SOIL IMPROVEMENT USING WASTE GLASS POWDER AND FLY ASH

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Abstract - *Engineering properties of soil may be altered by any method of soil stabilization, one of the methods of soil stabilization is by addition of admixtures. In this work, the waste materials like Fly Ash and Waste Glass Powder have been used as admixture to enhance the properties of soil. Atterberg's limit tests (for calculating liquid limit and plastic limit), standard proctor tests (for calculating MDD and OMC), California bearing ratio (C.B.R) tests, and Unconfined Compressive strength (UCS) tests were performed on both soil and soil mixed with different percentages of fly ash (5%,7.5%,10%,12.5%and 15%), Properties like MDD, CBR and UCS were found to be maximum with 10% fly ash. After that, with that sample of 10% Fly Ash, different percentages of waste glass powder (5%,7.5%,10%,12.5% and 15%) were mixed with the soil and the properties were studied*

Key Words: Fly Ash, WGP, Proctor Tests, CBR, UCS, Liquid limit, Plastic Limit

1.INTRODUCTION

Soil improvement is a method or technique used to improve soil that doesn't have sufficient strength and other pertinent properties. Soil improvement is typically done to meet the requirements of the type of structure that will be built on the soil. By performing the soil improvement following advantages can be achieved:

- Improvement in the bearing capacity of soil.
- Reduction in the subgrade layers thickness in pavement design
- Reduction in soft ground settlements
- Improving stability of slopes

Many soil improvement techniques are developed throughout the years, and they are still being developed. Soil improvement methods can be categorized in following main categories:

- **i.** Soil improvement with replacement.
- **ii.** Soil improvement by soil reinforcement
- **iii.** Soil improvement with grouting and admixtures etc.
- **iv.** Soil improvement without admixture in coarse-grained soils (Dynamic compaction, Vibro-compaction, etc)
- **v.** Soil improvement without admixture in fine-grained soils (Preloading, Dynamic Consolidation etc. [1.]

In this work, two admixtures have been used to study the soil properties which are: **Waste Glass Powder and Fly ash.**

2. MATERIALS

2.1 SOIL

The soil used in this study was Intermediate plastic clayey soil (C I) which was obtained from the pit near pond in the B.I.T Sindri Campus.
The geotechnical properties of the soil are listed below:

Table 1: **Properties of soil**

Serial No	Properties	Test value
1.	Specific gravity	2.377
2.	Liquid Limit LL (%)	40.11
3.	Plastic Limit PL (%)	13.39
4.	Plasticity Index (I_p)	26.72
5.	Optimum Moisture Content (%)	16.67
6.	Maximum Dry Density (g/cm^3)	1.8201
7.	Unconfined Compressive Strength (UCS) (kN/m^2)	55.98
8.	California Bearing Ratio (unsoaked) (%)	1.70
9.	Percent Passing Through 75µ Sieve (%)	52.7

2.2 WASTE GLASS POWDER(WGP)

The Waste Glass powder was obtained from AKSHAR EXIM COMPANY PRIVATE LIMITED Kolkata, West Bengal. The waste glass powder was made by collecting waste glass bottles and crushing them into smaller pieces. The crushed glass was then sieved through a 1180 µm sieve and crushed in a ball mill before being sieved again through a 300 µm sieve, yielding waste glass powder.

Table 2: Specifications of WGP as per manufacturer (Akshar EXIM Co. Pvt ltd Kolkata)

1.	Silica (SiO_2)	72.5%
2.	Alumina (Al_2O_3)	0.4%
3.	Iron Oxide (Fe_2O_3)	0.2%
4.	Calcium Oxide (CaO)	9.7%
5.	Magnesium Oxide (MgO)	3.3%
6.	Sodium Oxide (Na_2O)	13.7%
7.	Potassium Oxide (K_2O)	0.1%
8.	Sulphur Trioxide (SO_3)	-
9.	Percent passing through 425µ sieve	100%
10.	Percent passing through 75 µ	0%
11.	Specific Gravity	2.58

2.3 FLY ASH

Fly ash is a byproduct of thermal power plants that uses coal as a fuel. The Fly Ash used for the investigation was of C Class and collected from the Fly ash brick factory in Industrial area, Sindri.

Table 3: General Specifications of class C Fly Ash

SiO_2	40%
Al_2O_3	17%
Fe_2O_3	6%
MgO	5%
CaO	24%
SO_3	3%
Specific Gravity	2.22

3. Experimental Procedure

The study was conducted in two stages, the first stage was to mix soil with Fly Ash in soil in different percentages (5%,7.5%,10%,12.5%,15%) and tests like Standard Proctor Tests, California Bearing Ratio Tests, Unconfined Compressive Strength Tests and Atterberg's Limit tests (for liquid limit and plastic limit) were performed and optimum proportion of Fly Ash was obtained based on the results of the tests mentioned above. In the second stage, keeping that proportion of Fly Ash constant, different percentages of Waste glass powder (WGP) (5%,7.5%,10%,12.5%,15%) were mixed and same tests were performed to obtain the effective proportion of Waste Glass Powder.

4. RESULTS AND DISCUSSION

4.1 EFFECT OF FLY ASH

The study was conducted in two stages, the first stage was mixing of Fly Ash with the soil. Fly Ash was mixed with the soil in following order:

Table 4: Description of Samples of Soil and Fly Ash only

Serial No	Soil (%)	Fly Ash (%)
1.	100%	0%
2.	95%	5%
3.	92.5%	7.5%
4.	90%	10%
5.	87.5%	12.5%
6.	85%	15%

4.1.1 Effect of Fly Ash on Maximum Dry Density (MDD) and Optimum Moisture Content (OMC).

The variation in the MDD and OMC on increasing the Fly Ash content are shown in following table and graphs.

Table 5: Variation in MDD and OMC values on increasing Fly Ash proportion

Fly Ash (%)	0	5	7.5	**10**	12.5	15
MDD(g/cm³)	1.820	1.85	1.902	**1.93**	1.86	1.823
OMC (%)	16.67	14.28	12.12	**11.11**	13.04	16

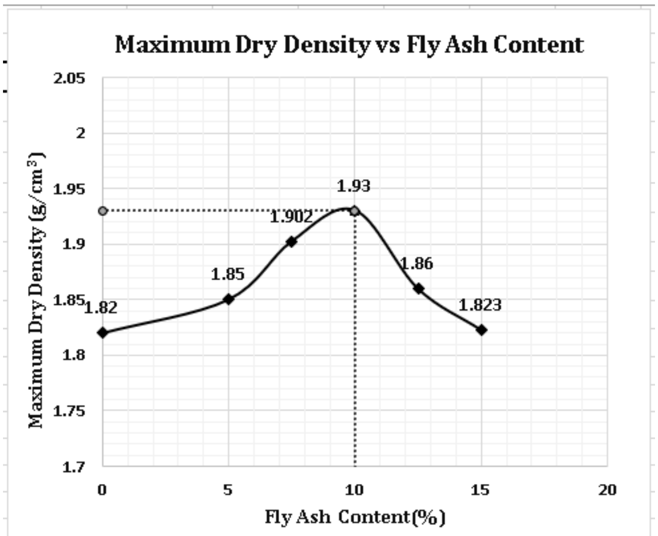

Fig 1: Variation in Maximum Dry Density on increasing the Fly Ash proportion

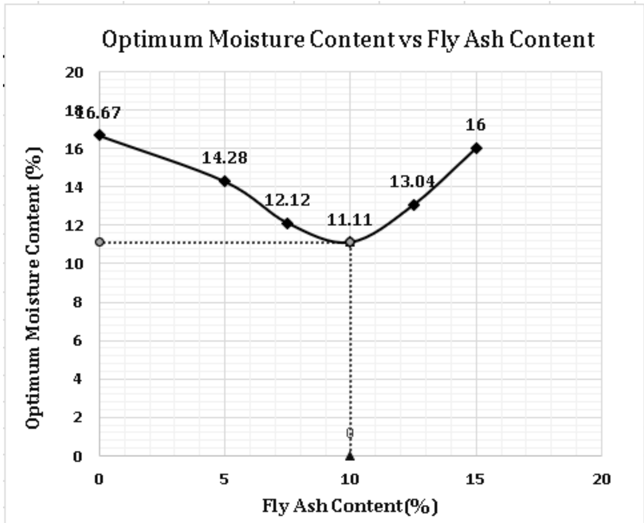

Fig 2: Variation in the OMC with increase in Fly Ash proportion

- The maximum dry density increased from 1.82 g/cm³ to 1.93 g/cm³ as the percentage of Fly Ash increased from 0% to 10%, which could be due to pozzolanic reactions with the lime content of the soil, resulting in the formation of Calcium Silicate Hydrates and Calcium Aluminate Hydrates having higher specific gravity than the soil [2.]. When the Fly Ash proportion is increased to 15%, the MDD value lowers, which could be due to the residual (unreacted) Fly Ash having a lower specific gravity than the soil, lowering the dry density of the soil mass.

- While the OMC decreased with the increase in Fly Ash proportion with the lowermost value of 11.11% with 10% Fly Ash.

4.1.2 Effect of Fly Ash on CBR (unsoaked) values.

Table 6: Variation in Unsoaked CBR values on increasing Fly Ash proportion

Fly Ash (%)	0	5	7.5	**10**	12.5	15
Unsoaked CBR (%)	1.7	6.29	7.23	**8.67**	8.164	7.82

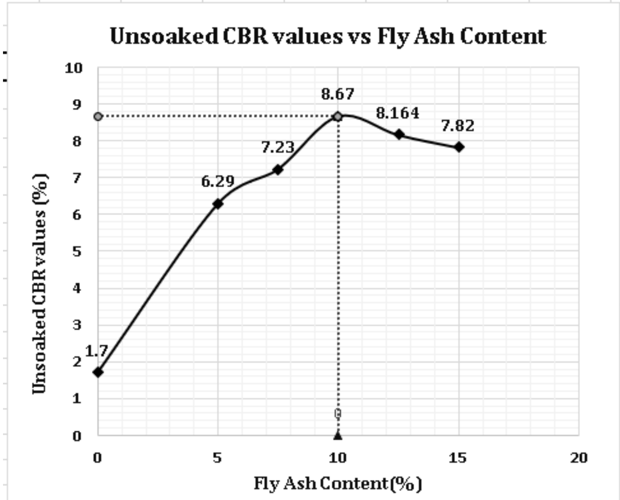

Fig 3: Variation in CBR values with increase in fly ash proportion

- With the addition of Fly Ash, unsoaked CBR (values) increased from 1.7 percent to 8.67 percent, possibly because to the stronger resistance to penetration offered by the denser material obtained as a result of the addition of Fly Ash.

4.1.3 Effect of Fly Ash on Unconfined Compressive Strength

Table 7: Variation in UCS on increasing Fly Ash proportion

Fly Ash (%)	UCS (kN/m²)
0	55.98
5	84.13
7.5	113.67
10	**157.32**
12.5	133.42
15	125.41

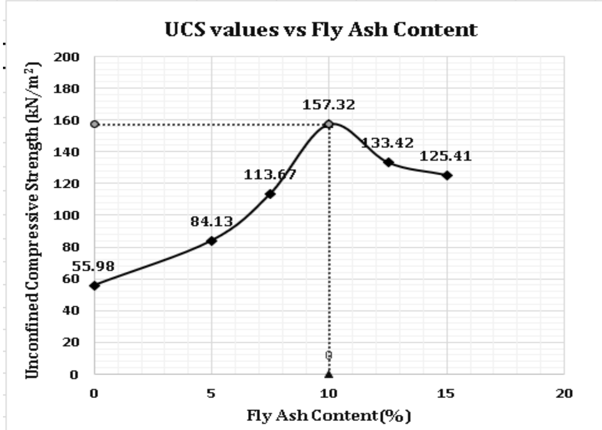

Fig 4: Variation in UCS values with increase in fly ash proportion

- The UCS values increased from 55.98 kN/m² to 157.32 kN/m² when the proportion of Fly Ash increased from 0% to 10%. The improvement in UCS value might be caused due to increase in shear strength caused by the bond developed between soil grains due to cementitious property of Fly-Ash.

4.1.4 Effect of Fly Ash on Liquid Limit and Plastic Limits.

Table 8: Variation in Liquid limit and Plastic limit on increasing Fly Ash proportion

Fly Ash (%)	Liquid Limit (%)	Plastic Limit (%)
0	40.11	13.37
5	38.00	12.25
7.5	37.30	12.01
10	35.85	11.63
12.5	34.19	10.93
15	33.20	10.05

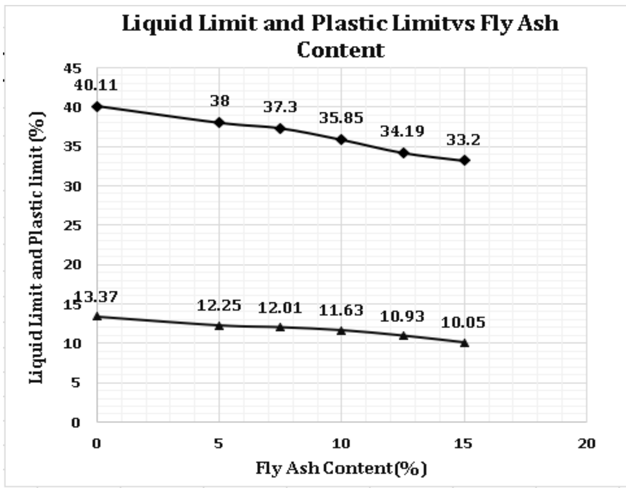

Fig 5: Variation in Liquid Limit and Plastic Limit with increase in fly ash proportion.

- With the increase of Fly Ash proportion, the liquid limit and plastic limit decreased. It's possible that the decrease is due to the fact that fly ash does not retain as much water as clay particles.

4.2 EFFECT OF WASTE GLASS POWDER

Since the MDD, CBR value and UCS value were found to maximum with 10% Fly Ash. So, it was taken as fixed proportion of Fly Ash for mixing of Waste Glass Powder. The Waste Glass Powder was added in following order.

Table 9: Description of Samples of Soil, Fly Ash and Waste Glass Powder.

Serial No	Soil (%)	Fly Ash (%)	WGP (%)
1.	90	10	0
2.	85	10	5
3.	82.5	10	7.5
4.	80	10	10
5.	77.5	10	12.5
6	75	10	15

4.2.1 Effect of WGP on MDD and OMC.

The variation in the MDD and OMC on increasing the WGP content are shown in following table.

Table 10: Variation in MDD and OMC values on increasing WGP proportion

WGP Proportion (%)	MDD (g/cm³)	OMC (%)
0	1.93	11.11
5	1.95	10.25
7.5	1.97	9.76
10	1.995	9.09
12.5	2.016	8.163
15	1.98	8.89

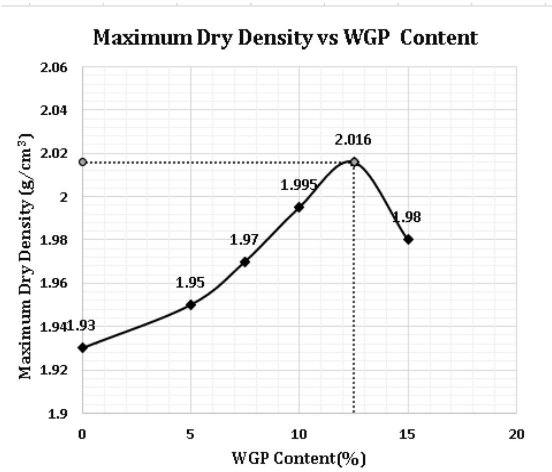

Fig 6: Variation in Maximum Dry Density with increase in WGP proportion.

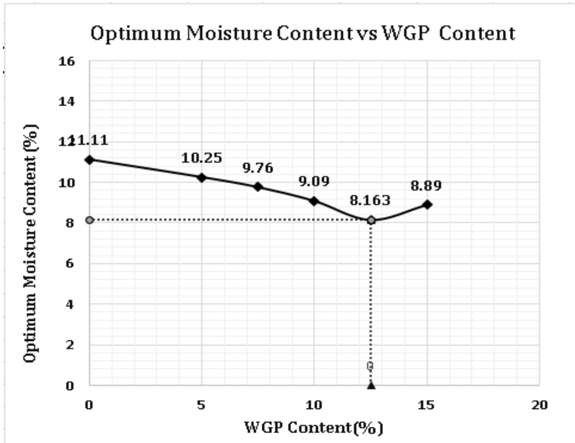

Fig 7: Variation in Optimum Moisture Content with increase in WGP proportion.

- As the WGP proportion increased from 0% to 12.5%, the maximum dry density increased from 1.93 g/cm³ to 2.016g/cm³. The increase in dry density is most likely due to the higher specific gravity of WGP in comparison to the specific gravity of soil. On further increase in WGP proportion to 15% the MDD decreases to 1.98 g/cm³ which may due to larger voids created by the coarser WGP particle in the soil mass.
- As the WGP proportion increased from 0% to 12.5%, the OMC decreased from 11.11% to 8.163%. It's possible that the decrease is due to the fact that glass powder does not absorb water like clay particles do.

4.2.2 Effect of WGP on Unsoaked CBR Values.

Table 11: Variation in unsoaked CBR values on increasing WGP proportion

WGP (%)	0	5	7.5	10	**12.5**	15
Unsoaked CBR (%)	8.67	11.14	12.93	16.72	**18.34**	14.76

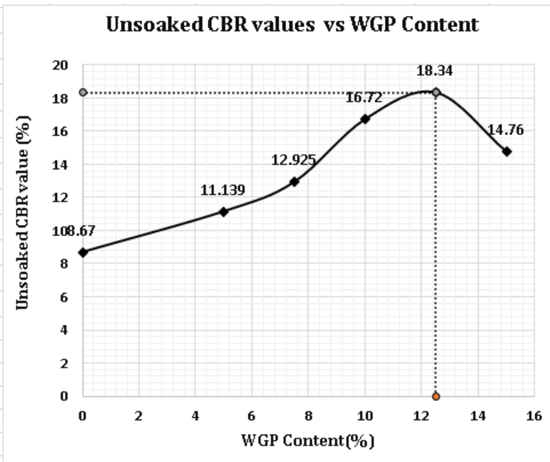

Fig 8: Variation in Unsoaked CBR value with increase in WGP proportion.

- As the WGP proportion increased from 0% to 12.5%, the Unsoaked CBR value increased from 8.67% to 18.34 %. When WGP is added which is coarser and have larger particle size, the overall grain size distribution of the soil shifts toward well-graded soil, resulting in a more compacted state of the soil and thus a higher CBR value. On further increase in WGP proportion the CBR value drops to 14.76%.

4.2.3 Effect of WGP on Unconfined Compressive Strength.

Table 12: Variation in UCS values on increasing WGP proportion

WGP (%)	UCS (kN/m²)
0	157.32
5	199.83
7.5	222.69
10	266.734
12.5	**292.824**
15	259.77

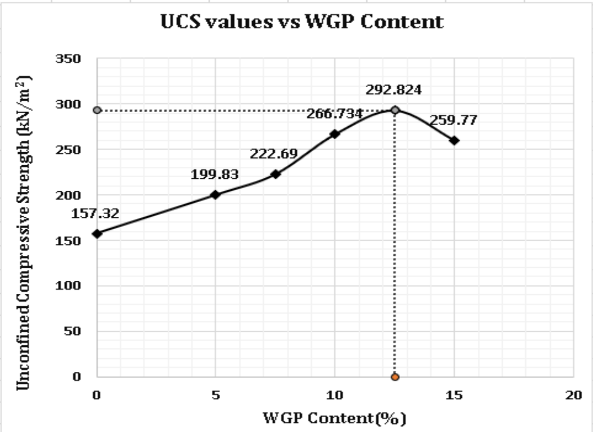

Fig 9: Variation in UCS values with increase in WGP Proportion

- The UCS value increased from 157.32 kN/m² to 292.824 kN/m² as the WGP proportion increased from 0% to 12.5% which may be due to increase in shear strength due to shift of overall grain size distribution of soil towards well graded due to addition of WGP. On increasing the WGP proportion to 15% the UCS value decreased to 259.77 kN/m² which may be due to decrease in cohesion due to increase in WGP content.

4.2.4 Effect of WGP on Liquid Limit and Plastic Limit

Table 13: Variation in Liquid Limit and Plastic Limit on increasing WGP proportion

WGP (%)	Liquid Limit (%)	Plastic Limit (%)
0	35.85	11.632
5	31.05	9.82
7.5	30.11	9.4
10	29.667	8.8
12.5	28.883	8.57
15	27.53	8.002

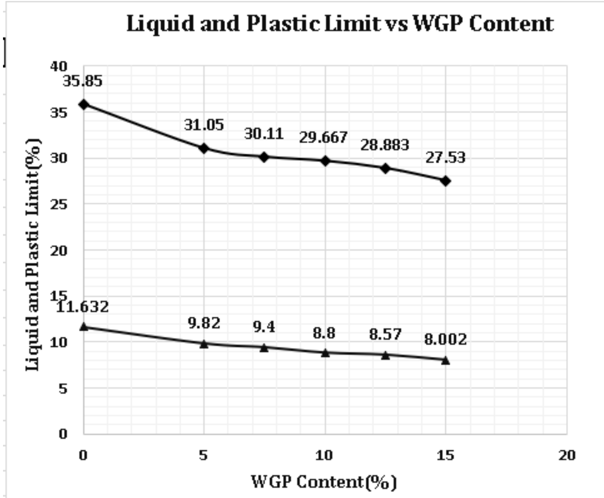

Fig 10: Variation in Liquid Limit and Plastic Limit with increase in WGP proportion

- The Liquid Limit decreased from 35.85% to 27.53% and Plastic Limit decreased from 11.632% to 8.002% as the WGP proportion increased from 0% to 15%. The decrease in liquid and plastic limit is may be because WGP does not absorb water like clay particles .

5. CONCLUSIONS

The following conclusions can be drawn based on the results of various experiments conducted on different samples of soil mixed with Fly Ash and Waste Glass Powder:

1. The soil used for the study was clay of intermediate plasticity (C I soil).
2. When only Fly Ash was mixed with the soil, the MDD improved from 1.82 g/cm³ to 1.93 g/cm³ and the maximum value of 1.93 g/cm³ was observed with 10% Fly Ash.
3. Similarly, when only Fly Ash was mixed with soil the Unsoaked CBR value increased from 1.7% to 8.67%and Unconfined Compressive Strength increased from 55.98 kN/m² to 157.32 kN/m². The maximum value of both unsoaked CBR and Unconfined compressive strength was observed with 10% Fly Ash.
4. So, 10% Fly Ash was taken as optimum percentage of Fly Ash for mixing of Waste Glass Powder (WGP).
5. With constant percentage of Fly Ash of 10% and different percentages of WGP, highest value of Maximum Dry Density was observed with 12.5 % WGP and the highest value of MDD was 2.016 g/cm³.
6. With constant percentage of Fly Ash of 10% and different percentages of WGP, the value of unsoaked CBR increased from 8.67% to 18.34% and the maximum value of unsoaked CBR was observed with 12.5% WGP.

7. The Unconfined compressive strength also improved from 157.32 kN/m² to 292.824 kN/m² and the maximum UCS value was observed with 12.5% WGP.
8. Liquid limit decreased throughout the process of addition of admixtures from 40.11% to 27.53%.
9. Plastic limit also decreased throughout the process of addition of admixtures from 13.37% to 8.002%.
10. From above results, the optimum percentage of Fly Ash and WGP were found to be 10% and 12.5% respectively.

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