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Performance Evaluation of Flexible Pavement using Glass Powder as Waste Material

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Abstract: Most of the constructed structures such as roadways, railways, water reservoirs etc. requires huge amount of soil. In most areas borrow earth is not easily available and has to be transported from a long distance. One way to overcome these problems in soils is to stabilize with admixtures; this is because such a stabilization procedure improves engineering properties of the soil such as volume stability, strength and durability. The main objective is to improve the characteristics of the available soil and make the soil capable of carrying load and to increase strength of the soil. In this study, the clay soil is modified or stabilized with powdered glass. Waste broken glass is a non-biodegradable material, which creates environmental related problem therefore its use in sub grade soil modification, will minimize the problem. In the present research, used waste glass powder i.e. stabilizer is obtained from various glass cutting and fitting shops, Gwalior, Madhya Pradesh and soil samples which are modified obtained from in between the area of Gole ka Mandir and Bada Gaon, Gwalior, Madhya Pradesh. Selecting optimum percentage i.e. 15% of cement as base by weight of soil sample mixed with various proportions of waste glass powder i.e. 1%, 2%, 5%, 10% and 15%., also by weight of soil sample and the modified soil is then studied. Various cement properties, glass properties along with Soil properties viz atterberg's limits, plasticity index, maximum dry density (MDD), optimum moisture content (OMC), California bearing ratio (CBR), Direct Shear test on a number of soil samples mixed with mixture of cement and glass powder (15 % cement & 1%-15% of glass powder) were studied and results with the non-stabilised soil was compared. Results of various tests demonstrated that the inclusion of cement and glass powder in soil with appropriate proportion improved strength and properties of soils.

Keywords: Atterberg limits, PL, LL, MDD, OMC, CBR, Direct Shear.

I. INTRODUCTION

Pavements are a conglomeration of materials. These materials, their associated properties, and their interactions determine the properties of the resultant pavement. Soil is a base of any structure, which supports the structure from the beneath and distributed the load effectively. The subgrade layer is responsible for transferring the load from the above layers to the ground. Flexible pavements are designed in such a way that the load that reaches the subgrade does not exceed the bearing capacity of the subgrade soil. Therefore, Sub grades should adequately compacted before the construction of any pavement, and sometimes to improve the subgrade strength modified by the addition of fly ash, fibers, plastic, Portland cement or other stabilizers. The length of national highways in India has increased from 70,934 km in 2010-11 to 101,011 km in 2015-16. (Annual Report 2015–16, Department of Road Transport and Highway, India).

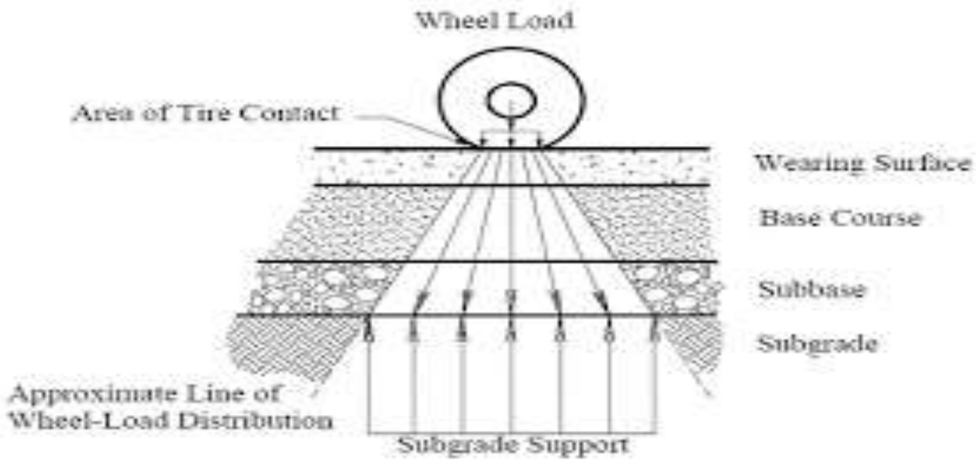

Fig 1: Components of Flexible Pavement

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Glass is a product of the super cooling of a melted liquid mixture consisting primarily of sand (silicon dioxide) and soda ash (sodium carbonate) to a rigid condition, in which the super cooled material, does not crystallize and retains the organization and internal structure of the melted liquid. Making glass needs a lot of fuel, which increases CO_2 in atmosphere, which is directly responsible for greenhouse effect (S K Patel, B Singh, 2019). When waste glass is crushed to sand like particle sizes, similar to those of natural sand, it exhibits properties of an aggregate material. The major environmental impact of glass production is caused by atmospheric emissions from melting activities (A Emersleben, M Meyer, 2014).

Glass is not Biodegradable, which is a big concern. In India, only 45% of waste glass is recycled which is very less as compared to the manufacture of glass. The waste Generation in India, according to the Press Information Bureau, India generates about 62 million tonnes of waste (mixed waste containing both recyclable and non-recyclable waste) every year, with an average annual growth rate of 4% (PIB 2016) (Published in Apr 20, 2018). About 10.2 million tons or 4.4% by weight of total waste generation comprises of glass products. This values about 68.9 pounds per person per year and 134.2 bottles per person per year.

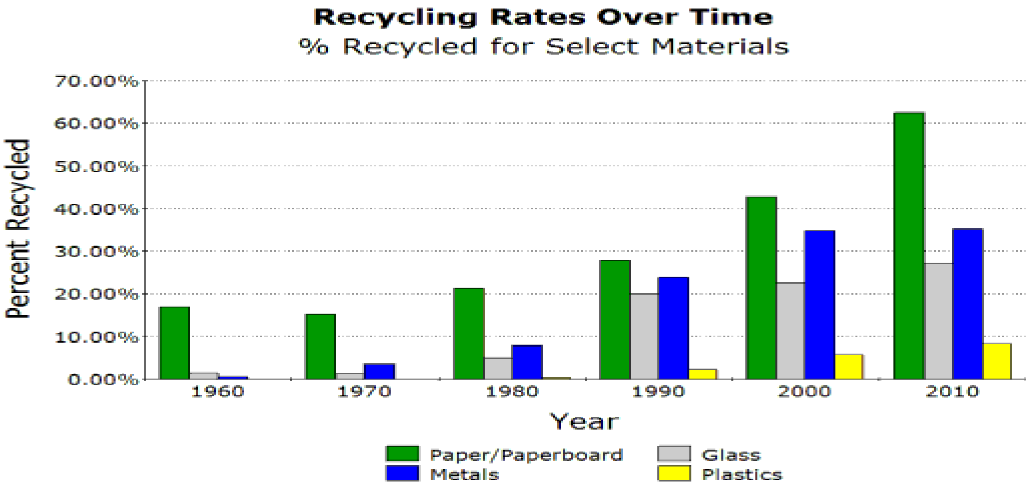

Fig 2: Percentage of Recycled Materials

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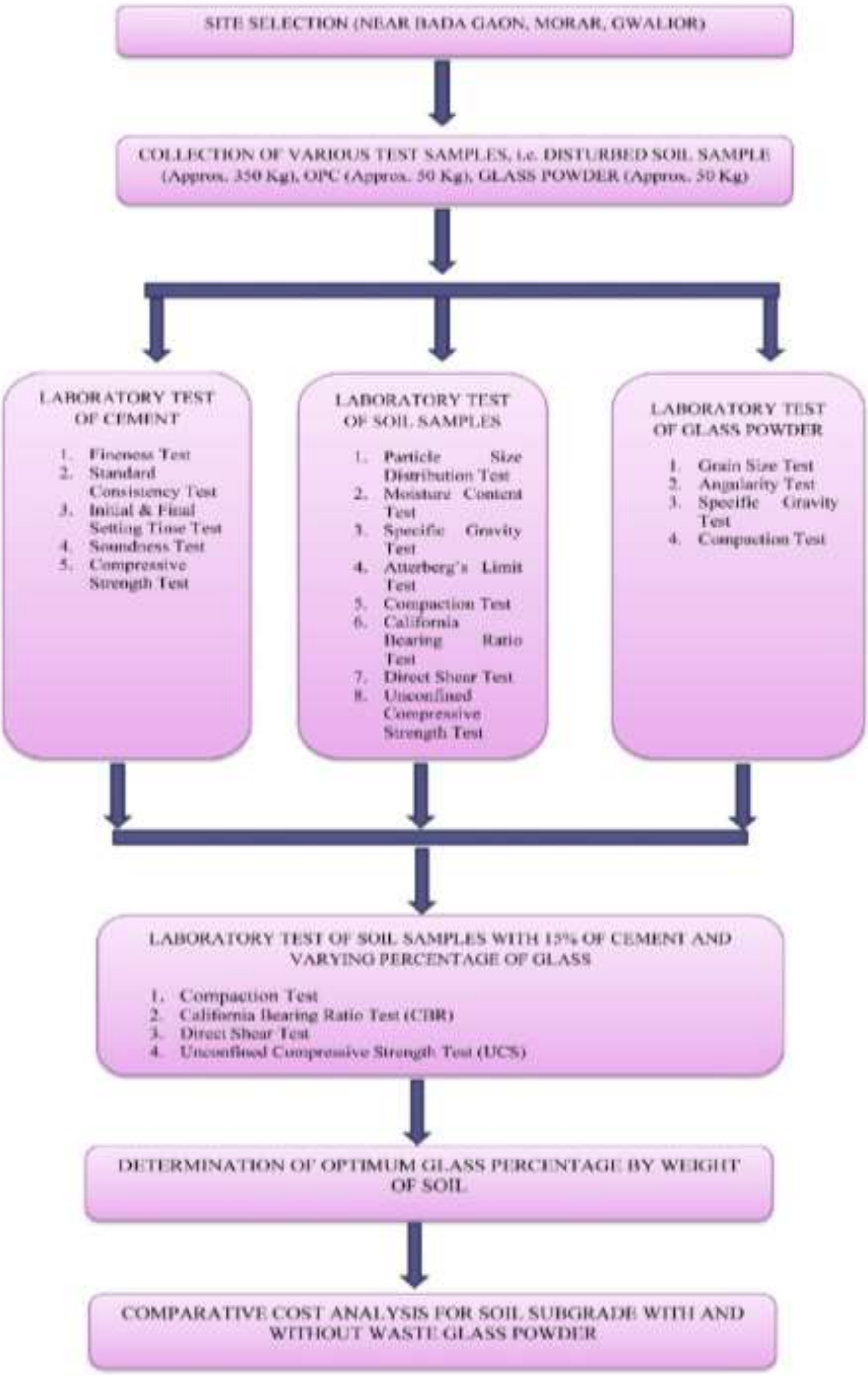

Fig 3: Detailed Methodology of Present Research

II. LITERATURE REVIEW

Gowtham S, Naveenkumar A, Ranjithkumar R, Vijayakumar P, Sivaraja M (2018):- The main objective of their study is to investigate the use of glass and plastic waste powder in geotechnical applications to evaluate the effects of glass and plastic waste powder on Specific gravity test, Atterberg limits test, Compaction test, and CBR test. The powdered glass and plastic waste powder material is added to the soil in different proportions like 2%, 4%, 6%, 8% find the percentage of which the maximum soil strength is obtained. The glass and plastic waste powder is effectively reduced and clay soil fit for pavement construction.
Rohit Singh Chauhan, Ajit Kumar, and Ankit Kumar (2015):- conducted triaxial compression tests to evaluate the effect of randomly distributed glass cullet reinforcement and cement inclusion on the response of a sandy soil to load. Glass cullets are in the contents of 0% and 3% by weight of dry soil-cement mixture. The waste glass cullet

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reinforcement increased both the peak and residual triaxial strength, decreased stiffness, and changes the cemented soil's brittle behavior to a more ductile one.

Kulkarni, V.R and Patil, G.K (2014):- studied the effect of blast furnace slag and glass fibers on certain properties of soil such as Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Differential free swell and California Bearing Ratio (CBR). The glass fiber with different length (6mm & 12mm) and proportions (0%, 0.25% 0.50%, 0.75%, 1.00% and 1.25% by weight of dry soil with optimum percentage of slag 25%) and concluded that Mixing of soil with varying percentage of slag increased CBR value from 1.27% to 3.98% for soaked condition. It was observed that CBR value increased with increment in length of fibre.

Baleshwar Singh, Shivanand Mali (2013):- stated that glass fibers (GF) can be used as aggregates in cement bound mixes and in asphalt concrete for road pavements. GF is used in various quantities (0%, 10%, 20% and 30%) combined with three amounts of Cements (3%, 4% and 5%). For road construction activities, it was found that 5% cement gave optimum values of different properties when GF content was not more than 10%.

III. MATERIAL & METHODOLOGY

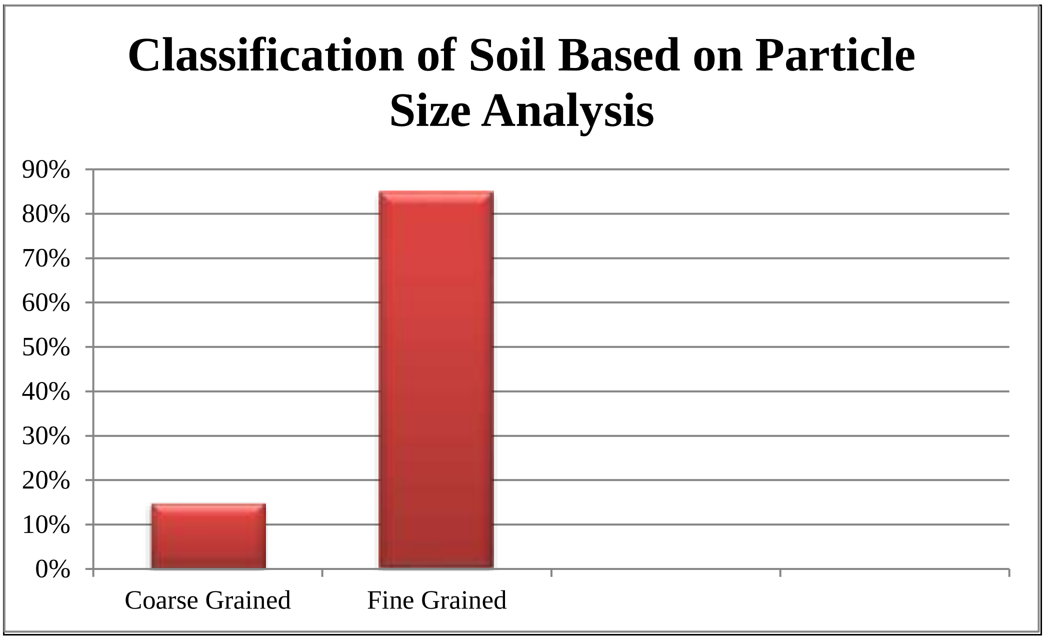
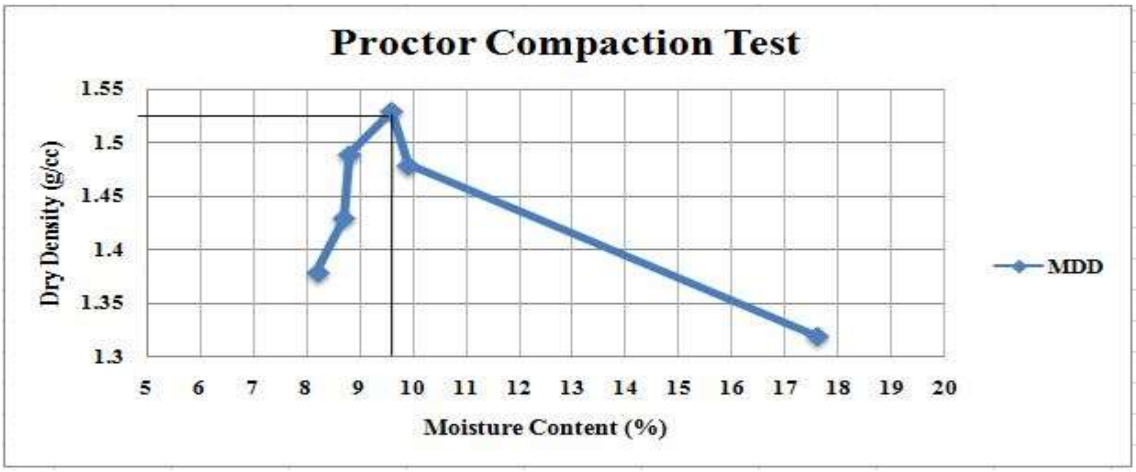


Fig 4: Soil Classification Based on Particle Size DistributionFig 5: Results of MDD and OMC for Test Pit



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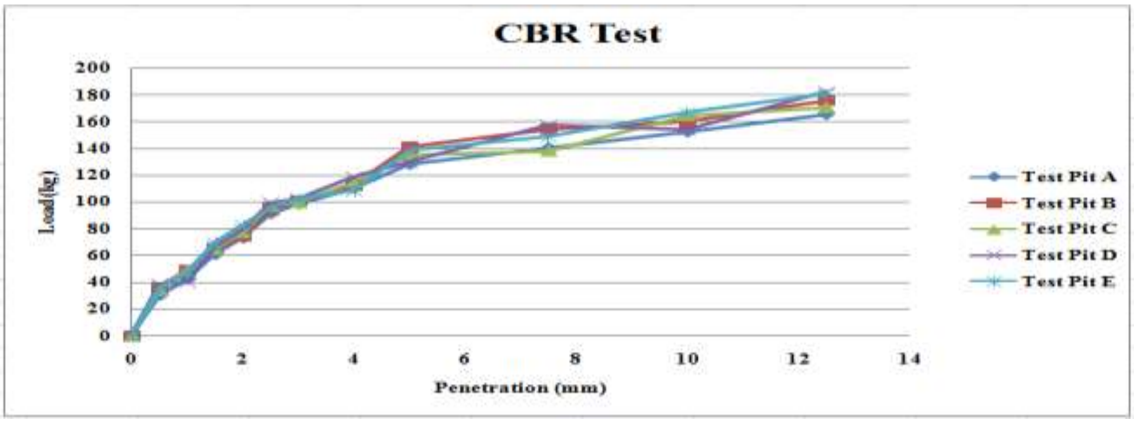

Fig 6: CBR Test Results for Test Pits A to E

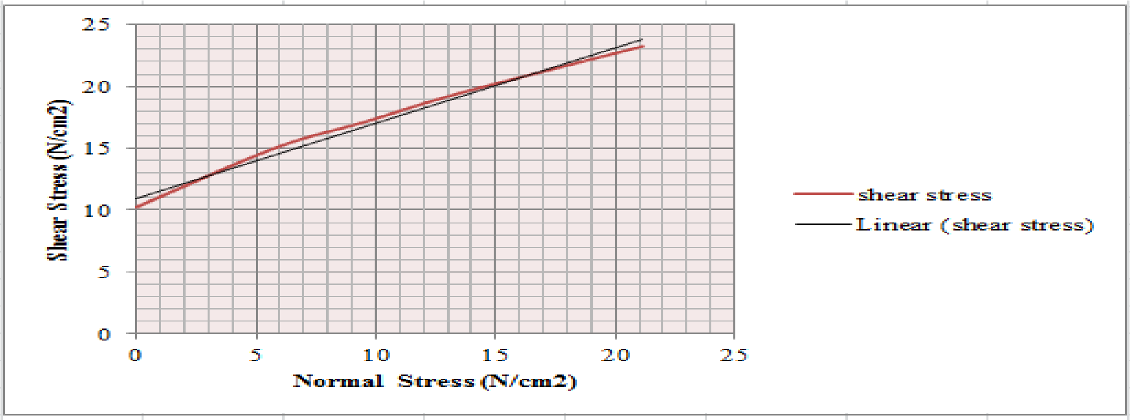

Fig 7: Shear Stress Graph for Test Pit A

Φ and C values were determined in the same manner for all the test pits the average value of φ and C was found to be 29.656 Degree and 11.676 respectively, which is taken as final value for the unstabilized soil.

Table.1 Summarized Engineering Properties of Soil

S. No.	Property	Value (Calculated)	Relevant IS Codes
1	Classification of Soil	CL	IS:1498-1970
2	Specific Gravity	2.65	IS:2720 Part III-1980
3	Liquid Limit (Mean Value)	28.87%	IS:2720 Part V-1985
4	Plastic Limit (Mean Value)	15.57%	IS:2720 Part V-1985
5	Plastic Index (Mean Value)	13.27%	IS:2720 Part V-1985
6	Maximum Dry Density	1.44g/cc	IS:2720 Part VII-1983
7	Optimum Moisture Content	10.46 %	IS:2720 Part VII-1983
8	California bearing ratio (Soaked)	6.82 %	IS:2720 Part XVI-1987
9	Direct Shear Value	φ=29.656Degree C = 11.676	IS:2720 Part I-1983

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Table. 2 Properties of Waste Glass

S.No.	Property	Detail
1.	Grain Size	Test showed that the waste glass powder sample comes under fine grained category
2.	Angularity	Angular Size ~ 01
3.	Specific Gravity	2.51 g/cc
4.	Maximum Dry Density	1.796≈1.8 g/cc
5.	Optimum Moisture Content	6.16 %

Table.3 Summarized Properties of Cement

S. No.	Property	Value (Calculated)	Relevant IS Codes
1	Fineness of Cement	8.233%	IS:4031 Part I-1996
2	Standard Consistency	28%	IS: 4031 Part IV-1988
3	Initial Setting Time	31 minutes	IS: 4031 Part V-1988
4	Final Setting Time	620 minutes	IS: 4031 Part V-1988
5	Soundness Value	2.8 mm	IS: 4031 Part III-1988

In the set of samples, after testing it is found that excess amount of cement can badly affect the properties of soil. After testing it is determined, that 15% cement is suitable for soil sample.

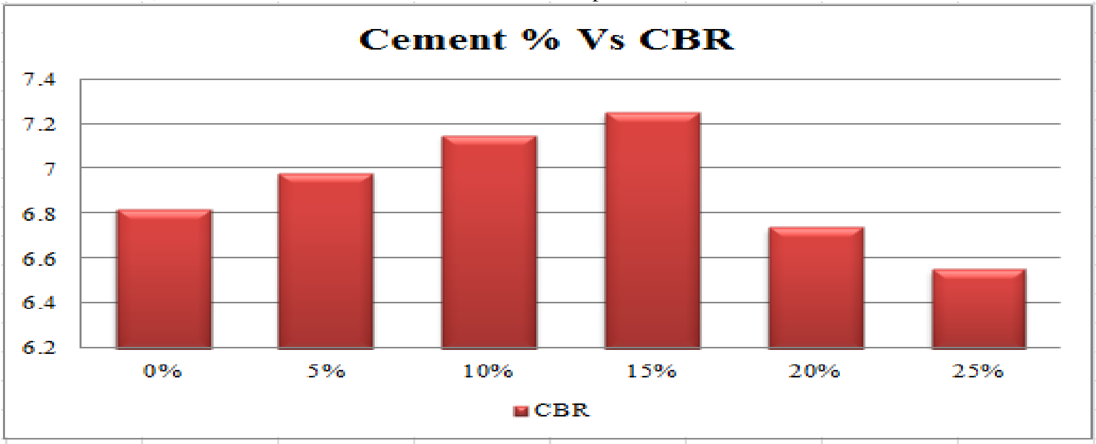

Fig 8: Cement Percentages vs. CBR

Table.4 Soil Sample Distribution

S. No.	Soil Sample (%)	Cement Content (% by weight of soil)	Powdered Glass (%) by weight of soil
1	85	15	0
2	84	15	1
3	83	15	2

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4	80	15	5
5	75	15	10
6	70	15	15

IV. RESULT & DISCUSSION

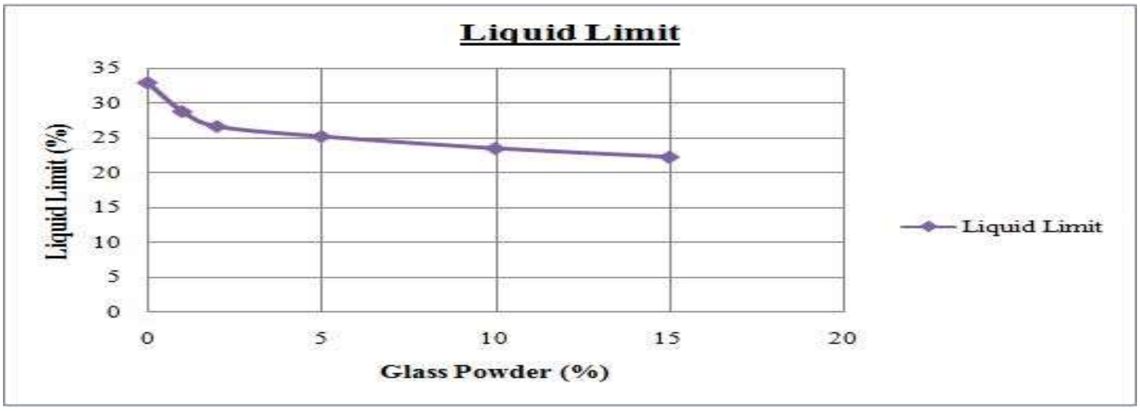

Fig 9: Variation of Liquid Limits with Soil mix

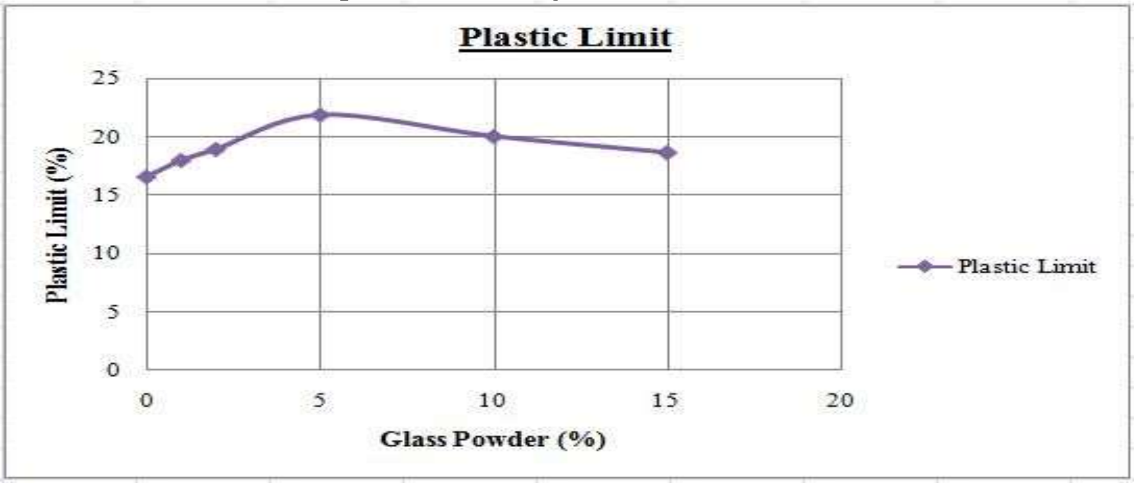

Fig 10: Variation of Plastic Limits with Soil mix

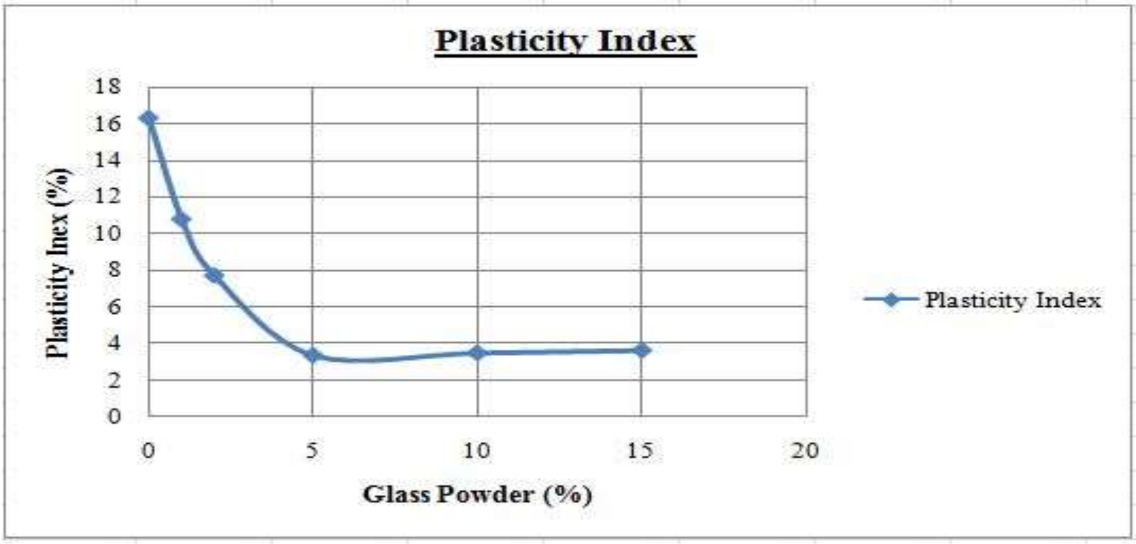

Fig 11: Variation of Plastic Indices with Soil mix

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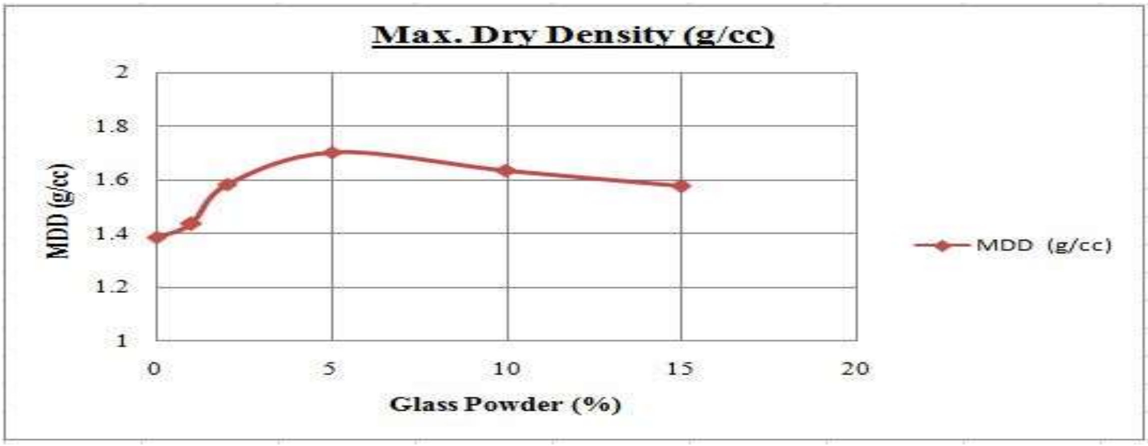

Fig 12: Variation of MDD with Soil mix

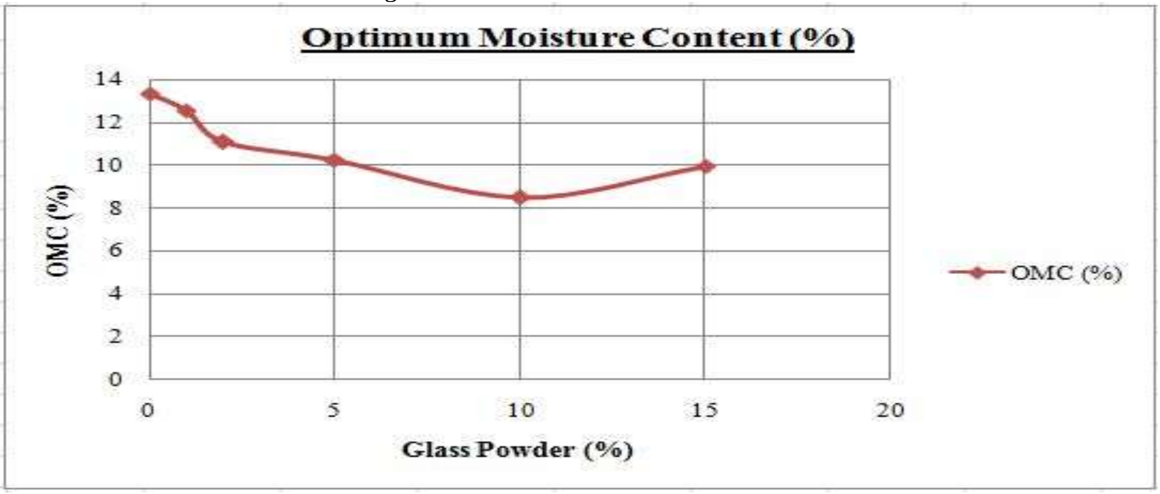

Fig 13: Variation of OMC with Soil mix

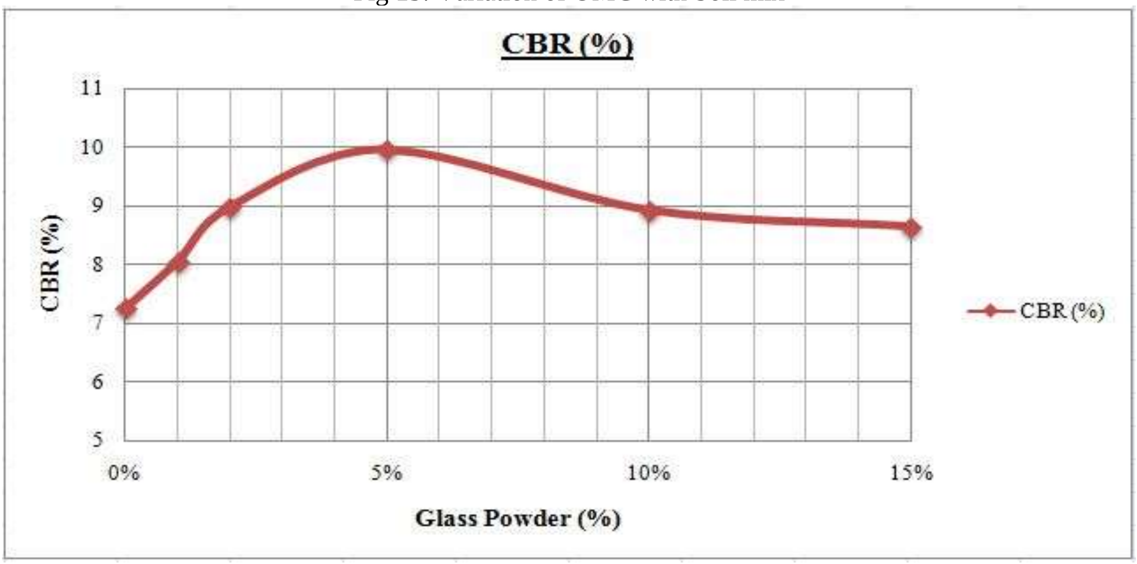

Fig 14: Variations of CBR Values with Soil Mix

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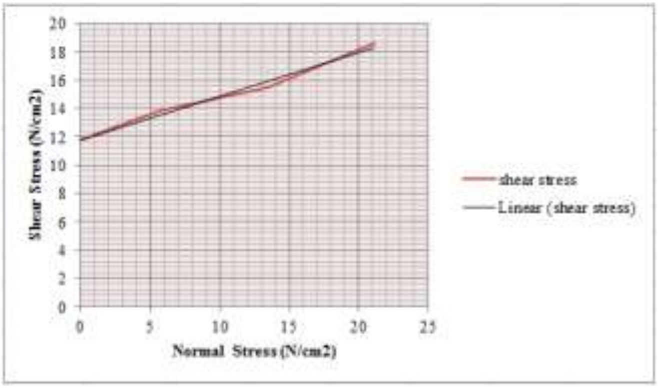

Fig 15: Shear Stress vs. Normal Stress Curve for Soil Mix I (Soil + 15% Cement)

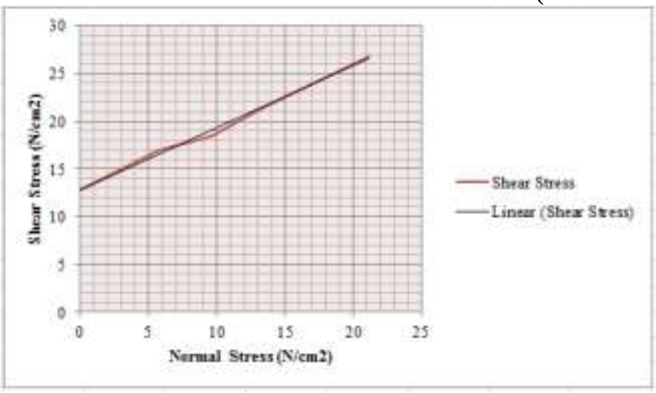

Fig 16: Shear Stress vs. Normal Stress Curve for Soil Mix II (Soil + 15% Cement + 1% Glass Powder)

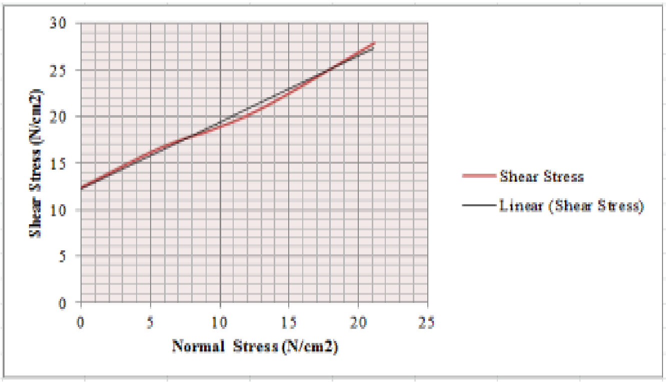

Fig 17: Shear Stress vs. Normal Stress Curve for Soil Mix III (Soil + 15% Cement + 2% Glass Powder)

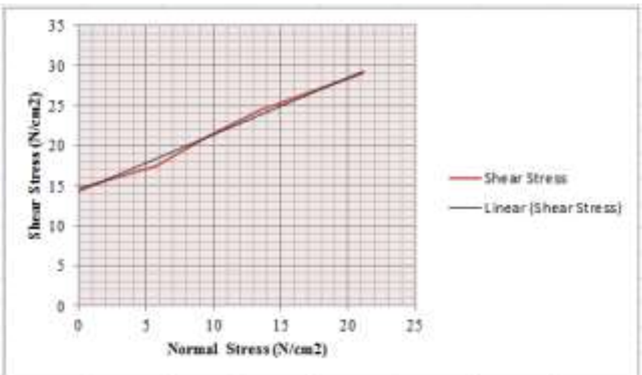

Fig 18: Shear Stress vs. Normal Stress Curve for Soil Mix IV (Soil + 15% Cement + 5% Glass Powder)

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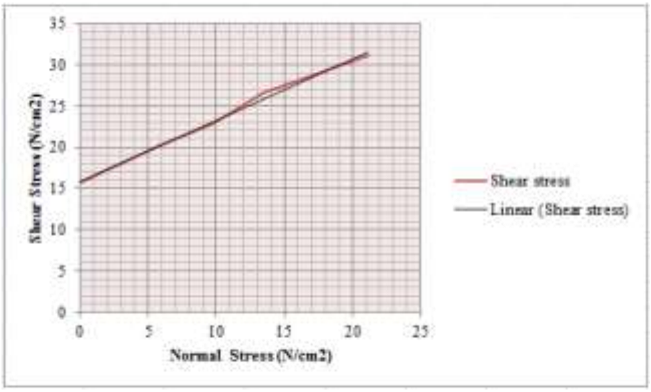

Fig 19: Shear Stress vs. Normal Stress Curve for Soil Mix V (Soil + 15% Cement + 10% Glass Powder)

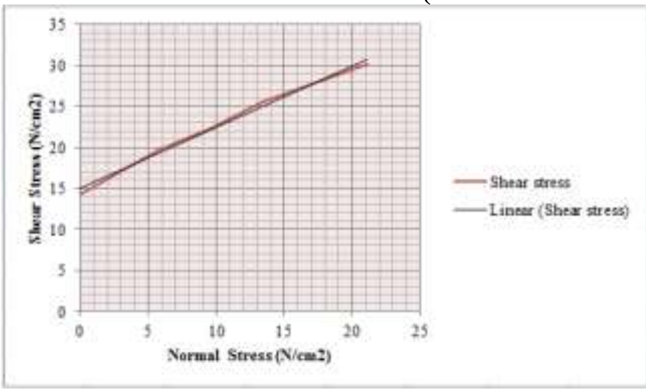

Fig 20: Shear Stress vs. Normal Stress Curve for Soil Mix VI (Soil + 15% Cement + 15% Glass Powder)

Table 5: Values of Φ and C for Different Soil Mix

S. No.	Soil mix No.	Soil mixes	Φ (Degree)	C (Kg/cm^2)
1	Soil mix I	85% Soil + 15% Cement + 0% GP	16.79	11.819
2	Soil mix II	84% Soil+ 15% Cement + 1% GP	32.26	12.874
3	Soil mix III	83% Soil + 15% Cement + 2% GP	33.75	12.325
4	Soil mix IV	80% Soil + 15% Cement + 5% GP	36.44	14.387
5	**Soil mix V**	**75% Soil+ 15% Cement + 10% GP**	**36.73**	**15.812**
6	Soil mix VI	70% Soil+ 15% Cement + 15% GP	36.21	14.697

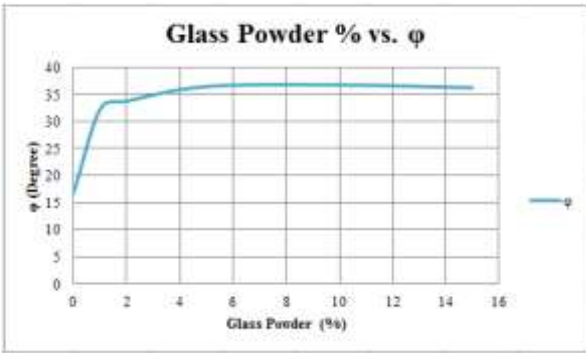

Fig 21: Curve between Varying Percentage of Glass Powder and Angle of Internal Friction

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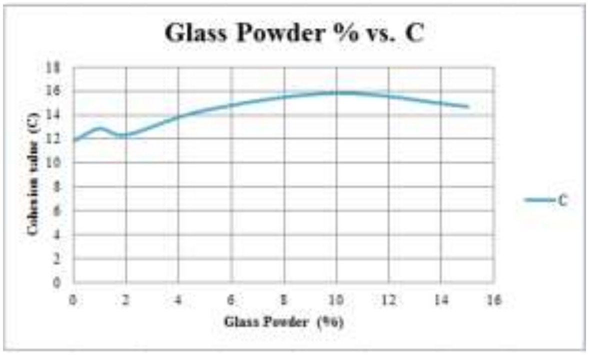

Fig 22: Curve between Varying Percentage of Glass Powder and Cohesion Value

V. CONCLUSIONS

- From proctor compaction tests, keeping cement 15% with increase in percentage of Glass powder, it is found that MDD increases that shows a good cohesive matrix between the finer clay and silt particles and the coarser glass particles. Whereas OMC decreases due to less moisture absorption of glass powder.
- CBR values have shown a mixed nature. CBR values of soil samples observed to be increasing with the increasing percentage of glass powder (up to 5 %) & keeping cement 15% because of reinforcement, further increasing percentage of glass powder and fixed percentage of cement shows a decrease in CBR in soaked conditions. This nature of the mix with respect to CBR values shows cementations nature of waste mix by the virtue of which particles attains strength under the action of moisture.
- In this study made with the collected samples of waste mix and soil, optimum mix was found to be 80:15:5 (Soil: Cement: Glass Powder) owing highest value of CBR of 9.96% in comparison to unreinforced soil with CBR of 6.82%.

VI. FUTURE SCOPE

- Waste glass powder can be used for future constructions so that a high strength of soil sub grade with very low cost stabilization can be achieved maintaining economic conditions.
- This investigation was carried out in locally available soil; there is a scope to study behavior of soils using optimum mixing of waste glass powder in other soils also.
- As waste glass powder is solid non-biodegradable waste, therefore using them as soil sub grade modifier will reduce environmental pollution in its high production areas.

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