Enhancement in Subgrade soil strength using Glass Powder as discrete fiber: A Review

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Abstract— To construct a better and smooth riding highway the major and our first priority goes for the enhancement of the subgrade strength of soil which we are going to use particularily in the road construction and many of the authorities which are working for this purpose are being involve in the process of finding such discrete fibers which are going affect various soil properties like- California bearing ratio (CBR) and shear strength. The discrete fiber which we are going to use in our studies is the glass powder as there are very few studies has been taken place in this field and it is not unique but a useful discrete fiber with the help of which we can bring changes in the strength of soil subgrade easily , if it is being mixed with the soil in the right proportions and to check the CBR values and Atterberg limits we can use the various tests like CBR test and Atterberg limit tests which will represent the fact that using of this discrete fiber will lead in increasing shear strength and it's particular California bearing ratio (CBR) value.

Keywords— **Glass powder, CBR value, Properties,Atterberg limit test ,Discrete fibers, Soil subgrade strength,CBR test,clayey soil etc.**

Introduction

In now a days it is being very much common to use waste materials and different kind of fibers in the strengthening of soil and soil stabilization, Because the dumping or deposition problem of these materials are being very much difficult in these days there are many kind of waste exists like-plastics, rice husk ash, fly ash and molasses etc but our main motive is to use the glass powder as a discrete fiber because in spite of being very useful it is not going to be very much used in the field of soil engineering. So the main purpose of this paper is to discuss various properties of glass powder which can be useful in the stabilization and soil strengthening of soil if mixed with soil in a different proportions and what will be the effect on the CBR value and various Atterberg limits due to this discrete fiber. The soil selection process will be based on the variation of their Atterberg limits and the soil which we are going to take for our research is classified as CH and CL according to system of Unified Classification System and we are just going to mix the glass powder in that soil with different proportions like in the percentages of 0.1%,0.3% and 0.5% etc to extract the better result and to finalize the one best value with the help of which we are going to attain the desired subgrade strength of soil which is going to be reliable and appropriate in effective way.

Properties of glass powder

To improve the engineering properties of soil we are going for mixing of broken glass powder in the soil as we know that it has the various properties like it is a totally non-biodegradable material and it is also a totally inert material and can be useful to enhance the various road building elements strength and it also can not get degraded in a very simple manner it has it's degradation phenomenon which is very much similar to the degradation of natural rocks.

It is a non-crystalline material which is also amorphous, and it is also very much hard & brittle and transparent as well. The glass which are generally used and are familiar to everyone are windows and drinking vessels ,and the glass material which is available readily is soda-lime glass having 75% of CaO, silica and Nitrogen oxides as well.

Collection, processing and composition of glass powder

The glass powder which is going to be used as a prime material has been collected through the various sources like-various soft drink bottles which are generally being used by the people mostly in summers in the stores and shops and after collection of these glass bottle, These bottles were properly washed and then dried after that these were broken down manually with the help of hammer into very much smaller sizes and after that process it has been passed through 400 number sieve to attain glass in the form of powder and the second useful material which are going to be used in this process was the clayey soil which has been collected at the ground of the LPU situated in Phagwara, Punjab in India. The general phenomenon is being adopted, firstly we have remove the top soil and excavate it upto the 0.7 m depth, to take both undisturbed and disturbed samples. The chemical composition of glass powder which is going to be used in that research is given as: 11.50% of AL_2O_3, 76% of SiO_2, and 11.6% of Na_2O and the other necessary components are upto 0.9%. It has 2.5-2.9 of specific gravity and hardness of 5 to 7 with softening point 1500-1750 C & 27-62 MPa tensile strength.

Principle of soil strengthening or stabilization

Strengthening or Stabilization is known as that process which is generally used for the improvement of aggregate properties of soil by blending process of materials that enhances the firmness, load bearing capacity and weathering resistance. It can be defined as the enhancing the desired engineering properties of soil by changing soil properties through various chemical and mechanical method. The main purpose is of that phenomenon is to increase the soil durability, weather resistance, control of permeability and mainly improvement of strength. These stabilization are mainly of three types first one is the mechanical stabilization, second one is chemical stabilization and third one is reinforced fiber stabilization ,the mechanical stabilization can be possible by the interlock soil-aggregate particle's compaction process. Compaction generally removes the largest pores of soil and an initial soil air is forced out of the upper plant root zone upto a large portion this causes the greatest continuity channels, least air movement resistance and root penetration and movement of water gets destroyed according to Bowles [2]. In the second method which is called chemical stabilization deals with soil's various engineering properties by adding chemicals and other materials which is considered as very expensive method. These methods can bind the soil properly as those additives which are being used in this process generally react with the soil with subsequent precipitation of new and minerals which are insoluble for example clay minerals usually [3]. The third type is known as reinforced fiber stabilization, in which mostly plant roots,straws ,cob and soil bricks were used for the improvement in the properties of soil and in all these materials the plant roots were found the best alternatives among all since most of the researchers has found that share strength of soil and natural slops stabilities constantly get increased as from the use of plant roots. Triaxial tests on kaolinite clay reinforced with cellulose pulp fibers were performed by the two researchers named Al-Khafaji and Andersland [4].Under various testing conditions and with the increasing content of fiber, the shear strength get increased and mode of failure get changed into plastic from brittle and with the increase in fiber content the specimen ductility get also increased and modified by this .

Laboratory tests and analysis

To evaluate the various effects on clay soil of the glass powder many analysis and tests were get performed which are mostly particle size distribution analysis, specific gravity test, Atterberg limit test, Compaction test, California bearing ratio test. The required quantity of glass for effective stabilization of clay soil was calculated based on these tests.

A.Particle size distrribution analysis

The size of the particles in terms of percentage by weight of soil which is going to be pass by each sieve can be evaluated by particle size distribution analysis. In this first of all the soil sample get oven dried for 24 hours and then get allowed it to cooled and then soaking of 24 hours also after that 75 μm sieve were used to wash and soil sieving after that it was again gets overdried and it's weight which has been resulted by the process were then recorded. According to the aperture size and on the basis of reweighed material the sieves were arranged accordingly and after pouring the sand in it it has been shaking for 10 minutes vigorously.

After that sieve was left for few minutes so that sample can get settled, the quantity of the sand which get retained on each sieve get weighed and recorded and respective percentages of passing and retained were calculated and then a graph between the sieve sizes and passing percentages were plotted accordingly.

Table 1. Particle Size Distribution Analysis.

Sieve Diameter (mm)	Mass Retained(g)	%Retained	%Passing
4.75	0	0	100
2.36	0.3	0.23	99.77
1.700	0.4	0.30	99.47
1.18	1.3	0.98	98.49
0.600	4.3	3.24	95.25
0.500	6.5	4.90	90.35
0.425	1.1	0.83	89.53
0.212	53.7	40.47	49.06
0.150	35.1	26.45	22.61

0.075	27	20.35	2.26
Pan	3	2.26	0.00

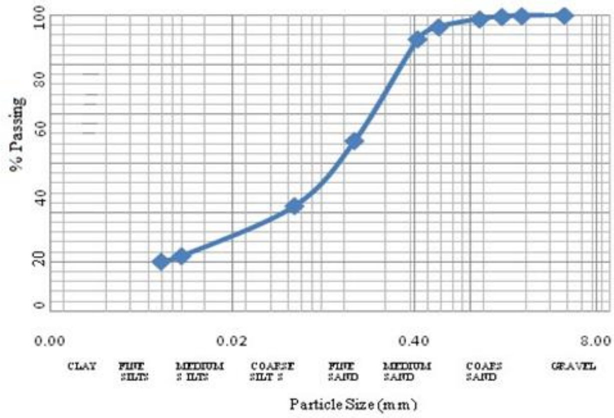

Fig. 1. Particle Size Distribution Chart.

B.Specific gravity test

Specific gravity can be defined as the proportion of weight in the air of soil particles of a given volume to the weight in air of the distilled water of equal volume at 40 C in temperature.

Table 2. Specific Gravity Test Results.

Masses (g)	**Test 1**	**Test 2**	**Test 3**
Mass of density bottle + Water (Full) = *m*4	604.5	588	593.1
Mass of density bottle + Soil + Water = *m*3	635.6	618	623.3
Mass of density bottle + Soil = *m*2	358.9	304.5	315.7
Mass of density bottle = *m*1	308.9	256.5	266.7
Specific gravity	2.65	2.67	2.61
Average specific gravity (*Gs*)		2.64	

C.Atterberg limit test

Basically Atterberg limits are the three types plastic limit, liquid limit and shrinkage limit and these limits are generally used to check the fine-grained soil nature which depends upon the water content of soil and appears in four states-plastic, liquid, solid and semi-solid,in every state soil's behaviour,engineering propertis and consistency are different.

Table 3(a). Liquid Limit Results.

Test	Number of blows	Mass of wet sample (g)	Mass of dry sample (g)	Moisture (g)	MC (%)
1	48	7.7	6.9	0.8	11.59
2	28	9.2	7.3	1.9	26.03
3	22	8	6.2	1.8	29.03
4	14	8.2	6.2	2	32.26

Average MC (%) = 24.73

Table 3(b). Plastic Limit Results.

Test	Mass of wet sample (g)	Mass of dry sample (g)	Moisture (g)	MC (%)
1	1	0.9	0.1	11.11
2	1.4	1.3	0.1	7.69

AVERAGE MC (%)= 9.40

Table 3(c). Shrinkage Limit Results

Test	Initial length (L_0) cm	Final length (L_1) cm	Change in length (cm)	Shrinkage limit (%)
1	14	13	1	7.14
2	14	13.2	0.95	6.79

AVERAGE SHRINKAGE (%)= 6.97

D.Compaction test

This test is generally used to evaluate maximum dry density and optimum moisture content of soil which has been used in experiments with given additives and without additives.

Table 4. Mix Proportions Used For Tests.

S/N	Clay soil (%)	Cement (%) by Mass of Soil	Glass Powder (%) by Mass of Soil
1	100	15	0
2	100	15	1
3	100	15	2
4	100	15	5
5	100	15	10
6	100	15	15

Table 5. Summary of MDD and OMC Values at Different Additives Proportions.

	Control (15% cement)	1% glass + 15% cement	2% glass + 15% cement	5% glass + 15% cement	10% glass + 15% cement	15% glass + 15% cement
MDD (kN/m^3)	25.37	25.79	25.87	25.90	25.67	25.32
OMC (%)	16.40	15.72	15.25	14.96	14.17	14.09

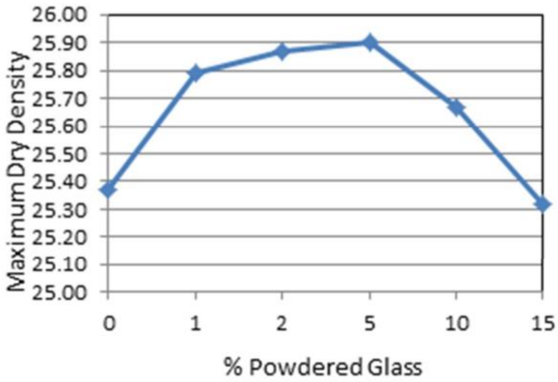

Fig. 2. Graph of Maximum Dry Density against Percentage Glass Powder.

Penetration (mm)	**5% glass + 15% cement**		**10% glass + 15% cement**		**15% glass + 15% cement**	
	Top (%)	Bottom (%)	Top (%)	Bottom (%)	Top (%)	Bottom (%)

E.California bearing ratio test

This test is mostly being performed to check the bearing capacity of subgrade strength of soil. The test is being conducted for both types of soils means compacted and natural soils under un-soaked and soaked conditions and the results were obtained and compared with the standard tests to represent the strength of the soil.The test is given in the details at [16,17].

Penetration (mm)	**Control (15% cement)**		**1% glass + 15% cement**		**2% glass + 15% cement**	
	Top (%)	Bottom (%)	Top (%)	Bottom (%)	Top (%)	Bottom (%)
5.0	89.98	88.26	94.00	89.98	88.26	94.00

Table 6(a). Summary of Unsoaked CBR

Penetration (mm)	**Control (15% cement)**		**1% glass + 15% cement**		**2% glass + 15% cement**	
	Top (%)	Bottom (%)	Top (%)	Bottom (%)	Top (%)	Bottom (%)
5.0	8.48	9.17	8.54	9.63	12.27	14.33

Values for the Clay Soil Samples

Table 6(b). Summary of Soaked CBR Values for the Clay Soil Sample

Penetration (mm)	**5% glass + 15% cement**		**10% glass + 15% cement**		**15% glass + 15% cement**	
	Top (%)	Bottom (%)	Top (%)	Bottom (%)	Top (%)	Bottom (%)
5.0	109.01	112.91	63.70	109.01	112.91	63.70

Conclusion

After so many observations which are extracted from different outputs by performing various tests it is proved that there are an improvement in clay soil properties after mixing of glass powder in it. The clay soil properties which lies between 5% and 10% by mass of soil are required glass powder in some quantity percentages for achieving best results. Since that maximum values were obtained at the glass fiber content of 5% in CBR tests and compaction tests and the maximum value for shear strength test were obtained at 10% of glass fiber content, that is why all this was possible efficiently. So it can be concluded that glass powder can be used as an effective soil strengthener or soil stabilizer because it has brought changes in various soil properties. Such as after using 5% glass powder by mass of soil bring changes in the MDD value as it became 25.90 kN/m3 from 25.37 kN/m3 and also we get the highest CBR values of 14.90% and 112.91% for both un-soaked and soaked samples and also got the maximum angle of friction value 17.0 and maximum cohesion value at 15.0 at content of glass powder of 10%.

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