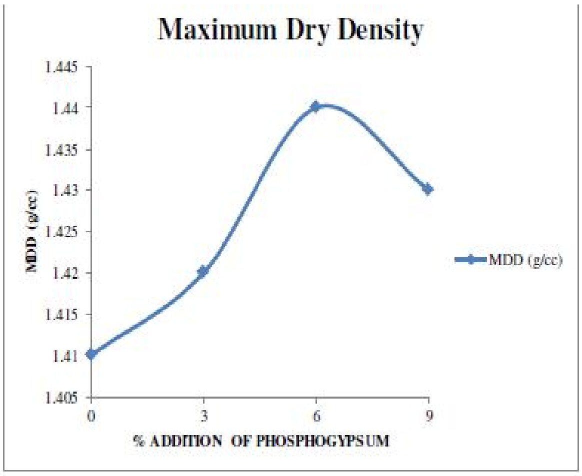

Fig 6.3 Plot showing the Variation in MDD with % addition of Phospogypsum

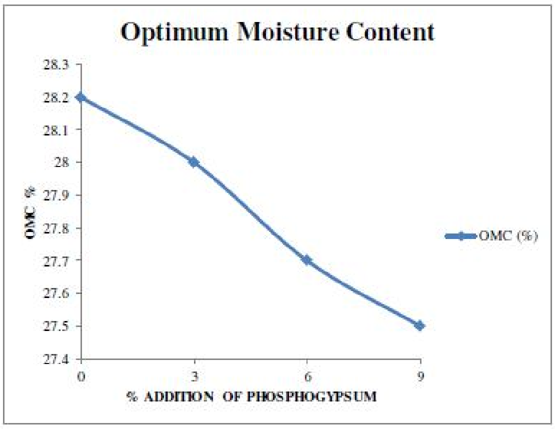

Fig 6.4 Plot showing the Variation in OMC VALUES with % addition of Phospogypsum

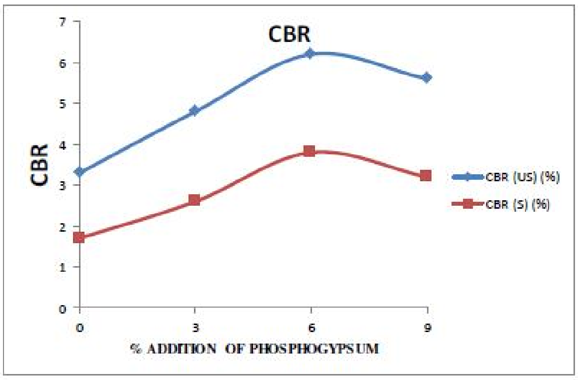

Fig 6.5 Plot showing the Variation in CBR with % addition of Phospogypsum

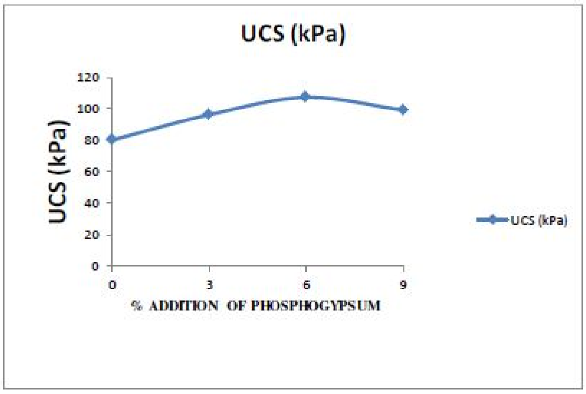

Fig 6.6 Plot showing the Variation in UCS with % addition of Phospogypsum

IT CAN BE INFERRED FROM THE ABOVE RESULTS THE OPTIMUM CONTENT OF PHOSPOGYPSUM AS ADDITION OF EXPANSIVE SOIL IS 6%.

4.2 EFFECT OF % CRUMB WASTE RUBBER ON THE PROPERTIES OF EXPANSIVE SOIL

The influence of on the Index, Compaction, CBR, UCS properties of Expansive soil are clearly presented in Table 6.2 and Figures 6.6, 6.7, 6.8, 6.9, and 6.10 respectively. The percentage of Crumb Waste Rubber was varied from 0%, 1%, 2%, and 4%. From the above graphs, it was observed that the treatment with 2% Crumb Waste Rubber has moderately improved the Expansive soil. It can be inferred from the graphs, that there is a gradual improvement in the Plasticity index with an increment in % addition up to 4%. Also maximum dry density is improved by an amount of 2.77% and it was about 33.64% for UCS and 40.3%, 63.1% for Unsoaked, Soaked CBR respectively .

4.2 Results of the tests conducted on Expansive soil with different percentages of Crumb waste rubber Content with 6% Phosphogypsum as addition to the Expansive soil

CWR (%) + PG (%)	MDD (g/cc)	OMC (%)	CBR (US) (%)	CBR (S) (%)	UCS (kPa)
0 + 6% PG	1.44	27.7	6.2	3.8	107
1 + 6% PG	1.45	27.5	7.9	5.1	121
2 +6% PG	1.48	27.1	8.7	6.2	143
4 + 6% PG	1.46	26.8	8.4	5.4	128

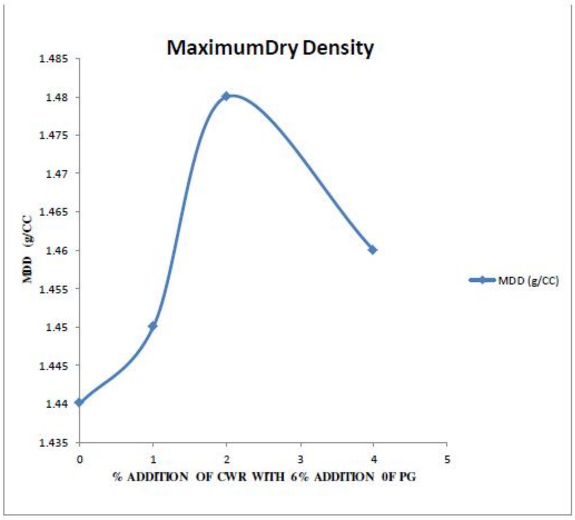

Fig 6.7 Plot showing the Variation in MDD with different % CRUMB WASTE RUBBER

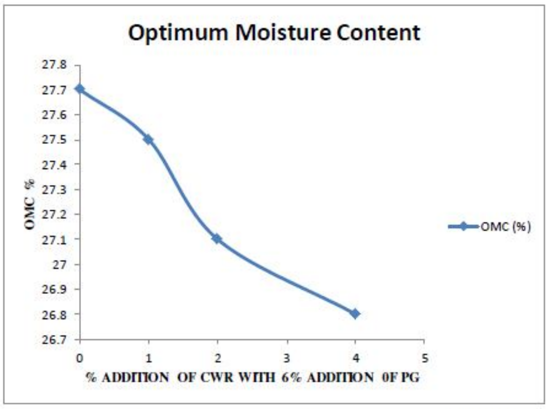

Fig 6.8 Plot showing the Variation in OMC with different % CRUMB WASTE RUBBER

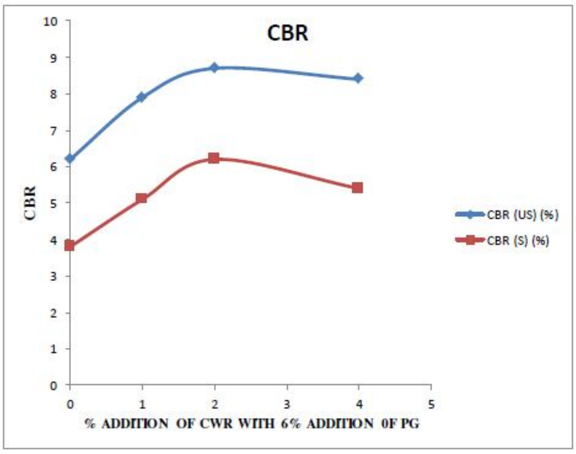

Fig 6.9 Plot showing the Variation in CBR with different % CRUMB WASTE RUBBER

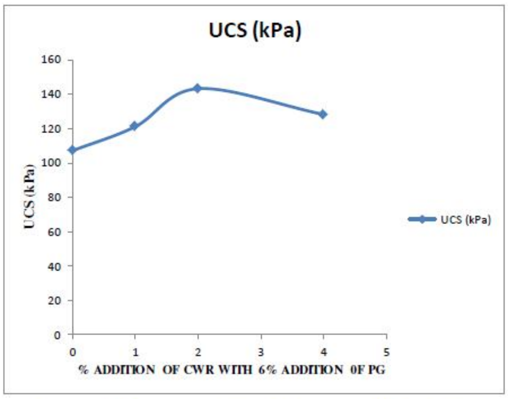

Fig 6.10 Plot showing the Variation in UCS with different % CRUMB WASTE RUBBER

IT CAN BE INFERRED FROM THE ABOVE RESULTS THE OPTIMUM CONTENT OFCRUMB WASTE RUBBER AS ADDITION OF EXPANSIVE SOIL WITH 6% PHOSPOGYPSUM IS 2%.

Table 4.3: Results of Durability Studies (Curing) on samples prepared with 6% PHOSPOGYPSUM +2% CRUMB WASTE RUBBER + EXPANSIVE SOIL

Curing Period (Days)	**CBR (US) (%)**	**CBR (S) (%)**	**UCS (kPa)**
0	8.7	6.2	143
7	9.4	7.3	158
14	9.8	8.1	171
28	10.3	8.5	180

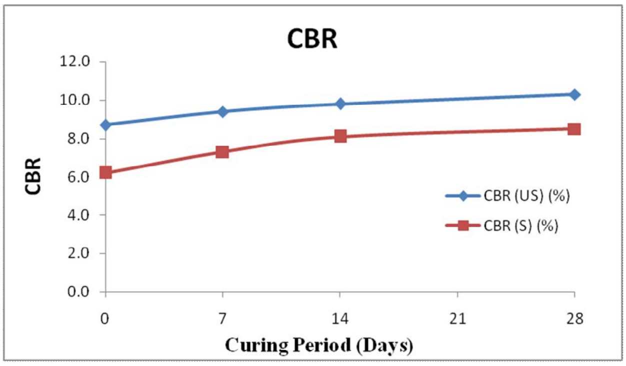

Fig 6.11 Plot showing the Variation in CBR at different curing periods

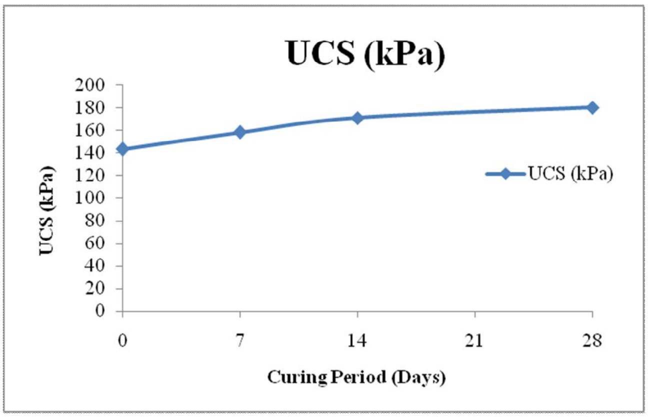

Fig 6.12 Plot showing the Variation in UCS at different curing periods

V. CONCLUSIONS

The following conclusions are made based on the laboratory experiments carried out in this investigation.

- From the laboratory studies, it is observed that the Expansive Soil chosen was a problematic soil having high compressibility characteristics.
- It was observed that Expansive Soil treated with Phospogypsum has moderately improved the Expansive Soil.
- There is a gradual increase in maximum dry density with an increment in the % addition of Phospogypsum up to 9% with an improvement of about 3% and it is observed that for the addition of 6% there is gradual increase in Maximum dry density about 2.12 %.
- There is an improvement in strength characteristics with an addition of Phospogypsum from 0% to 9% with an increment of 3%.There is an improvement of 87.87**%** for CBR un soaked and 123.5% for soaked. Also there is an improvement about 33.75% UCS values. Further addition of Crumb Waste Rubber from 0% to 4% with an increment of 2%. For Crumb Waste Rubber content of 2 % There is an improvement of 40.3**%** for CBR unsoaked, 63.15% for soaked CBR and 33.6% in UCS values
  - Durability Studies (Curing) on samples prepared with 6.0% PHOSPOGYPSUM + 2.0% Crumb Waste Rubber as Addition of Expansive Soil graph shows increment of CBR and UCS values with increment of curing periods.
  - It is evident that the addition of Phospogypsum to the virgin Expansive Soil showed an improvement in compaction, strength and penetration characteristics to some extent and on

further addition with Crumb Waste Rubber strength mobilization was more pronounced**.**

- Finally it can be summarized that the materials PHOSPOGYPSUM and CRUMB WASTE RUBBER had shown promising influence on the strength characteristics of Expansive Soil, thereby giving a two- fold advantage in improving problematic Expansive Soil and also solving a problem of waste disposal

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