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The Effects of Brick and Gypsum Mix on Weak Subgrade Soil and the Optimum Mix to be Added to Improve the Soil Strength, Ethiopia

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Abstract:- Weak sub-grade soil is one of the most plentiful soils in Ethiopia, which mostly causes significant damage to structures such as roads and bridges due to their weak in strength. Therefore this study assessed the effects of gypsum and brick mix on weak sub-grade soil to use as a road subgrade preparation. Weak sub-grade soil sample was collected from different location of Ethiopia. The weak subgrade soil were mixed with the brick and gypsum by percentage of the weight of soil taken for each samples tests starting from 0 to 40% within 10% differenceand 0 to 8% within 2% difference respectivelyand laboratory tests such as Atterberg limit, Compaction, and CBR are carried out to assess the alteration in its strength characteristics and index properties. Based on the laboratory test results, the subgrade material quality improved from A-7-5 to A-2-4 at combination 30% of crushed waste brick and 6% of gypsum with expansive soil. By the addition of material to weak sub-grade soil the least plasticity index value obtained was 9.0 % and the CBR increased to 10.7% from initial CBR value at the percentage of 30% brick and 6% gypsum. The MDD was increased to 1.5g/cm^{3}from the initial untreated soil test at percentage of 40% crushed waste brick and 8% gypsum mix with expansive soil. From analysis of results,it shown that the mixture of 30% of crushed waste brick and 6% of gypsum was the optimum combination material for stabilization of weak sub-grade soil to comply with the required technical specification specified in AASHTO. Treating weak sub-grade soil with the mix of crushed waste brick and gypsum respond and exhibited an improvement on its engineering properties including reduction in plasticity, increased strength and compaction characteristics.

Keyword:- *Crushed Waste Brick, Gypsum; Strength, Weak Sub-grade Soil.*

I. INTRODUCTION

Weak sub-grade soil is one of the most abundant soil in Ethiopia and unsuitable subgrade material covering about 40% of the area of Ethiopia[1]. Which mostly creates problems on preparation of sub-grade layer. These problems need wider application of cost effective and environmental friendly technology of improving soil properties to be customized or adopted to the current road construction trend in Ethiopia. The swell-shrink effect of expansive soils causes significant damage to structures such as buildings, roads and bridges. This damage is due to moisture fluctuation caused by seasonal variation. One of the weak sub grade soils that not favorable for road construction is expansive soils. Properties of the weak sub grade soil vary from place to place due to topography, climate and content soils etc. Expansive soils are the soils which swell significantly when they come in contact with water and shrink when dry[2]. Expansive soil exhibit volume change when subjected to moisture variation. Swelling or expansive clays soil is those that contain swelling clay mineral and have high degree of shrink-swell reversibility with change in moisture content[3]

In general way treatment of unsuitable subgrade soils is accomplished by modification, stabilization, or removal and replacement. Modification refers to a short-term subgrade treatment that is intended to provide a stable working platform during construction. Stabilization refers to a subgrade treatment intended to provide structural stability for improved long-term performance. Removal and replacement, as the name indicates, involves removal of the unsuitable subgrade soil and replacement with a select material (usually granular backfill).From several methods that available to mitigate the effects of swell-shrink nature of expansive soil is to stabilize it with admixtures that prevent it from volume changes or adequately modify the volume change characteristics of expansive soils[2]. Stabilization in a broad sense incorporates the various method employed for modifying the properties of a soil to improve its engineering performance. Stabilizing agents are selected according to the type of soil and stability problem at hand and the economics of their use. The problem of waste disposal has become a major concern for planners and engineers in developed country like Ethiopia. According to the researchers [4]says demolished waste from the construction can also be used as an admixture to improve the stability of the soil and also DBW has many of its chemical properties similar to cement and as cement can be used for the stabilization of soil so can DBW. Demolished Bricks Waste is inexpensive and readily available so it is a better option for stabilization of soil. According to, ERA[5] manual proposes: Alignment improvement (avoiding the area of expansive soil), Excavation/soil replacement

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(replacing expansive soil with good quality material along the road route), Stabilization with stabilizing agent and Minimizing of water content change (implementing measure to prevent water infiltration)

II. STATEMENT OF THE PROBLEM

The fact that weak sub-grade soils are major engineering problem makes their study an important aspect due to their low strength. A difficult problem in civil engineering works exists when the sub-grade is found to be weak soil. Soils having high clay content have the tendency to swell when their moisture content is allowed to increase[6].Ethiopia is one of the country that have distributed weak subgrade soils. To reduce the impact of weak road subgrade soils, improvement of their engineering properties is required. Increasing the strength is commonly used to improve the performance of soils with high plasticity, poor workability, and low strength and stiffness. To achieve effective soil strength, special attention needs to be given to proper type and concentration of the mixing. Besides, the effectiveness and efficiency of the stabilizer in terms of strength and durability improvement should be stated and specified. The strength and bearing capacity of the soil is impressively enhanced by soil stabilization through controlled compaction, proportioning and the expansion of reasonable admixtures[7].

III. OBJECTIVES OF THE STUDY

The objective of this study is to evaluate the Effects of Brick and Gypsum Mix on weak subgrade soil Strength and the optimum mix to be added.

IV. PREVIOUSLY STUDY

4.1. Effects of Waste Bricks on Strength

As the researcher justified, Brick dust and lime adjustment makes expansive soil more stable and increases its engineering properties, their impact on it is positive and they should be used as stabilizers as brick dust is a waste and it can be used preferably to increase properties of black cotton soil[7].According to the researcher explore when 40% of demolished bricks waste is added to in expansive soils it is increases the dry density of the stabilized soils and the optimum moisture content value showed a decreasing trend for the soil stabilized with DBW as the DBW content is increased[4].

4.2. Effects of Gypsum on Strength

As the researchers says that at low gypsum contents (i.e., gypsum content ranging from zero to about 30% by weight) there was a slight increase in the maximum dry density associated with a slight decrease in the optimum water content when gypsum content increased up to 15%[8].Researchers conclude that depending on experimental result [9]by mixing the expansive soil with different percentages of gypsum (2%, 4%, 6%, and 8%) and curing for seven days the results obtained, the optimum moisture content (OMC) and maximum dry density (MDD) at 4% gypsum is 11.76% and 19.16KN/m^3 and The swelling of soil reduced from 47% to 4.16% and CBR Value increases from 2.73% to 7.57%.

V. METHODOLOGY AND MATERIALS

5.1 Data and Sample Collection Process

- ✓ Field visual inspection, field investigation,
- ✓ After finished the initial visual inspection and categorized the soil conditions of the area and then selected the representative locations for sampling based on the availability of expansive soil.
- ✓ Disturbed soil sample was excavated from test pit up to a maximum depth of 1.5m in order to avoid the inclusion of organic matter. The soil sample collected from different location of Ethiopia was black cotton soil and selected for laboratory test due to its expansiveness.
- ✓ Finally the results from laboratory test were analyzed with standard specifications.

VI. RESULT AND DISCUSSION

6.1 The Effect of Gypsum and Crushed Waste Brick Mix on Atterberg Limit

Table 1: Laboratory test results of Atterberg Limit

Natural Soils and Percent's of Stabilizer	LL (%)	PL (%)	PI (%)	The reduction of PI (%)
WSS+ 0% CWB + 0% G	76.5	40.0	36.5	-
WSS + 10% CWB + 2% G	74.4	38.8	35.6	2.4
WSS + 20% CWB + 4% G	60.2	34.5	25.7	27.7
WSS + 30% CWB + 6% G	40.0	31.0	9.0	64.9
WSS + 40% CWB + 8% G	39.8	N.P.	-	-

The highest reduction in plastic index occur when it was stabilized by the combination of 30% brick with 6% gypsum ratio and the minimum reduction occur when it was stabilized by the combination of 10% brick with 2% gypsum ratio.

In general from Table 1 for gypsum and crushed waste brick mix stabilization for expansive soil the following observation have been made.

- ❖ Liquid limit decreases with increasing the mix of gypsum and crushed waste brick ratio to the expansive

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soil.This is on the grounds that when gypsum synthetically consolidates with water, it can be utilized viably to dry wet soil.

- ❖ Plastic limit decreases with increasing the mix of gypsum and crushed waste brick ratio and plastic limit became undetermined as the stabilizer increased to 40% of crushed waste brick and 8% of gypsum to expansive soil. These effects are due to the partial replacement of plastic particles (expansive soil) with Crushed Waste Brick and Gypsum which is non plastic materials and flocculation and agglomeration of clay particles caused by cation exchange may be the other cause.
- ❖ Plastic index decreases up to the mixture of expansive soils with mix of 30% brick and 6% gypsum.
- ❖ Changing stabilization ratio changes liquid limit, plastic limit and plastic index values of the weak sub-grade soil.

6.2 The Effect of Gypsum and Crushed Waste Brick Mix on Soil Classification

The system is based on particle size, liquid limit and plasticity index of the soil.

Table 2: Soil Classification

SAMPLE	ATTERBERG LIMIT			SOIL CLASSIFICATION
	LL, %	PL, %	PI, %	AASHTO
Expansive soil	76.5	40.0	36.5	A-7-5
WSS+10%CWB+2%G	74.4	38.8	35.6	A-7-5
WSS+20%CWB+4%G	60.2	34.5	25.7	A-7-5
WSS+30%CWB+6%G	40.0	31.0	9.0	A-2-4
WSS+40%CWB+8%G	39.8	-	-	-

6.3 Effect of the Mix of Gypsum and Crushed Waste Brick on CBR and CBR-Swell

6.3.1 CBR Value at 10, 30 and 65 Blow

The soaked CBR values for all the samples increased with percentage of the mix of Gypsum and crushed waste Bricks increased. Results are illustrated in Table 3 below.

Table 3: CBR test result of the treated expansive soils at different penetration depth and blows

Natural Soil and percent of Stabilizer	CBR Value (%) at 2.54mm penetration depth			CBR Value (%) at 5.08mm penetration depth		
	10 Blow	30 Blow	65 Blow	10 Blow	30 Blow	65 Blow
WSS+ 0% CWB + 0% G	1.4	1.5	1.6	1.2	1.2	1.4
WSS + 10% CWB + 2% G	1.6	1.7	2.0	1.5	1.7	1.8
WSS + 20% CWB + 4% G	3.5	4.0	4.9	3.0	3.6	4.8
WSS + 30% CWB + 6% G	9.2	10.9	13.9	9.9	11.4	12.9
WSS + 40% CWB + 8% G	7.1	8.0	8.7	6.8	7.9	8.9

According to Table 3, the CBR value at 2.54mm and 5.08mm penetration depth for 10 blow, 30 blow and 65 blow are increases as content of stabilizer increases to weak sub-grade soil and also as number of blow increases, at constant mix of weak soil with gypsum and crushed waste brick stabilizer agent, the value of CBR increases. The increase in CBR value in increasing of number blow from 10 to 30 to 65 can be explained as a result of better compaction and packing of the mix. A better compaction improves intermolecular attractions which in turn enhance the strength of the subgrade material.

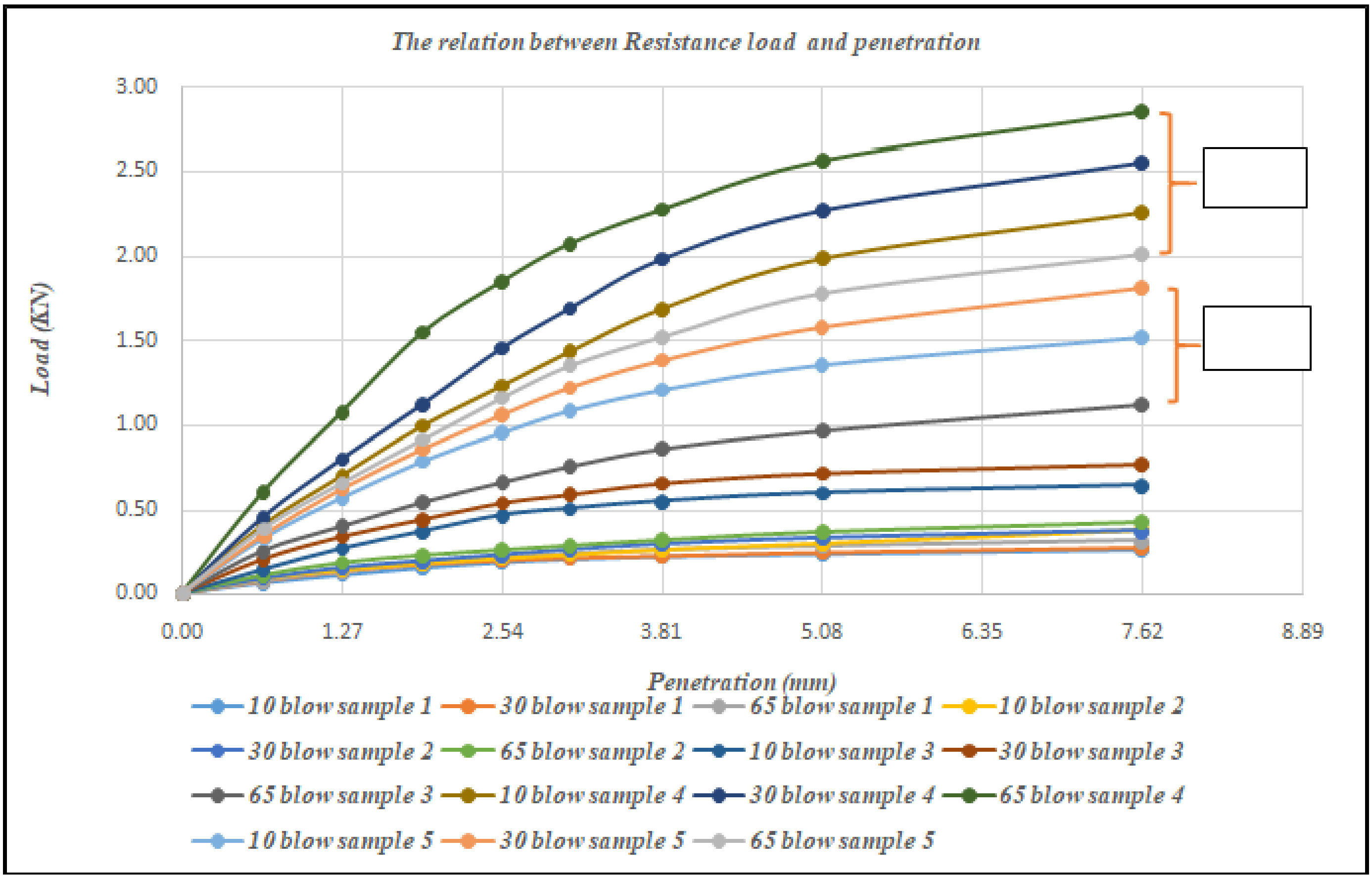

Figure 1: Resistance Load vs Penetration of weak soil with stabilizer

As indicated in Figure 1 Variation of Penetration and Resistance load with addition of gypsum and crushed waste brick mix content to expansive soil and number of blow. As the mixture of expansive soil with gypsum and crushed waste brick content increases to 30% of crushed waste brick and 6% of gypsum the load carrying capacity of the soil increases, then starts to decrease as the increment of gypsum and crushed waste brick mix to 40% of CWB and 8% of gypsum.Generally, the soaked CBR value at 95% of compaction of the unstabilized and stabilizedExpansive soil sample improved from 1.5% to10.7% at combination of 30% of crushed waste brick and 6% of gypsum and the CBR value started to decrease when it reached to the combination expansive soil with the percentage of 40% of crushed waste brick and 8% of gypsum mix. The percentages above the mix of 20% of crushed waste brick and 4% of gypsum were satisfied the quality and the strength the expansive soils. Thus we can take gypsum and crushed waste brick as a weak subgrade soils stabilizer for road subgrades, but need covered with blanketing material.

6.4 Effect of the Mix of Gypsum and Crushed Waste Brick on Dry Density and Moisture Content before and After Soak of Weak Sub-Grade Soil

From Table 4 at 10, 30, and 65 blow dry density before soak greater than after soak as the percentage of gypsum and crushed waste brick was increased, this was due to decreased the intermolecular attractions and create a void for water accumulation after soak. On other hand the dry density was increased as the amount of gypsum and crushed waste brick percentage was increased.

Table 4: Dry Density test results before and after soak

SAMPLE	DRY DENSITY					
	Before Soak			After Soak		
	10 Blow	30 Blow	65 Blow	10 Blow	30 Blow	65 Blow
WSS+ 0% CWB + 0% G	1.320	1.366	1.412	1.241	1.289	1.322
WSS + 10% CWB + 2% G	1.332	1.389	1.422	1.247	1.350	1.407
WSS + 20% CWB + 4% G	1.335	1.420	1.487	1.278	1.364	1.415
WSS + 30% CWB + 6% G	1.348	1.422	1.518	1.289	1.375	1.454
WSS + 40% CWB + 8% G	1.378	1.432	1.547	1.291	1.384	1.468

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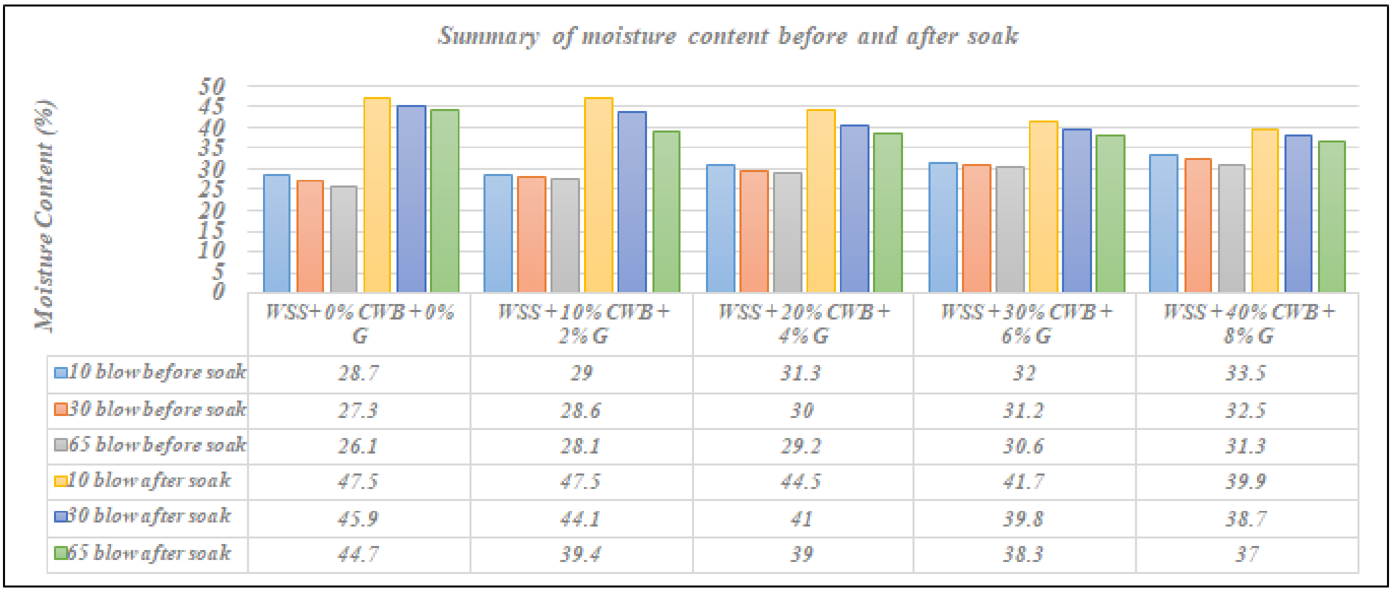
Based on Figure 2 the moisture content directly affected by number of blow and gypsum-crushed waste brick stabilizer.

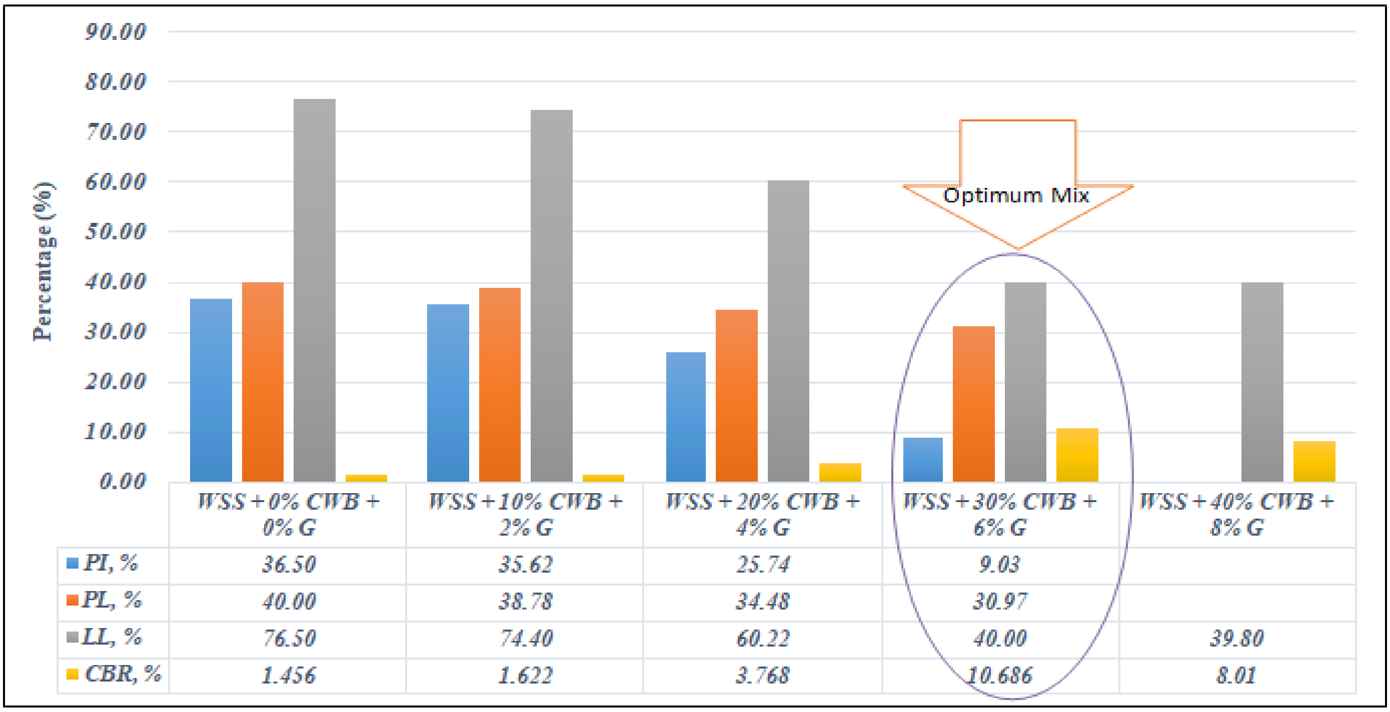


	WSS+0% CWB+0% G	WSS+10% CWB+2% G	WSS+20% CWB+4% G	WSS+30% CWB+6% G	WSS+40% CWB+8% G
10 blow before soak	28.7	29	31.3	32	33.5
30 blow before soak	27.3	28.6	30	31.2	32.5
65 blow before soak	26.1	28.1	29.2	30.6	31.3
10 blow after soak	47.5	47.5	44.5	41.7	39.9
30 blow after soak	45.9	44.1	41	39.8	38.7
65 blow after soak	44.7	39.4	39	38.3	37

Figure 2: Moisture Content before and after soak

6.5 The optimum Mix of Gypsum with Crushed Waste Brick to be added to improve the SoilStrength

Depending on Figure 3 the CBR value increased form 1.5% to 10.7% as the percentage of gypsum and crushed waste brick increased from zero to 30% of crushed waste brick and 6% of gypsum to expansive soil, then decreased to 8.0% at the mix of 40% crushed waste brick and 8% gypsum with expansive soil and According to Atterberg limit test results shows in Figure 3 the plastic index results decreased from 36.5% to 9.0% as the amount of gypsum and crushed waste brick increased to weak soil, then became to non-plastic. This is due to none plastic material of gypsum and crushed waste brick in high amount in weak soil. On the other hand based on AASHTO soil classification system and Atterberg limit test result value the weak sub-grade soil was improved from poor to good as the amount of stabilizer increased to the combination of 30% of brick and 6% of gypsum with weak sub-grade soil. Therefore depending on the value of CBR and AASHTO soil classification system the optimum mix of Gypsum with crushed waste brick to be added to improve the weak soils strength was the combination of crushed waste brick and gypsum which was achieved maximum CBR value and minimum Plastic Index of the material.



	WSS + 0% CWB + 0% G	WSS + 10% CWB + 2% G	WSS + 20% CWB + 4% G	WSS + 30% CWB + 6% G	WSS + 40% CWB + 8% G
PI, %	36.50	35.62	25.74	9.03	
PL, %	40.00	38.78	34.48	30.97	
LL, %	76.50	74.40	60.22	40.00	39.80
CBR, %	1.456	1.622	3.768	10.686	8.01

Figure 3:The optimum mix to be added to improve the strength

VII. CONCLUSION

- ✓ Based on the AASHTO soil classification was grouped under poor subgrade soil.
- ✓ The sub grade soils considered for this study have a very low load bearing capacity which makes the soils unsuitable for sub grade without improvement.
- ✓ The liquid limit and the plastic limit decreased from 76.5% to 39.8% and 40.0% to non-plastic respectively as the amount of gypsum and crushed waste brick mix was increased.
- ✓ The plastic index is decreased from 36.5% to 9.0% at combination of soil with 30% crushed waste brick and 6% gypsum.
- ✓ The soil classification improved to A-2-4 stabilized the expansive soil with the combination of 30% of Crushed Waste Brick + 6% of Gypsum based on AASHTO soil classification system.
- ✓ At 10, 30, and 65 blow dry density before soak greater than after soak as the percentage of gypsum and crushed waste brick was increased, this was due to decreased the intermolecular attractions and create a void for water accumulation after soak.
- ✓ As number of blow was increased the moisture content decreased for both before and after soak. As the percentage of gypsum and crushed waste brick mix was increased, the moisture content also increased for all blow before soak, but after soak the moisture content was decreased. The moisture content after soak was higher than before soak. The moisture content before and after soak have inversely relationship.
- ✓ The optimum moisture content increased with increment of gypsum and crushed waste brick content. The optimum moisture content of weak subgrade soil changed from 25.4% to 29.2%.
- ✓ The engineering properties of the soils is improved due to mixed with gypsum and crushed waste brick. The MDD increased from 1.4g/cm^3 to 1.5g/cm^3 as the increment of gypsum and crushed waste brick to 40% of crushed waste brick and 8% of gypsum mix.
- ✓ The CBR value increases from 1.5% to 10.7% as the content of gypsum and crushed waste brick increases from 0% to 6% G + 30% CWB then decreased to 8.0% as increased the stabilizer to 8% G + 40% CWB.

From the above discussion it can be concluded that the optimum combination of gypsum and crushed waste brick to improve the expansive soil is the mixture of expansive soil with the combination of 30% of crushed waste brick and 6% of gypsum.Generally the mix of crushed waste brick with gypsum can effectively utilized with weak subgrade soil in improving the soil CBR values and MDD. The use of Crushed Brick resulted in utilization of demolition wastes and found to be economical for local area. This will results in the utilization of rejected weak soil in construction. From the results, it is concluded that impact of Crushed Brick and Gypsum is positive on soil strength.

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