STUDY OF SOIL STABALIZATION ON SUBGRADE USING BAGASSE ASH AND PHOSPHOGYPSUM

K. Rajeswari[1], CH. Damodar Naidu[2], K. Bhanuji Rao[3], G. Himala Kumari[4]
[1]P.G.Student, Department of Civil Engineering, Gokul Group of Institutions, A.P, India.
[2]Assistant Professor, Department of Civil Engineering, Gokul Group of Institutions, A.P, India.
[3,4]Assistant Professor, Department of Civil Engineering, Sri Sivani College of Engineering, A.P, India.

Abstract: The soil bed should bear all the stresses transmitted by the structure. If the soil is weak and has not enough stability to resist heavy loading, the soil should be reinforced and stabilized. As the quality of the soil is increased, the ability of the soil to distribute the load over a greater area is generally increased. Soil stabilization refers to alteration of soil properties to improve the stability or bearing power of the soil by controlled compaction, proportioning or by adding admixtures. Soil stabilization can be done by different methods like mechanical, chemical stabilization or by using different types of admixtures. Sustainable development cannot be done without adaption of new technology to make the structure enduring. The most common improvements achieved through stabilization include better soil gradation, reduction of plasticity index or swelling potential, and increases in durability and strength. A study has been carried out to investigate the strength of soil by Bagasse Ash and Phosphogypsum with varying percentages of reinforcement by conducting different tests like, compaction test, CBR (California Bearing Ratio). The tests were performed as per Indian standard specification. The results obtained are compared and inferences are drawn towards their usability and effectiveness to make these materials for different geotechnical applications as a cost effective approach
Keywords: Red loamy soil, Bagasse Ash, Phosphogypsum, compaction test, CBR test.

I. INTRODUCTION

Soil stabilization is a procedure in which existing properties of soil are improved by means of addition of cementing materials or chemicals. One of the more common methods of stabilization includes the mixing of natural coarse grained soil and fine grained soil to obtain a mixture that develops adequate internal friction and cohesion and thereby provides a material that is workable during placement. Stabilization of soil can be carried out by using mechanical stabilization, cementing stabilization and chemical stabilization. Rearrangement of soil particles by some of mechanical compaction is referred as Mechanical Stabilization., use of cementing material such as cement, lime, bitumen/asphalt etc is added to soil is Cementing Stabilization. And use of chemicals in soil such as calcium chloride; sodium chloride etc is Chemical Stabilization. The Soil stabilization, in the broadest sense it is the alteration of any inherent property of a soil to improve its engineering performance. Improvement of stability or bearing power, density, shear parameter, reduce compressibility, permeability, swelling and shrinkage property by the use of controlled compaction, proportioning and/ or the addition of suitable admixtures or stabilizers. The prime objective of soil stabilization is to improve the California Bearing Ratio of in-situ soils by 4 to 6 times. The other prime objective of soil stabilization is to improve on-site materials to create a solid and strong sub-base and base courses. In certain regions of the world, typically developing countries and now more frequently in developed countries, soil stabilization is being used to construct the entire road.

1.1. Need of soil stabilization

Soil stabilization refers to the process of changing soil properties to improve strength and durability. There are many techniques for soil stabilization, including compaction, dewatering and by adding material to the soil. This summary will focus on mechanical and chemical stabilization based adding materials. Mechanical stabilization improves soil properties by mixing other soil materials with the target soil to change the gradation and therefore change the engineering properties. Chemical stabilization used the addition of bagasse ash , gypsum materials to improve the soil properties. materials that can be used individually, or mixed with other materials, to achieve soil stabilization.

1.2. Materials:

- Red loamy soil
- Bagasse ash
- phosphogypsum

II. MATERIALS AND THEIR PROPERTIES

Red loamy Soils:

Red soil is any of a group of soils that develop in a warm, temperate, moist climate under deciduous or mixed forests and that have thin organic and organic-mineral layers overlying a yellowish-brown leached layer resting on an illuvial (see illuviation) red layer. Red soils generally form from iron-rich sedimentary rock. They are usually poor growing soils, low in nutrients and humus and difficult to cultivate. Red soils denote the second largest soil group of India covering an area of about 6.1 lakhs sq. km (18.6% of India's area) over the Peninsula from Tamil Nadu in the south to Bundelkhand in the north and Rajmahal hills in the east to Kachch in the west. They surround the black soils on their south, east and north.

Characteristics of Red Loamy Soil:

The texture of red soils varies from sand to clay, the majority being loam. Their other characteristics include porous and friable structure, absence of lime, kankar and free carbonates, and small quantity of soluble salts. Their chemical composition include non-soluble material 90.47%, iron 3.61%, aluminium 2.92%, organic matter 1.01%, magnesium 0.70%, lime 0.56%, carbon-Di-oxide 0.30%, potash 0.24%, soda 0.12%, phosphorus 0.09% and nitrogen 0.08%. However significant regional differences are observed in the chemical composition.

Bagasse Ash :
Bagasse is a residue obtained from the burning of bagasse in sugar producing factories. Bagasse is the cellular fibrous waste product after the extraction of the sugar juice from cane mills. It is currently used as a bio fuel and in the manufacture of pulp and paper products and building materials. For each 10 tons of sugarcane crushed, a sugar factory produces nearly 3 tons of wet bagasse which is a by-product of the sugar cane industry. When this Bagasse is burnt the resultant ash is bagasse ash. Western Maharashtra is having maximum number of sugar factories, these factories faces a disposal problem of large quantity Bagasse. The effective utilization of this waste product is a challenging task for a researcher through economical and environmental impact. This material contains amorphous silica which is indication of cementing properties, which can develop good bonding between soil grains in case of weak soil.Sugar cane Bagasse Ash also a type of biomaterial. Bagasse is the biomass remaining after sugar stacks are crushed to extract their juice. The main elements in this biomaterial are Carbon, Hydrogen, Oxygen, Nitrogen and sulphur.

Description	Abbreviation	Percentage (%)
Silica	Sio2	60.26
Iron	Fe2o3	5.03
Calcium	Cao	8.35
Magnesium	Mgo	0.40
Sodium	Na20	1.33
Potassium	K_2o	5.57
Chloride	CL	0.20
Sulphate	So_4	1.30
Phosphorous	P_2o_5	2.69
Loss of ignition	-	3.39
Alumina	Al_2o_3	10.73
Titanium	Tio_2	0.13
manganese	Mn	0.078
Wax content	-	Nil

Table 2.1Chemical Composition of Bagasse Ash

Phosphogypsum:

Gypsum (CaSO4 .2H2O) is a hydrated calcium sulphate used widely in industry because of its special property of losing three-fourth of the combined water of crystallization when moderately heated (calcined) to about 130oC. Besides, calcined gypsum when cooled, finely ground and made plastic with water can be spread out, cast or moulded to any desired surface or form. On drying, it sets into a hard rock-like form. Selenite is a colourless, transparent, crystalline variety of gypsum, whereas alabaster is a fine grained, massive variety, white or shaded in colour. Silky and fibrous variety of gypsum is called satin spar. Anhydrite (CaSO4) is a calcium sulphate mineral found associated with gypsum commonly as a massive or fibrous mineral. Gypsum that occurs in nature is called mineral gypsum. In addition to mineral gypsum, seawater and some chemical plants are sources of byproduct marine gypsum and by-product chemical gypsum, respectively. The later is obtained as byproduct phospho-gypsum or fluoro-gypsum, depending upon the source. Phosphoric acid plants are important sources of by-product phospho-gypsum. Marine gypsum is recovered from salt pans during production of common salt in coastal region, particularly in Gujarat and Tamil Nadu.

Properties of Phosphogypsum:
Depending on the reaction temperature used to produce phosphoric acid, calcium sulfate in either the dihydrate (CaSO4.2H20) or the hemihydrate (CaSO4. H20) form is generated as a by-product filter cake. The gypsum cake, after filtration, usually has free moisture content between 25 and 30 percent. Hemihydrate, in the presence of free water will, fairly rapidly, convert to dihydrate (phosphogypsum) and in the process, if left undisturbed, will set up into a relatively hard cemented mass. Dehydrate consists of relatively soft, principally silt-size (<0.075mm) aggregates of crystals, the morphology of which depends on the source of the phosphate rock and the reactor conditions. Typical engineering properties of phosphogypsum can be found in Wissa, Properties, such as density, strength, compressibility and permeability (hydraulic conductivity), are not only controlled by the rock source and reaction process, but also by the method of deposition, age, location and depth within the landfill or stack in which the gypsum is placed. The deeper the gypsum is within a stack and the older the stack, the higher its density and strength and the lower its compressibility and permeability, provided solution channels and cavities have not developed in the stack as a result of rainfall infiltration.

Chemical Properties:
Phosphogypsum consists primarily of calcium sulphate dehydrate with small amounts of silica, usually as quartz, and unreacted phosphate rock. Radium and uranium, as well as minor amounts of USEPA toxic metals, namely, arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver and phototoxic fluoride and aluminum are also present in Phosphogypsum and its pore water. The concentrations of the heavy metals and radionuclides depend on the composition of the phosphate rock feed Garlanger.

Chemical Composition of Phosphogypsum:

Parameter	Composition in %
H_2O cryst	18.0
SO_2	43.6
CaO	32.0
MgO	0.40
$Al_2O_3 + Fe_2O_3$	1.82
SiO_2 ins. In HCl	1.64
Na_2O	0.36
P_2O_5 total	1.03
F_{total}	0.76
Organic matter	0.26

Table 2.2 Composition of Phosphogypsum

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Characteristics of Phosphogypsum:

Phosphogypsum is a gray coloured, damp, fine grained powder, silt or silty-sand material with a maximum size ranges between 0.5 mm (No. 40 sieve) and 1.0 mm (No. 20 sieve) and the majority of the particles (50-75 %) are finer than 0.075 mm (No. 200 sieve). The specific gravity of phosphogypsum ranges from 2.3 to 2.6. The maximum dry bulk density is likely to range from 1470 to 1670 kg/m3 (92 to 104 lb/ft3), based on Standard Proctor Compaction. Phosphogypsum consists of primarily of calcium sulphate dihydrate with small amounts of silica, usually as quartz and unreacted phosphate rock, radioactive material (like radium, uranium), heavy metals namely arsenic, cadmium, chromium, mercury and fluoride. The concentration of the metals depends on the composition of the phosphate rock. The following are the main concerns with respect to management of phosphogypsum;

- High fluoride concentration (in the range of 0.5 -1.5 %) may leach fluoride and contaminate the groundwater, if not stored and handled properly;
- Presence of radio-nuclide radium -226 which upon decay may emits harmful alpha particles;
- May contain heavy metals (Cd, Cr, Pb etc) that may enter into the food chain through potable water and agriculture products.

Permeability of Phosphogypsum depends on stabilization. Permeability in unstabilized phosphogypsum has been found to range from 1.3 x 10-4 cm/sec down to 2.1 x 10-5 cm/sec for stabilized phosphogypsum. Phosphogypsum is a fine powder with high calcium sulphate content. The phosphatic and fluoride impurities present in Phosphogypsum cannot be removed completely either by washing or chemical treatments.

Applications of Phosphogypsum :

Cement, fertilizer (ammonium sulphate) and plaster of paris are the three important industries in which gypsum is utilised. Gypsum of less purity in crushed form is utilised in portland cement manufacture for controlling the setting time of Portland cement (i.e. as a retarder to prevent quick set). It is added to the clinker just before final grinding to finished cement. Proportion of gypsum in cement industry is 4-5% of the cement produced. Both, mineral and by-product gypsum are used in cement manufacture.

Calcined gypsum finds use in manufacturing plaster of Paris. It is also used in manufacturing partition blocks, sheets and tiles, insulation boards for stucco and lattice works. Gypsum board is primarily used as a finish for walls and ceilings. It is also used as a binder in fast dry tennis court clay. Low grade gypsum is calcined and used as gypsum plaster after preparation of mortar. It is used for internal plastering and masonry work. Requirement of low-grade gypsum for use in building industry as per IS: 12654-1989 (Reaffirmed 2010) is: $CaSO_4 .2H_2O$ not less than 60%. In pottery, calcined gypsum is used for preparation of moulds in the production of sanitary wares. The used and discarded moulds are in turn again used as source of gypsum in cement and other industries.

4.2 Flow chart of Lab tests:

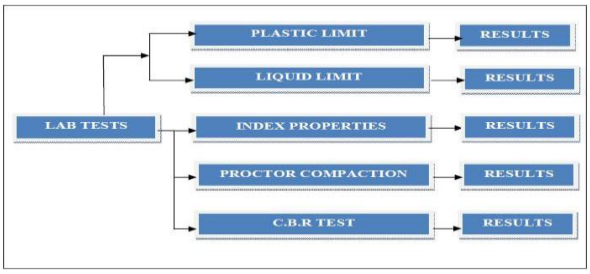
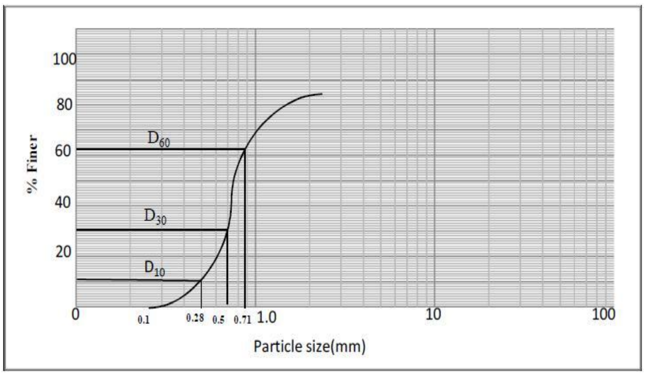


Figure 2.1: Flow Chart of Lab tests

SIEVE ANALYSIS:

S.No	Sieve size	Wt of soil retained	Cumulative wt. retained	Cumulative % retained	%finer
1	4.75	4	4	1.28	98.72
2	2.36	0.9	4.9	1.57	98.43
3	1.18	8.6	13.5	4.33	95.67
4	`600u	19.2	32.7	10.49	89.51
5	300u	145.6	178.3	57.23	42.77
6	150u	110.6	288.9	92.74	7.26
7	75u	21.8	310.7	99.74	0.26
8	<75u	.8	311.5	100	0

Table 2.3: Sieve analysis of sample 1



Graph 2.1 : Sieve analysis of sample 1 From graph Cu and Cc

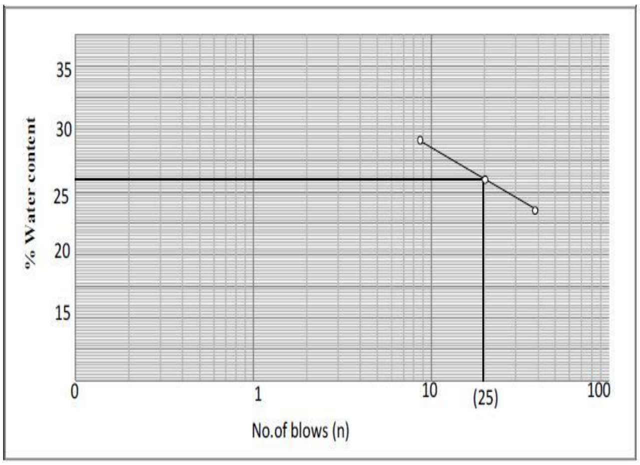
Cu=Uniform coefficient=D60/D10 =0.36/0.16=2.25

Cc=Coefficient of curvature = (D30xD30)/(D60xD10) =1

Result: Classified soil is Low compressible clay (CL)

S.No	Description	Sample					
		1	2	3	4	5	6
1	Wt of empty can (w1) gms	7.7	7.7	7.7	7.7	7.7	7.7
2	wt of can+wt of wet soil (w2) gms	30.5	26.6	26.2	33.3	31.7	32.5
3	wt of can+ wt of dry soil(w3) gms	26.2	22.5	22.3	28.3	26.4	27.4
4	water content (w)=w2-w3/(w3-w1)x100	23.24	27.7	26.71	21	28.34	25.88
5	No .of blows(n)	70	7	30	28	8	27

Table 2.3: Liquid limit of soil sample



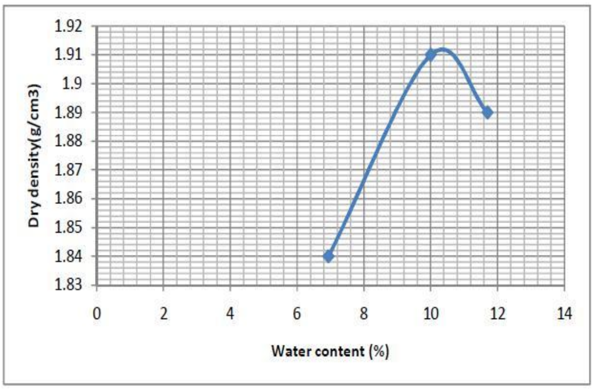
Graph 2.2: Liquid limit of soil sample

Result: Liquid limit of soil sample is 26% for 25 blows.
Plasticity Index:
P.I = 21-16.12 = 4.88 %

FIELD DETERMINATION OF MAXIMUM DRY DENSITY AND OPTIMUM MOISTURE CONTENT OF SOILS:

S.No	Details	8%	12%	14%
1	wt.of empty mould	2.328	2.222	2.328
2	Wt.of. Mould+ compacted soil	4.310	4.380	4.450
3	wt of compaction soil	1.982	2.158	2.122
4	Bulk density (kg/m3)	2.01	2.18	2.16
5	Can no	2	1	4
6	Wt. of can	7.7	7.7	7.7
7	wt.of wet soil with can(w1)	38.5	44	47.7
8	wt of dry soil with can(w2)	36	40	42
9	Water content(w3/w2)x100	6.94%	10%	11.70%
10	Dry density	1.84	1.91	1.89

Table 2.4: Results of proctor compaction of soils sample replacement 0 %(1.5% BA + 1.5% GY)



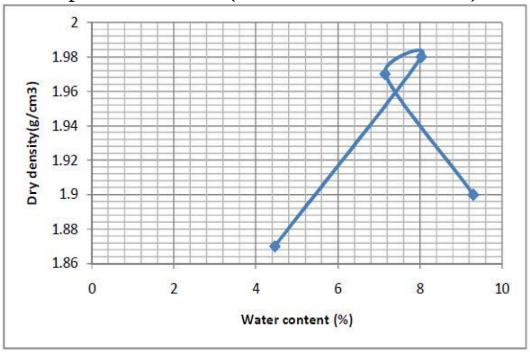
Graph 2.3: Results of proctor compaction of soil sample replacement of 0%

Result: For MDD of 1.91 g/cm^3 optimum dry density is 12.38 %

3% Replacement (1.5% BA + 1.5% GY):

S.No	Details	6%	8%	10%	12%
1	wt.of empty mould	2.3	2.2	2.3	2.2
2	Wt.of. Mould+ compacted soil	3.90	4.16	4.47	4.38
3	wt of compaction soil	1600	1960	2170	2180
4	Bulk density (kg/m3)	1.62	1.99	2.21	2.22
5	Can no	4	11	T_1	T_2
6	Wt. of can	7.7	7.7	20	20.40
7	wt.of wet soil with can(w1)	48.42	59.85	70.4	80.12
8	wt of dry soil with can(w2)	46.35	55.40	65.70	73.30
9	Water content(w3/w2)x100	4.46%	8.03%	7.15%	9.30%
10	Dry density	1.53	1.82	2.04	2.01

Table 2.5: Results of proctor compaction of soils sample replacement 3 %(1.5% BA + 1.5% GY)



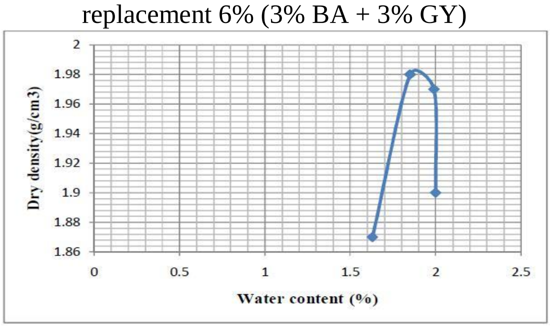
Graph 2.4: proctor compaction of soil sample replacement 3% (1.5% BA + 1.5% GY)

Result: For MDD of 2.04 g/cm^3 optimum dry density is 8.10 %

6% Replacement (3% BA + 3% GY):

S.No	Details	6%	8%	10%	12%
1	wt.of empty mould	2.2	2.33	2.33	2.33
2	Wt.of. Mould+ compacted soil	3.92	4.33	4.5	4.5
3	wt of compaction soil	1720	2000	2170	2170
4	Bulk density (kg/m3)	1.75	2.03	2.2	2.2
5	Can no	11	4	5	9
6	Wt. of can	7.7	7.7	7.7	7.7
7	wt.of wet soil with can(w1)	48.2	42.8	57.9	50.80
8	wt of dry soil with can(w2)	45.5	39.7	53.2	46.92
9	Water content(w3/w2)x100	5.93%	7.80%	8.83%	8.26%
10	Dry density	1.63	1.85	1.99	2.00

Table 2.6: Results of proctor compaction of soils sample replacement 6% (3% BA + 3% GY)



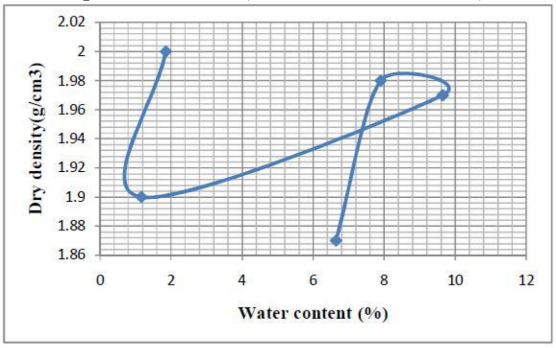
Graph 2.5: proctor compaction of soil sample replacement 6% (3% BA + 3% GY)

Result: For MDD of 2.00 g/cm^3 optimum dry density is 9.89 %

9% Replacement (4.5% BA + 4.5% GY):

S.No	Details	6%	8%	10%	12%	14%
1	wt.of empty mould	2.3	2.2	2.3	2.2	2.3
2	Wt.of. Mould+ compacted soil	4.06	4.13	4.33	4.35	4.41
3	wt of compaction soil	1760	1930	2030	2150	2110
4	Bulk density (kg/m3)	1.79	1.96	2.06	2.19	2.13
5	Can no	7	6	8	3	8
6	Wt. of can	7.7	7.7	7.7	7.7	7.7
7	wt.of wet soil with can(w1)	42.34	66.58	60.70	59.85	86.71
8	wt of dry soil with can(w2)	39.70	61.70	55.40	53.60	75.62
9	Water content(w3/w2)x100	6.64	7.90	9.65	1.16	1.46
10	Dry density	1.65	1.79	1.85	1.92	1.83

Table 2.7: Results of proctor compaction of soil sample replacement 9% (4.5% BA + 4.5% GY)



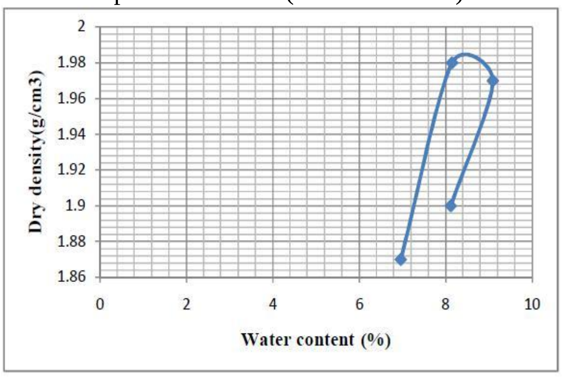
Graph 2.8: proctor compaction of soil sample replacement 9% (4.5% BA + 4.5% GY)

Result: For MDD of 1.92g/cm^3 optimum dry density is 13.61%

10% Replacement (5% BA + 5% GY) :

S.No	Details	6%	8%	10%	12%
1	wt.of empty mould	2.328	2.222	2.328	2.222
2	Wt.of. Mould+ compacted soil	4.35	4.37	4.50	4.29
3	wt of compaction soil	2022	2148	2172	2068
4	Bulk density (kg/m3)	2.05	2.18	2.21	2.10
5	Can no	4	5	10	11
6	Wt. of can	7.7	7.7	7.7	7.7
7	wt.of wet soil with can(w1)	38.6	51.5	41.8	52.9
8	wt of dry soil with can(w2)	35.9	47.3	38	43
9	Water content(w3/w2)x100	6.96	8.15	9.09	8.12
10	Dry density	1.87	1.98	1.97	1.90

Table 2.8: Results of proctor compaction of soil sample replacement 10% (5%BA+5%GY)



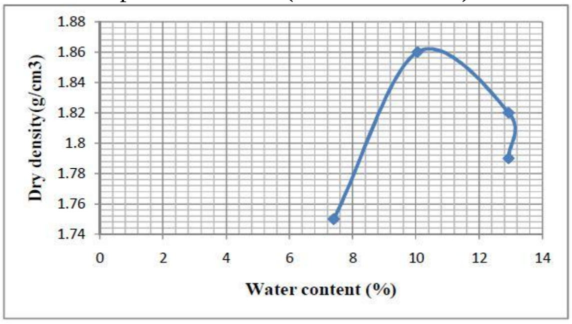
Graph 2.9: proctor compaction of soil sample replacement 10% (5%BA+5%GY)

Result: For MDD of 1.98 g/cm^3 optimum dry density is 10.60%

12% Replacement (6% BA + 6% GY):

S.No	Details	6%	8%	10%	12%
1	wt.of empty mould	2.22	2.33	2.22	2.33
2	Wt.of. Mould+ compacted soil	4.07	4.32	4.25	4.33
3	wt of compaction soil	1850	2020	2030	2000
4	Bulk density (kg/m3)	1.88	2.05	2.06	2.03
5	Can no	12	5	2	10
6	Wt. of can	7.7	7.7	7.7	7.7
7	wt.of wet soil with can(w1)	70.8	67.02	61.40	57.5
8	wt of dry soil with can(w2)	66.45	61.60	55.25	51.80
9	Water content(w3/w2)x100	7.40	10.05	12.93	12.93
10	Dry density	1.75	1.86	1.82	1.79

Table 2.9: Results of proctor compaction of soils sample replacement 12%(6% BA+6%GY)



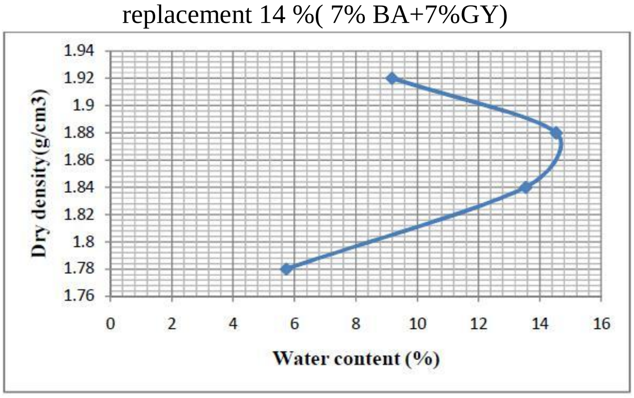
Graph 2.10: proctor compaction of soil sample replacement 12 %(6% BA+6%GY)

Result: For MDD of 1.86g/cm^3 optimum dry density is 10.05 %

14% Replacement (7% BA + 7% GY) :

S.No	Details	6%	8%	10%	12%
1	wt.of empty mould	2.22	2.33	2.22	2.33
2	Wt.of. Mould+ compacted soil	4.29	4.46	4.32	4.37
3	wt of compaction soil	2070	2130	2100	2040
4	Bulk density (kg/m3)	2.10	2.169	2.139	2.07
5	Can no	4	11	5	9
6	Wt. of can	7.7	7.7	7.7	7.7
7	wt.of wet soil with can(w1)	38.6	47.1	73.1	53.3
8	wt of dry soil with can(w2)	36	42.1	65.3	47.1
9	Water content(w3/w2)x100	9.18	14.53	13.54	5.73
10	Dry density	1.92	1.88	1.84	1.78

Table 2.10: Results of proctor compaction of soils sample replacement 14 %(7% BA+7%GY)



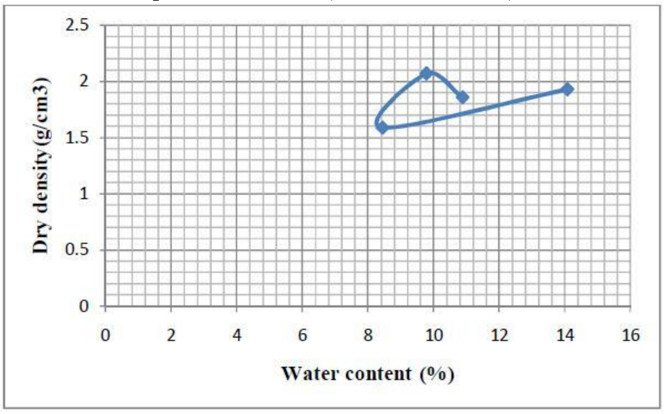
Graph 2.11: proctor compaction of soil sample replacement 14% (7%BA+7%GY)

Result: For MDD of 1.92 g/cm^3 optimum dry density is 9.18%

18% Replacement (9% BA + 9% GY)

S.No	Details	6%	8%	10%	12%
1	wt.of empty mould	2.33	2.33	2.33	2.33
2	Wt.of. Mould+ compacted soil	4220	4355	4340	4324
3	wt of compaction soil	1900	2035	2020	2004
4	Bulk density (kg/m3)	2.01	2.18	2.16	
5	Can no	9	5	11	4
6	Wt. of can	7.7	7.7	7.7	7.7
7	wt.of wet soil with can(w1)	43.3	45	46	39.5
8	wt of dry soil with can(w2)	37.2	41.2	41.5	35.2
9	Water content(w3/w2)x100	14.08	8.44	9.78	10.88
10	Dry density	1.93	1.59	2.07	1.86

Table 2.11: Results of proctor compaction of soils sample replacement 18 %(9% BA+9%GY)



Graph 2.12: proctor compaction of soil sample replacement 18 %(9% BA+9%GY)

Result: For MDD of 1.86 g/cm^3 optimum dry density is 11.34 %

CALIFORNIA BEARING RATIO: (Soaked)

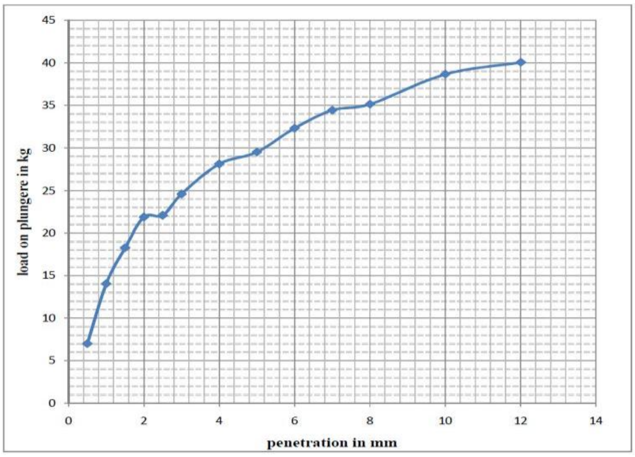
Penetration depth(mm)	Total Standard load(Kg)	Unit Standard load Kg/ cm2
2.50	1370	70
5.00	2055	105
7.50	2630	134
10.00	3180	162
12.50	3600	183

0% Replacement

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	1	7.03
2	1	2.1	14.76
3	1.5	2.6	18.27
4	2.0	3	21.09
5	2.5	3.2	22.49
6	3.0	3.5	24.60
7	4	4	28.12
8	5	4.2	29.52
9	6	4.6	32.33
10	7	4.9	34.44
11	8	5	35.15
12	10	5.5	38.66
13	12	5.7	40.07

Table 2.12: C.B.R. value for soil sample replacement of 0%

CBR $_{2.5}$ = 1.64, CBR $_{5.0}$ = 1.43



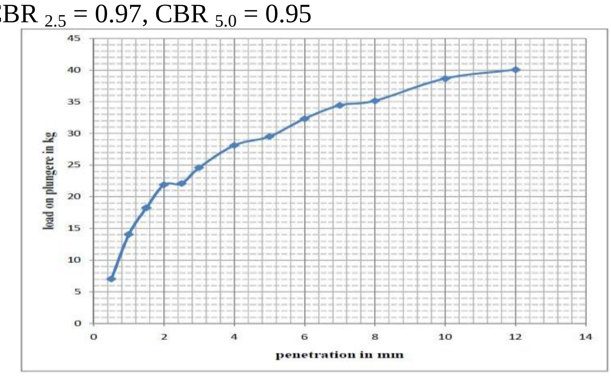
Graph 2.13: C.B.R for soil sample replacement of 0%

10% Replacement (5% BA + 5% GY):

S.No.	Penetration(mm)	Proving ring dial ring	Load on plunger(Kg)
1	0.5	1	7.03
2	1	1.1	7.73
3	1.5	1.3	9.13
4	2.0	1.8	12.65
5	2.5	1.9	13.35
6	3.0	2	14.06
7	4	2.3	16.16
8	5	2.8	19.68
9	6	3	21.09
10	7	3.2	22.49
11	8	3.4	23.90
12	10	3.9	27.41
13	12	4	28.12

Table 2.13: C.B.R. value for soil sample replacement of 10%

CBR $_{2.5}$ = 0.97, CBR $_{5.0}$ = 0.95



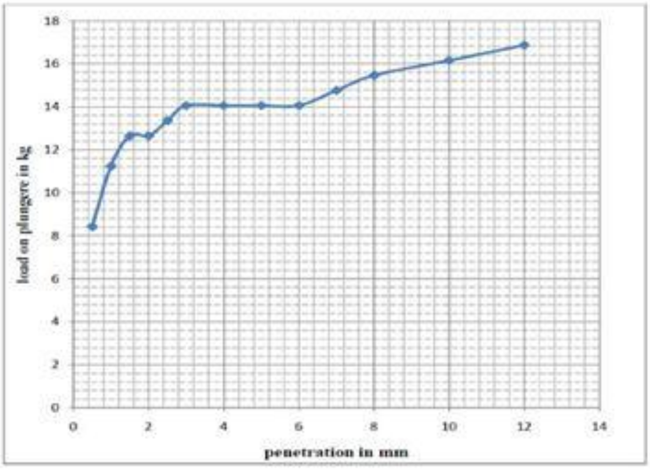
Graph 2.14: C.B.R for soil sample replacement of 10% (5% BA + 5% GY)

14% Replacement (7% BA + 7% GY):

S.No.	Penetration mm	Proving ring dial ring	Load on plunger(Kg)
1	0.5	1.2	8.43
2	1	1.6	11.24
3	1.5	1.8	12.65
4	2.0	1.8	12.65
5	2.5	1.9	13.35
6	3.0	2	14.06
7	4	2	14.06
8	5	2	14.06
9	6	2	14.06
10	7	2.1	14.76
11	8	2.2	15.46
12	10	2.3	16.16
13	12	2.4	16.87

Table 2.14: C.B.R. value for soil sample replacement of 14% (7% BA + 7% GY)

CBR $_{2.5}$ = 0.97, CBR $_{5.0}$ = 0.68



Graph 2.15: C.B.R for soil sample replacement of 14% (7% BA + 7% GY)

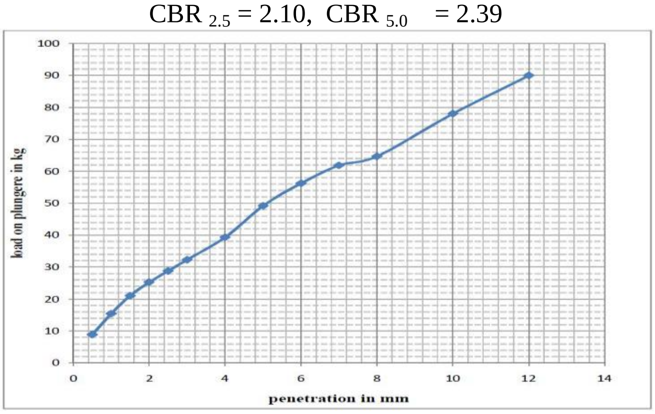
CALIFORNIA BEARING RATIO (C.B.R) (UnSoaked):

Penetration depth(mm)	Total Standard load(Kg)	Unit Standard load Kg/ cm^2
2.50	1370	70
5.00	2055	105
7.50	2630	134
10.00	3180	162
12.50	3600	183

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	1.9	8.93
2	1	2.2	15.46
3	1.5	3	21.09
4	2.0	3.6	25.30
5	2.5	4.1	28.82
6	3.0	4.6	32.33
7	4	5.6	39.36
8	5	7	49.21
9	6	8	56.24
10	7	8.8	61.86
11	8	9.2	64.67
12	10	11.1	78.03
13	12	12.8	89.98

Table 2.16: C.B.R. value for soil sample replacement of 0%

CBR $_{2.5}$ = 2.10, CBR $_{5.0}$ = 2.39



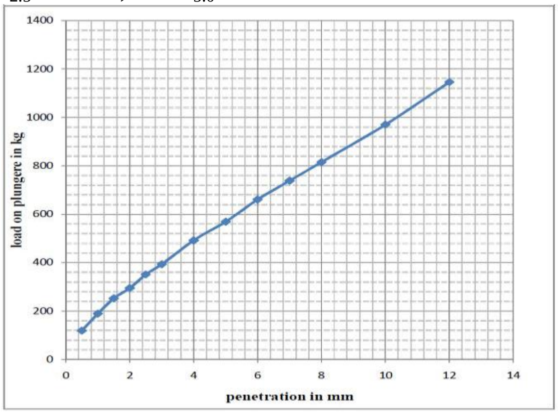
Graph 2.17: C.B.R for soil sample replacement of 0%

3% Replacement (1.5% BA + 1.5% GY)

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	17	119.5
2	1	27	189.8
3	1.5	36	253.0
4	2.0	42	295.2
5	2.5	50	351.5
6	3.0	56	393.6
7	4	70	492.1
8	5	81	569.4
9	6	94	660.8
10	7	105	738.5
11	8	116	815.4
12	10	138	970.1
13	12	163	1145.8

Table 2.17: C.B.R. value for soil sample replacement of 3%

CBR $_{2.5}$ = 25.65, CBR $_{5.0}$ = 27.70



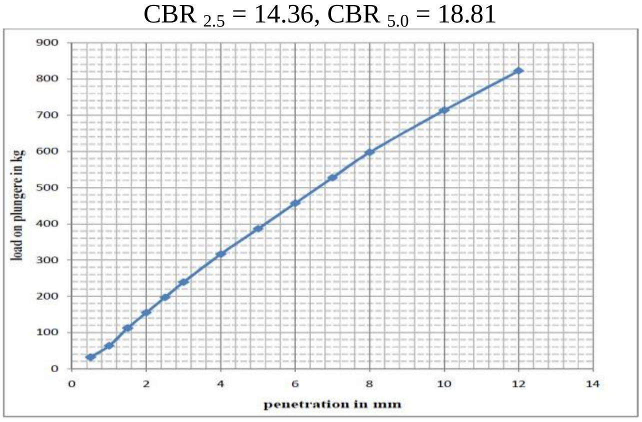
Graph 2.18: C.B.R for soil sample replacement of 3%

6% Replacement (3% BA + 3% GY) :

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	4.5	31.63
2	1	9	63.27
3	1.5	16	112.4
4	2.0	22	154.6
5	2.5	28	196.8
6	3.0	34	239.0
7	4	45	316.3
8	5	55	386.5
9	6	65	456.9
10	7	75	527.2
11	8	85	597.5
12	10	101.5	713.5
13	12	117	822.5

Table 2.18: C.B.R. value for soil sample replacement of 6%

CBR $_{2.5}$ = 14.36, CBR $_{5.0}$ = 18.81

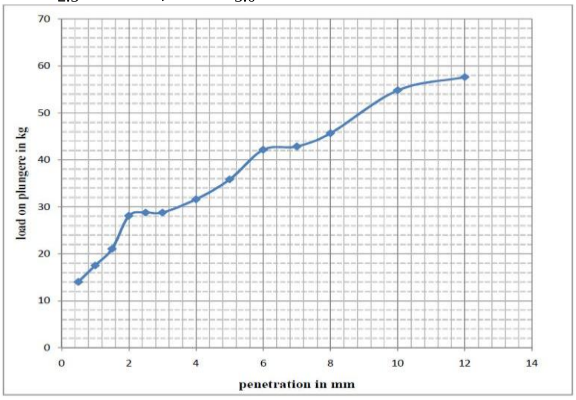


Graph 2.19: C.B.R for soil sample replacement of 6%

9% Replacement (4.5% BA + 4.5% GY):

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	2	14.06
2	1	2.5	17.57
3	1.5	3	21.09
4	2.0	4	28.12
5	2.5	4.1	28.82
6	3.0	4.1	28.82
7	4	4.5	31.63
8	5	5.1	35.85
9	6	6	42.18
10	7	6.1	42.88
11	8	6.8	45.69
12	10	7.8	54.83
13	12	8.2	57.64

Table 2.19: C.B.R. value for soil sample replacement of 9%
CBR $_{2.5}$ = 2.10 , CBR $_{5.0}$ = 1.74

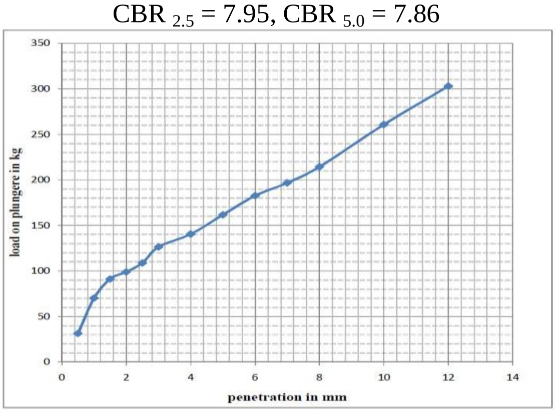


Graph 2.20: C.B.R for soil sample replacement of 9%

10% Replacement (5% BA +5% GY):

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	4.5	31.63
2	1	10	70.3
3	1.5	13	91.39
4	2.0	14.1	99.12
5	2.5	15.5	108.9
6	3.0	18	126.5
7	4	20	140.6
8	5	23	161.6
9	6	26	182.7
10	7	28	196.8
11	8	30.5	214.4
12	10	37.1	260.8
13	12	43.1	302.9

Table 2.20: C.B.R. value for soil sample replacement of 10%
CBR $_{2.5}$ = 7.95, CBR $_{5.0}$ = 7.86

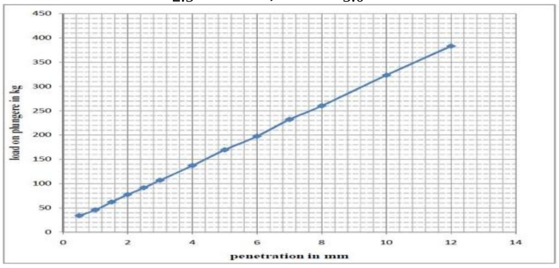


Graph 2.21: C.B.R for soil sample of replacement of 10%

12% Replacement (6% BA + 6% GY):

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	4.8	33.74
2	1	6.5	45.69
3	1.5	8.8	61.86
4	2.0	11	77.33
5	2.5	13	91.39
6	3.0	15.2	106.85
7	4	19.5	137.08
8	5	24.1	169.42
9	6	28.1	197.54
10	7	33	231.99
11	8	37	260.11
12	10	43.5	323.28
13	12	54.5	383.13

Table 2.21: C.B.R. value for soil sample replacement of 12%
CBR $_{2.5}$ = 6.67, CBR $_{5.0}$ = 8.92

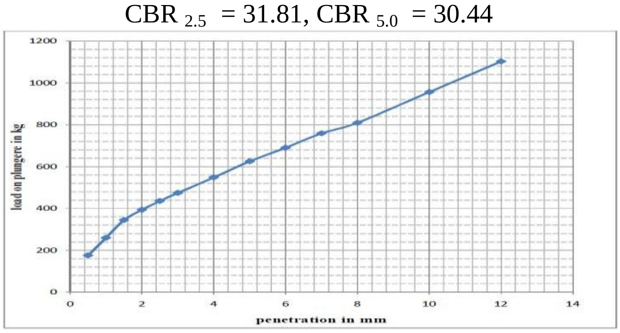


Graph 2.22: C.B.R for soil sample of replacement of 12%

14% Replacement (7% BA + 7% GY):

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	25	175.7
2	1	37	260.1
3	1.5	49	344.4
4	2.0	56	393.6
5	2.5	62	435.8
6	3.0	67.5	474.5
7	4	78	548.5
8	5	89	625.6
9	6	98.2	690.34
10	7	108	759.2
11	8	115.2	809.8
12	10	136	956.6
13	12	157	1103

Table 2.22: C.B.R. value for soil sample replacement of 14%
CBR $_{2.5}$ = 31.81, CBR $_{5.0}$ = 30.44

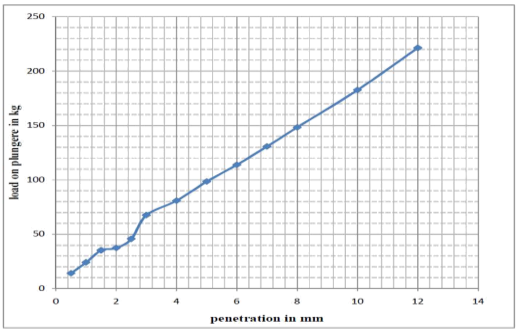


Graph 2.23: C.B.R for soil sample replacement of 14%

18% Replacement (9% BA + 9% GY) :

S.No.	Penetration (mm)	Proving ring dial ring	Load on plunger(Kg.)
1	0.5	2	14.06
2	1	3.5	24.60
3	1.5	5	35.15
4	2.0	5.3	37.25
5	2.5	6.5	45.68
6	3.0	9.6	67.48
7	4	11.5	80.84
8	5	14	98.42
9	6	16.2	113.8
10	7	18.6	130.7
11	8	21.1	148.3
12	10	25.9	182.6
13	12	31.5	221.4

Table 2.23: C.B.R. value for soil sample replacement of 18%
CBR $_{2.5}$ = 3.33, CBR $_{5.0}$ = 4.78



Graph 2.24: C.B.R for soil sample replacement of 18%

III. RESULTS

Soil test	Liquid limit %	Plastic limit %	Plasticity index %	Dry Density (g/cm3)
Results of unmodified Soil Sample	26	16.12	4.88	1.91

RESULTS OF BAGASSE ASH:

BAGASSE ASH	L.L %	P.L %	P.I %
0%	26	16.12	4.88
1.5%	21	10.9	10.1
3%	19	13.4	5.6
4.5%	21	17.1	4
5%	21	15.85	5.2
6%	23	16	7
7%	22	16.6	5.4
9%	25	18	7

RESULTS OF PHOSPHOGYPSUM:

PHOSPHOGYPSUM	L.L %	P.L %	P.I %
0%	26	16.12	4.88
1.5%	21	14.4	6.6
3%	20	17.2	2.2
4.5%	18	16.8	1.2
5%	20	17.2	2.2
6%	19	17.2	1.8
7%	21	15	6
9%	22	16.5	5.5

RESULTS OF MODIFIED SAMPLE:

SOIL TEST	MODIFIED SAMPLE (%BAGASSE ASH +%PHOSPHOGYPSUM)						
	1.5%+1.5%	3%+3%	4.5%+4.5%	5%+5%	6%+6%	7%+7%	9%+9%
L.L	16	22	21	21	21	21	24
P.L	10.8	15.3	15.2	15.7	16.9	18	19.3
P.I	5.2	6.7	5.8	5.3	4.1	2.9	4.7
Dry Density (g/cm^3)	2.04	2.00	1.92	1.98	1.86	1.92	1.86

IV. CONCLUSIONS

An experimental program was undertaken to investigate the influence of B.A & Phosphogypsum on the strength of sub grade soil. The following conclusions can be drawn from the study:

1. The natural soil used in the work is classified as low compressibility clay (CL).
2. The plasticity index of modified soil increases at the addition of 6% (3% B.A + 3% phosphogypsum) & decreases at 14% (7% B.A +7% phosphogypsum).
3. It was observed that by the addition of B.A & Phosphogypsum from 3% to 14% to the soil sample, the density has significantly decreased from 2.04g/cm3 to 1.92g/cm3 but these values are comparatively more than the unmodified soil.
4. The increase in unsoaked CBR value at 3% & 14% dosages have better effect compared to the other dosages. Increase in CBR indicates reduction in settlements
5. CBR (unsoaked) increased by 91.37% at 3% of replacement and 92.49% at 14% of replacement.
6. The effective percentage replacements of B.A & Phosphogypsum were found to be 3% & 14%.

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