JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

ENHANCING SUBGRADE STRENGTH OF RIGID PAVEMENTS WITH FLY ASH, CHICKEN MESH, BAMBOO FIBER AND PLASTIC WASTE: A COMPREHENSIVE ANALYSIS

Arige Pradeep [1], M.Harish Kumar[2]

[1]PG Student, Civil Department,Holymary Institute Of Technology And Science,Hyderabad.

[2]Assistant Professor, Civil Department ,Holymary Institute Of Technology And Science,Hyderabad.

ABSTRACT:Because it forms the bedrock upon which the pavement is built, the subgrade plays a pivotal role in the design of flexible road projects. Pavement construction must, therefore, be carried out and evaluated with the utmost care. There is a lot of clay and silt in the expanding soils. Stabilising or compacting the soil subgrade is an essential step in constructing a flexible pavement. The subgrade soil can be replaced with an alternate substance to stabilise these soil types. Fly ash is now being utilised at a rate of about 55%. It is an industrial waste product. Substituting fly ash into the subgrade in various amounts and with chicken mesh coated with bitumen can be a useful use for the fly ash. Adding bitumen-coated chicken mesh for additional reinforcement greatly improves the California bearing ratio. The investigation involves compressing fly ash samples to their maximum dry density while maintaining the ideal moisture level. The samples are subsequently placed in the CBR mould under two distinct circumstances: one which involves chicken mesh layers and another which does not, as well as bamboo meshes covered with bitumen. The chicken mesh's proportions match those of the CBR mold's plan view. Following steps 1, 2, 3, and 4, the chicken mesh was placed into each layer. Lab testing determines CBR values; four layers of bitumen-coated chicken mesh, which accounts for 15% of the fly ash, yields the greatest CBR value, suggesting good mechanical capabilities. The soil's moisture content is reduced by partially replacing it with plastic rubbish. Soil samples were prepared by mixing different amounts of plastic trash with the soil for this investigation. Afterwards, the original, unaltered soil is compared to the calculated values of optimum moisture content (OMC), maximum dry density (MDD), unconfined compressive strength (UCS),and CBR).

Introduction:Overview Fly ash is a byproduct of thermal power facilities' usage of suspension fueled furnaces to burn pulverised coal. Fly ash gets its name from the fact that, when dry, it has a very fine texture that allows it to float effortlessly through the air. Mineral particles or broken rock that fills the spaces between coal seams make up the bulk of coal ash. Prior to their release into the environment, mechanical collectors or electrostatic precipitators remove fly ash, a small particle that remains in hot flue gases. One group of substances that fly ash belongs to is the Pozzolanas. Pozzolana, a silicious substance, lacks setting qualities when mixed with water alone but can set with calcareous materials, giving it strength. The Italian hamlet of Pozzolana is the origin of the term "pozzolana" because it was there that this particular type of volcanic ash was found. There is no one chemical formula or method for making fly ash. The primary constituents of fly ash, an alkaline substance with a fine texture and a grey colour, are non-crystalline spherical particles. Other components include microcrystalline material, free lime, and unburned carbon. When ionised, it can release a number of positively charged ions, including Ca^{2+} and Al^{3+}. Because of the cation exchange that occurs, the clay particles that are distributed are encouraged to clump together. Nearly 45 well-known thermal power plants spread out around the nation produce almost 10 million metric tonnes of fly ash every year. As more and more low-grade coals with high ash content are used to generate power at a lower cost, the building of super thermal power plants is expected to drive up the yearly production of fly ash to approximately 100 million tonnes by the year 2000. Near thermal power stations, fly ash dumps take up a lot of good land. Mehndiratta h.c. and Ramlal estimate that the national exchequer will spend 50 crores rupees per year even if the disposal cost is a pitiful 5 rupees per metric tonne. The importance of efficiently and quickly using fly ash has been recognised as a national concern. As a result, we must spare no effort in our pursuit of the most efficient use of this substance. Geotechnical, environmental, hydrological, and other regulatory factors must be taken into account during the establishment of an ash disposal site. Previous studies have helped us understand how fly ash can be used in cement concrete and brick making, but we still don't have a full picture of the geotechnical considerations when mixing fly ash with black cotton soil for engineering projects. In this paper, we look at the geotechnical properties of fly ash and mixtures of fly ash and soil. Pulverised coal, when burned, produces a finely divided residue known as fly ash. Because of its strong pozzolanic characteristics, it is taken out of the combustion chamber by the exhaust gases. In 2017, the total amount of fly flotsam and jetsam shipped was 166 million metric tonnes, which is equivalent to 171 million tonnes. Power stations that burn coal and use steam or electricity produce fly ash and bottom ash as waste materials. Coal is usually ground and mixed with air before being blown into the furnace's combustion chamber. As soon as it lands, the coal instantly burns, creating heat and a constant mineral residue. The vent gas is cooled because pot tubes allow heat to be transferred from the radiator. Epoxy resin and solid waste are both enhanced by this process in the mineral fluid.

The heavier compartment collects larger waste particles (coarse debris or slag) which settle to the bottom, while the lighter ones (fly debris) continue to float in the vent gas. Before the gas line is compromised, free release control methods like electrostatic precipitators or fabric filter baghouses are used to remove airborne debris. The primary use of fly ash in concrete mixes including Portland cement is as a pozzolanic ingredient. The materials have a finely separated structure and are made of alumina and silica. They create cement mixtures when exposed to water and calcium hydroxide ($Ca(OH)_2$) at room temperature. Hot mix asphalt benefits from the table's round form, compact size, and mobility as a mineral additive. It makes liquid fillers and grouts smoother.

Figure 1: Fly Ash

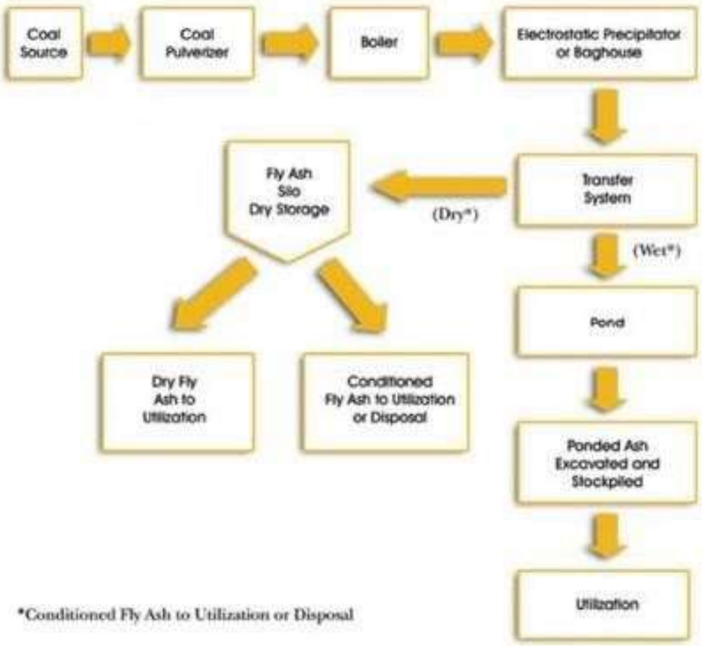


Figure 2: Utilization of Industrial Fly Ash

Literature Review: It is well-known that sweeping sediments can cause significant damage to fragile structures like homes and road pavements. Damage to roads constructed on expansive soil subgrades is an expensive affair, with a global cost estimated in the billions of dollars. Treatment evaluations for lime correction, soil restoration, and moisture regulation can vary. Both the 1996 study by Bansal et al. and the 1976 study by Robneet looked at various degrees of achievement. But, there are some limitations to how flexible these strategies are. For example, it takes a long time to initially wet very plastic soil, it's hard to set up the best moisture barriers, it's hard to mix and compact lime-modified soil, and it's expensive to get good soil to replace it. According to Rao (1996), scientists have identified favourable circumstances for utilising geosynthetics in structural building. Prior research mostly concentrated on two areas: the asphalt overlay interface (Button, 1989; Pradeep Kumar, 1995) and the usage of geosynthetics as a separator between the asphalt sub level contact (Jorenby and Hicks, 1986; AL Qadi and Bhutta, 1999). On the other hand, there have been a handful of instances where geo synthetics were used to reinforce one of the pliable asphalt layers that are laid over traditional, non-expanding subgrades (Hass et al, 1988). Asphalt, soil modification, and waste fill liners are just a few of the geotechnical uses of fly ash that have been documented by Pandian (2003) and Chia-Chia et al. (2003). Prasada Raju (2001) found that when geo matrix, Bitumen Coated Chicken mesh, and Bamboo mesh were added to the sub layer course, the load-bearing capability of the flexible asphalt system on expansive soil subgrades was significantly increased. Fly ash is being used in place of bond in concrete, say Bhavana and Shah (2001). Using fly ash in place of cement has several benefits, the most notable of which is an improvement in strength. When building banks or filling and refilling the granular layer in the sub base course, base debris and lake debris can be useful (Guruvittal and Murthy, 1998). One hundred and eighteen Customers in the construction business, including those in the concrete, road, and other development sectors, can be supplied with the small particles, also called dry debris (Murthy, 1998; Guruvittal and Murthy, 1998). In the near future, most structural engineering difficulties might be solved using the fortified earth technology, say specialists Rao (1996) and Dembichi and Jermolowietz (1988). Using reinforced fly ash as a prototype, Krishna Swamy and Santhosha Rao (1995) performed experimental tests on embankments. According to Anderson et al. (1995) and Hausmann (1990), this method has been used to build retaining walls, flyovers, bridge abutments, embankments, and foundations for big storage tanks. Research by Lindh and Eriksson (1991) indicated that fibre reinforced sand improved asphalt's strength and durability when used in road building. When laying asphalt over a foundation of loose soil, Dresher et al. (1991) discovered that using old tyres in the sub base/street base improved rubbish disposal. Asphalt performance has been improved in recent years with the use of the fortified earth system, which effectively addresses subgrade and other issues (Hass et al., 1988). When building dikes and filling in areas behind retaining walls for restoration,Digioia and Nuzzo (1972) primarily used fly detritus as a material. The engineering qualities of compacted soils were improved by adding fly ash, as Phani Kumar and Radhey noted. As the amount of fly ash grew, they also saw that the soil's fluidity decreased and its strength increased. As the quantity of fly debris rose relative to the water content, the efficacy in preventing mixture entry improved dramatically. There have been recent successful laboratory tests evaluating the efficacy of fly ash as a foundation layer in flexible asphalt construction. Soil replacement, pre-wetting, moisture control, and lime adjustment are some of the restoration approaches that specialists have tried in the past, with mixed results. Considerable time and effort is needed to pre-wet extremely plastic soils (Felt, 1953); there are challenges in building effective moisture barriers (Snethen et al., 1975); problems with deterioration and mixing when lime adjustment is involved (Ramana Murty, 1998); and so on, all of these strategies have limitations in terms of their practicality. Also, in areas where the thick layers of dirt go deep under the asphalt, these alternatives might be very difficult to implement. Under these conditions, it's smart to look at mechanical adjustment options. The use of geosynthetics as building materials for highways, retaining walls, landfills, and other civil engineering projects has been on the rise since the 1970s. There is a vast variety of geosynthetic products on the market today. One of the five uses for geosynthetics is separation; the others are reinforcement, filtration, drainage, and containment (Kwon, 2007). In many cases, the longevity and resilience of asphalt structures can be improved with the use of geosynthetics.

Methodology:Topsoil One To find the maximum dry density and acceptable moisture level, this study conducted compaction experiments with different percentages of fly ash substitutes. The following table details the outcomes:

Table 3-1: OMC & MDD of Modified Soil with variations in Fly ash content and CBR values of same

S.No.	OMC (%)	MDD (%)
Unmodified soil	20.8	1.51
Soil + % fly ash		
Soil + 5	22.1	1.46
Soil + 10	29.2	1.42
Soil + 15	26.3	1.52
Soil + 20	25.5	1.425

Additionally, the fly ash component with the highest dry density was taken into account for future research. The protocol was followed in accordance with the IS code to conduct the CBR testing. Various layers of chicken wire coated with bitumen were inserted into the specimen. The chicken mesh was inserted in each of the four layers of the 150 mm x 128 mm CBR mould, starting at the 1, 3, and 2 locations and working its way through each layer. The CBR values of the chicken mesh were recorded in both the drenched and unsoaked tests.

Sample 2 of Soil 3.2 The present study determined the optimal moisture level and maximum dry density by conducting compaction tests with varied percentages of fly ash replacements. The following table details the outcomes:

Table 3-3: OMC & MDD of Modified Soil with variations in Fly ash content and CBR values of same

S.No.	OMC (%)	MDD (%)
Unmodified soil	20.24	1.47
Soil + % fly ash		
Soil + 5	22.36	1.44
Soil + 10	27.84	1.38
Soil + 15	24.12	1.48
Soil + 20	23.10	1.42

Additionally, the fly ash component with the highest dry density was taken into account for future research. The protocol was followed in accordance with the IS code to conduct the CBR testing. The specimen was layered with the bitumen- coated bamboo mesh. The CBR mould, which has a diameter of 150 mm and a height of 128 mm, is divided into four layers. The bamboo mesh is inserted into each layer separately, at the 1, 3, and 2, 4 positions, and then into every layer again. The CBR values of each layer were recorded in both the soaked and unsoaked tests.

Table 3-4: CBR Values of Soaked and Unsoaked samples with Different Field conditions

S.No.	CBR Value (%)	
	Unsoaked	Soaked
Unmodified soil	5.9	4.12
Modified soil	6.12	4.33
First layer	6.2	4.54
Second layer	6.14	4.28
Third layer	6.01	4.18
Fourth layer	5.94	4.09
1st and 3rd layers	6.18	4.51
2nd and 4th layers	6.39	4.82
1,2,3,4th layers	6.91	5.01

3.3 Soil Sample-3 In this study, we tested different percentages of plastic waste replacements in compaction experiments to find the optimal moisture content and greatest dry density. The following table details the outcomes:

Table 3-5: OMC & MDD of Soil with Plastic Waste replacement

S.No.	OMC (%)	MDD (%)
Unmodified soil	16	1.61
Soil + % plastic waste		
Soil + 0.2	15.32	1.68
Soil + 0.4	14.5	1.75
Soil + 0.6	14.2	1.81
Soil + 0.8	14.8	1.86
Soil + 1	15	1.91
Soil + 1.2	16.2	1.8

Table 3-6: CBR & UCS values at different Percentages of Plastic Waste

S.No.	CBR (%)	UCS (MPa)
Unmodified soil	2.92	0.15
Soil + % Plastic Waste		
Soil + 0.2	3.08	0.152
Soil + 0.4	3.14	0.159
Soil + 0.6	3.22	0.165
Soil + 0.8	3.89	0.174
Soil + 1	4.11	0.178
Soil + 1.2	3.86	0.162

Material used:Section 4.1: Soil 1 4.1.1 Ground The dirt used in this study was dug from a depth of less than one metre on the outskirts of Hyderabad. After being dried, the soil was passed through a 4.75 mm IS size sieve; this will aid in future investigations. The dirt that was collected and passed through a sieve with a mesh size of 425 microns was used to determine the Liquid Limit and the Plastic Limit. The table below shows the geotechnical qualities of soil.

:

Table 4-1: Geotechnical properties of natural unmodified soil

S.No.	Composition	Values
1	Sand (%)	16.2
2	Silt (%)	20.3
3	Clay (%)	63.5
4	Specific Gravity	2.71
5	Liquid Limit (%)	56.6
6	Plastic Limit (%)	27.2
7	Plasticity Index (%)	29.4

4.1.1 Fly ash for Sample-1 Coal, the primary fuel for power generation, produces fly ash as a byproduct of combustion. The most recent data shows that only around half of the fly ash produced is actually used for building and other general purpose purposes in our nation. The ecosystem is facing a plethora of challenges as the remaining 45% is apparently discarded without usage. It has recently come to light that soil stabilisation through the substitution of fly ashes in subgrade has greater significance. Previous research has shown that reinforcing subgrade increases pavement strength and durability. The following table provides the details of the experimental work that used fly ash, which was procured from a nearby vendor.

.

Table 4-2: Chemical composition of fly ash

S.No.	Chemical Composition	Mass (wt %)
1	Al_2O_3	16.8
2	SiO_2	62.32
3	Fe_2O_3	6.40
4	CaO	6.43
5	MgO	3.44
6	SO_3	1.12
7	Loss on Ignition	3.49

The chicken mesh obtained from the dealer is coated with bitumen which is heated atabout 150 centigrade temperature and two coats are applied on the entire chicken mesh for stiffness purpose.

Table 4-3: Properties of Chicken Mesh

Properties	Units
Mass	210 Gms/m^2
Tensile Strength	8 KN/m
A.O.S.	<75 m
Roll Width	4 mts

4.2 Soil Sample-2 4.2.1 Soil The current soil sample was taken one metre below the permissible ground level, left to dry, and then passed through an IS sieve to make it suitable for testing. Below are the tabulated results of the soil properties tests.

Table 4-4: Geotechnical properties of unmodified soil

S.No.	Property	Values (%)
1	Sand	15.8
2	Silt	22.4
3	Clay	61.8
4	Specific Gravity	2.68
5	Liquid Limit	54.32
6	Plastic Limit	28.16
7	Plasticity Index	26.16

4.2.1 Fly ash for Sample-2

It is an industrial byproduct or waste obtained from power generation plants. As per recent estimation, nearly half of the fly ash produced seems to be useless. So, fly ash can be used as a partial replacement of sub-grade through which California bearing ratio of material is increased which in turn reduces the settlement in expansive soils. The present fly ash used was obtained from a local dealer with chemical composition tabulated as below:

Table 4-5: Chemical composition of fly ash

S.No.	Chemical Composition	Mass (wt %)
1	Al_2O_3	17.6
2	SiO_2	61.32
3	Fe_2O_3	5.99
4	CaO	6.88
5	MgO	3.69
6	SO_3	1.34
7	Loss on Ignition	3.38

4.2.2 Bamboo coated Bitumen

The bamboo is covered with bitumen and applied in two coats to expand the coupling property of the dirt.

Table 4-6: Bamboo Mesh Properties

Properties	Units
Mass	330 Gms/m^2
Tensile Strength	12 KN/m
A.O.S.	<75 m
Roll Width	6 mts

4.3 Soil Sample-3

4.3.1 Soil

The dirt example for present investigation was gathered in the edges of Hyderabad, beneath 1 meter profundity starting from the earliest stage. The acquired soil was dried and later permitted to go through 4.75mm IS sifter and the dirt went through it was utilized for examination. The dirt went through 425 microns strainer was utilized for count of fluid farthest point and plastic utmost. The geotechnical values of soil are displayed in the below Table.

Table 4-7: Geotechnical properties of Natural Unmodified soil

S.No.	Property	Values (%)
1	Sand	17.2
2	Silt	20.8
3	Clay	6.2
4	Specific Gravity	2.67
5	Liquid Limit	55.30
6	Plastic Limit	28.10
7	Plasticity Index	27.20

4.4 Plastic Waste

The plastic waste, for example, convey sacks, cups, disposables, and so forth are destroyed in the destroying machine and subsequently fall in various rates with the totals. Obtained subtleties of the procedure are available underneath.

Squander pieces are destroyed under the way toward cutting plastic into little size pieces between 2.36 mm - 4.75 mm with the assistance of plastic destroying machine.

Table 4-7: Geotechnical properties of Natural Unmodified soil

S.No.	Property	Values (%)
1	Sand	17.2
2	Silt	20.8
3	Clay	6.2
4	Specific Gravity	2.67
5	Liquid Limit	55.30
6	Plastic Limit	28.10
7	Plasticity Index	27.20

4.4 Plastic Waste

The plastic waste, for example, convey sacks, cups, disposables, and so forth are destroyed in the destroying machine and subsequently fall in various rates with the totals. Obtained subtleties of the procedure are available underneath.

Squander pieces are destroyed under the way toward cutting plastic into little size pieces between 2.36 mm - 4.75 mm with the assistance of plastic destroying machine.

4.5 Delicate Aspects of Shredding Equipment A "scrap grinder" is used for the destruction of polyethylene. The process involves using rotating cutting blades to shred plastic waste into small bits. About thirty minutes is all it takes to complete the treatment. As it shed, the melted plastic rained down on the heated total, covering it completely. Various levels of plastic were used to alter the coating. The qualities of totals are expanded when the level of plastic increases. There are many other types of plastic trash on the market; however, the non- degradable plastic trash is being used in this project. 4.6 Pavement coating One common type of fastener used in construction is bitumen. Its main source is the byproduct of oil processing plants, which are emptied out after higher components such as petrol, diesel, oil, etc. are removed. Bitumen is defined by the International Standards

Soil Sample-1:

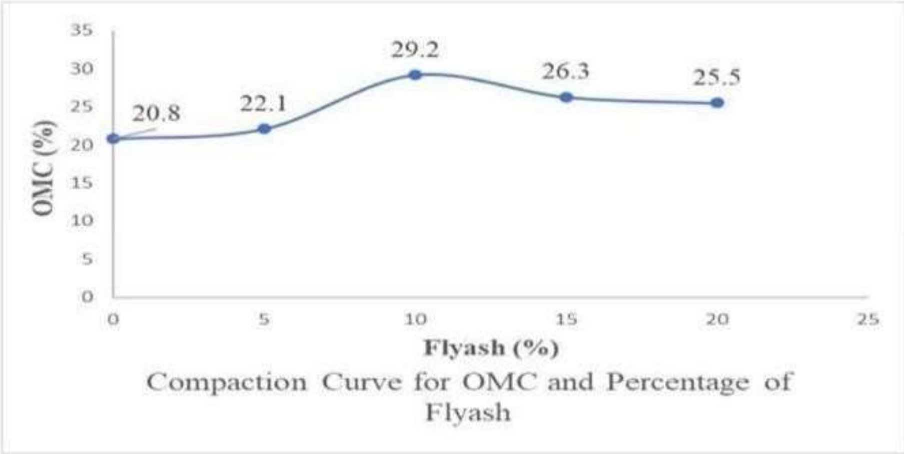


Figure 7.1: Compaction Curve for OMC and Percentage of Fly Ash

Based on the test details, the impact of fly ash used on soil with respect to OMC, MDD and the influence of bitumen coated ***chicken mesh*** on the CBR values is graphically represented as above.

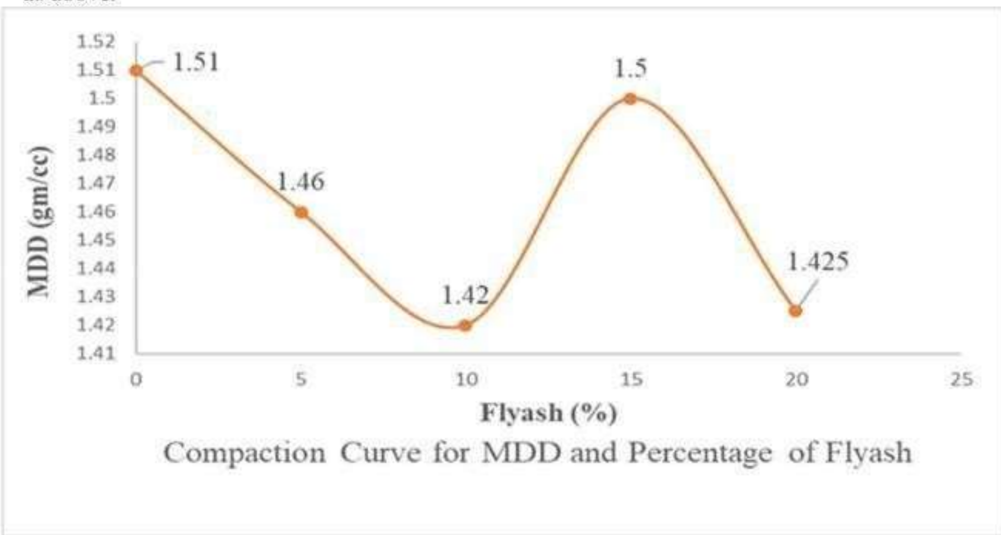


Figure 7.2: Compaction Curve for MDD and Percentage of Fly Ash

A water content of 20.8% is determined to be optimal for the natural material. The OMC value goes up from 22.1 to 26.3 for 5% to 15% fly ash replacements as the fly ash content is up. This suggests that a substantial quantity of moisture is needed to cover the particles with one another. Currently, the MDD value of the soil is
1.51g/cc. The measured dry density value is lower than the soil's when the fly ash content is increased from 5% to 20%. Because fly ash has a lower specific gravity value, this is the result. The results show that under 15% replacement, the high west dry density is 1.50g/cc. It follows that the value is taken into account for subsequent permissible CBR testing.

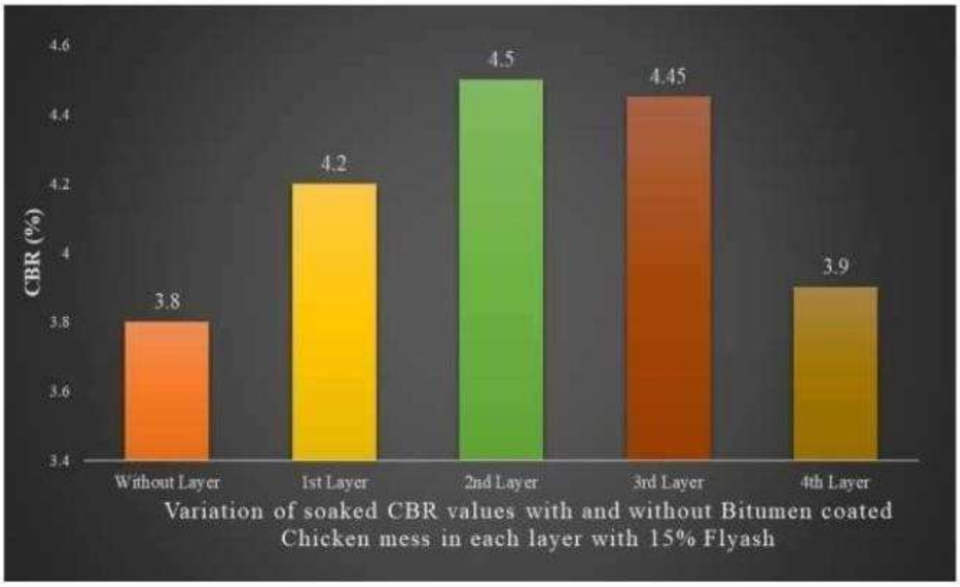


Figure 7.3: Variation of Soaked CBR Values with and without Bitumen CoatedChicken Mesh in each layer with 15% Fly Ash

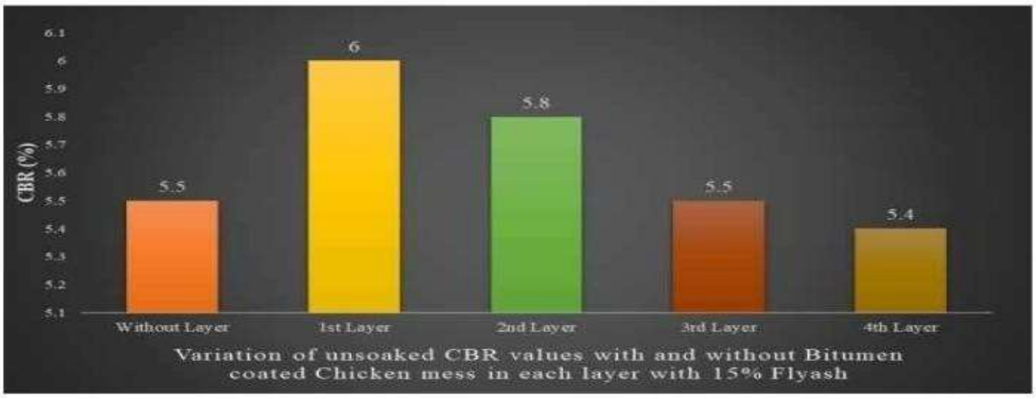


Figure 7.4: Variation of Unsoaked CBR Values with and without BitumenCoated Chicken Mesh in each layer with 15% Fly Ash

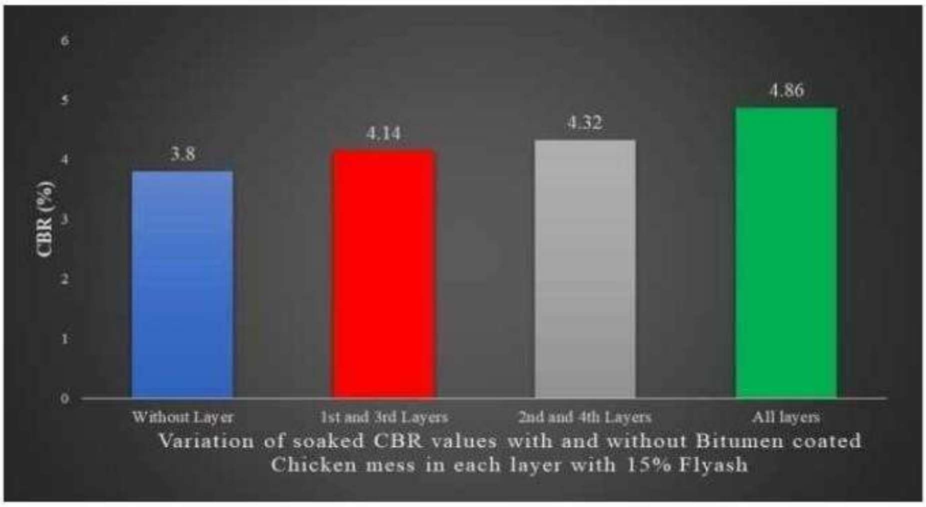


Figure 7.5: Variation of Soaked CBR Values with and without Bitumen CoatedChicken Mesh in each layer with 15% Fly Ash

Based on the observed, CBR value for available soil is 3.8%. Due to the addition offly ash, the CBR value was raised to 4.01% which allows an increment of 5.52%. As the obtained CBR value was 4.5%, if the bitumen coated ***chicken mesh*** is placed in the 2nd layer is found to be maximum compared with other layers.

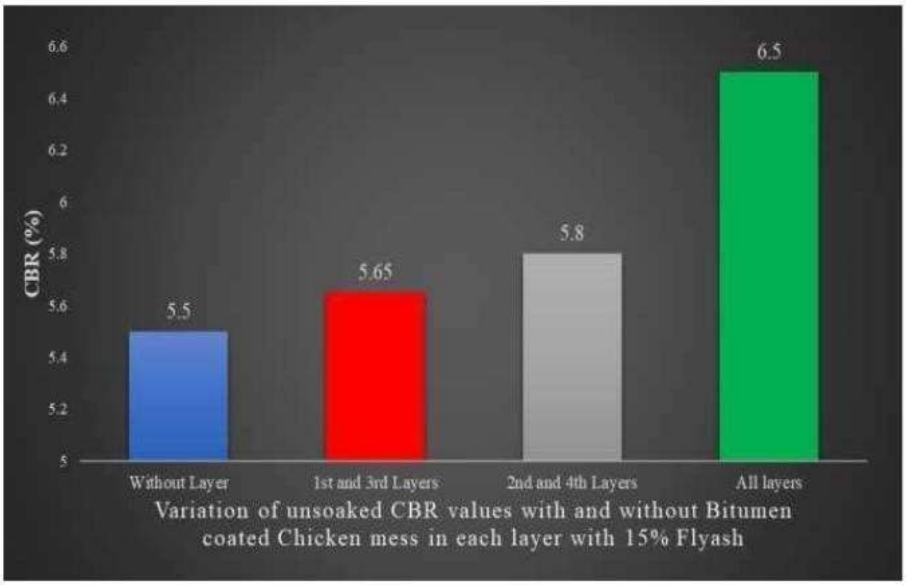
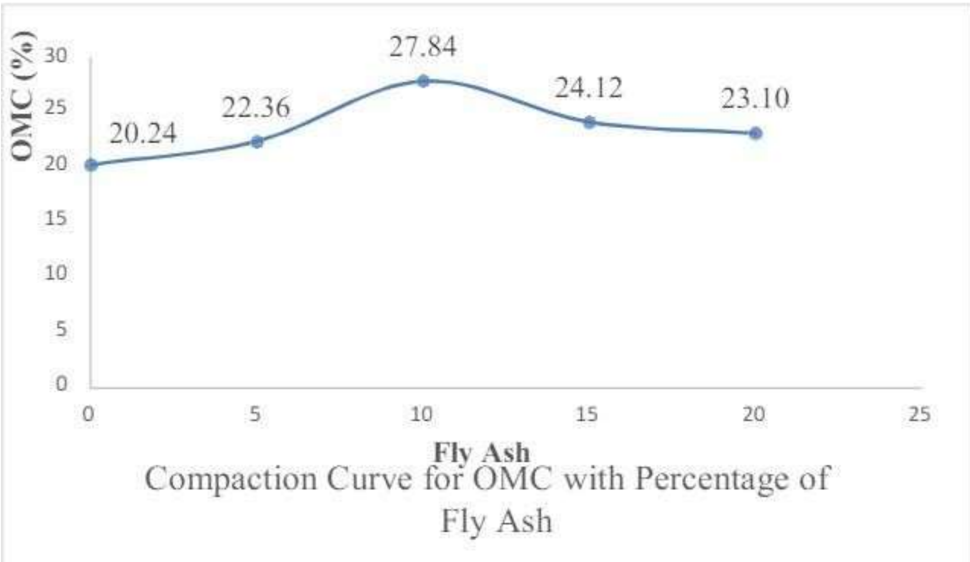


Figure 7.6: Variation of Unsoaked CBR Values with and without Bitumen Coated Chicken Mesh in each layer with 15% Fly Ash

Incorporating bitumen-coated chicken mesh into the second and fourth layers yields a CBR value of 4.32. When bitumen-coated chicken mesh is used in all layers, the highest CBR value is 4.86 in the soaked test and 6.5 in the unsoaked test. Differences between the wet and unsoaked tests show an increase of 83% and 83%, respectively. Sample 2 of Soil: Below is a graphical representation of the functional behaviour of soil with fly ash substituted and the influence of bitumen coated bamboo mesh on organic matter content and maximum dry density (MDD), based on prior soil studies.

Figure 7.7: Compaction Curve for OMC and Percentage of Fly Ash



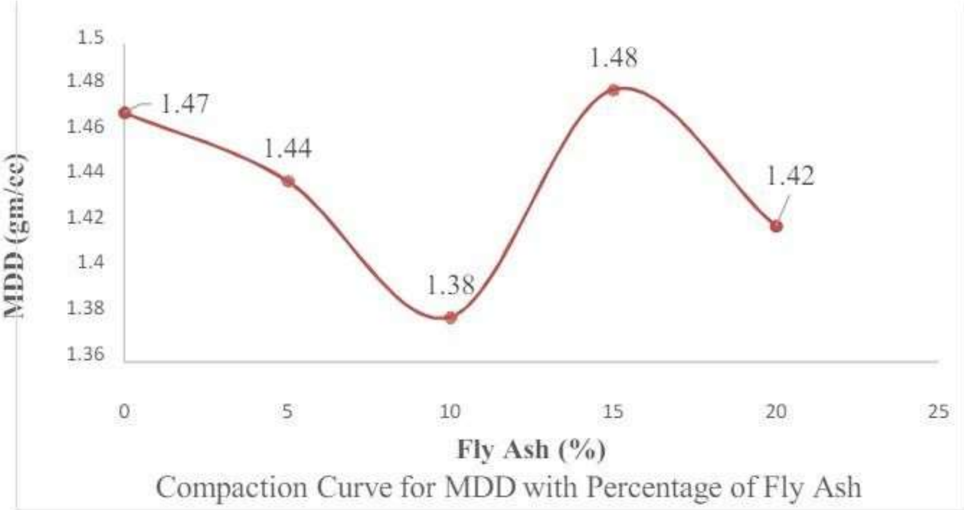


Figure 7.8: Compaction Curve for MDD and Percentage of Fly Ash

The available water content available in the natural soil is found at 20.24%. As fly ash is replaced at different percentages by weight of the material the moisture contentis increasing with increase in fly ash and attained its favourable moisture content value at 15% of fly ash replacement which is found to be 24.12%. Thus, the point indicates the maximum dry density achieved is 1.48 and the water content at 15% fly ash replacement is considered in present expansive soil.

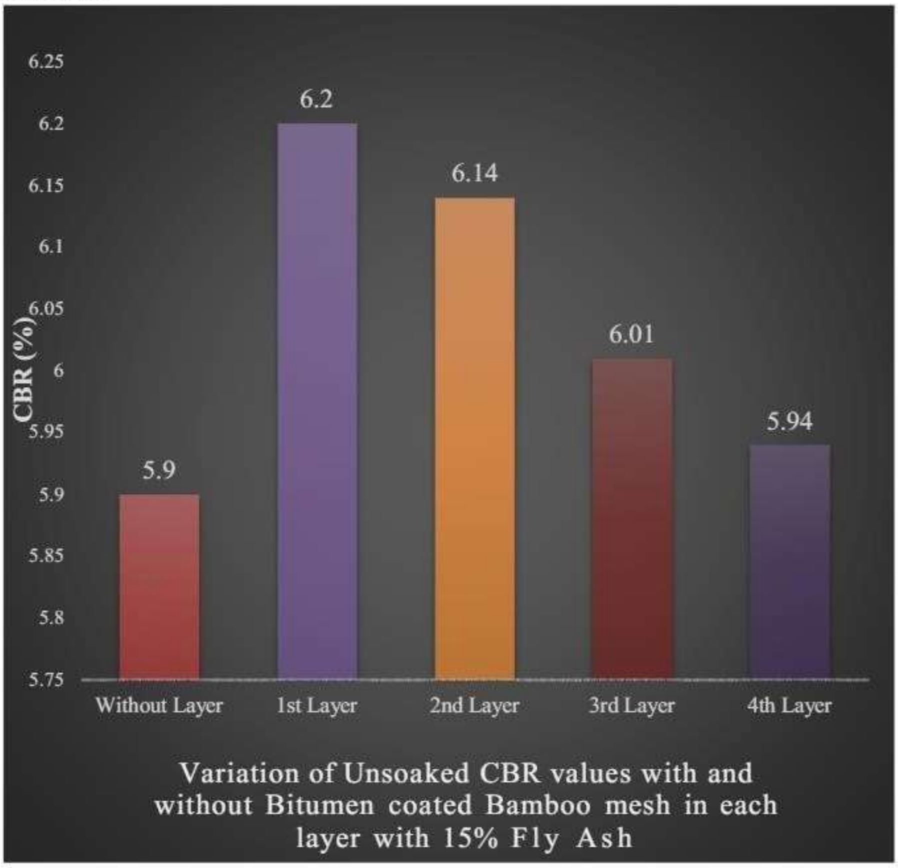


Figure 7.9: Variation of Unsoaked CBR Values with and without BitumenCoated Bamboo Mesh in each layer with 15% Fly Ash

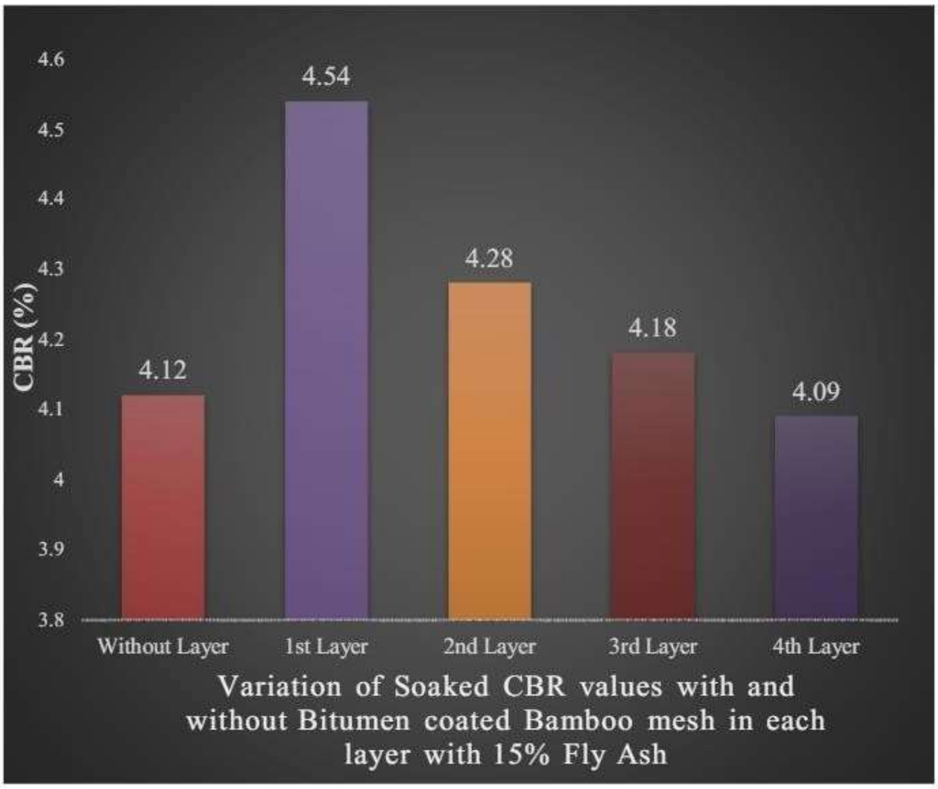


Figure 7.10: Variation of Soaked CBR Values with and without Bitumen Coated Bamboo Mesh in each layer with 15% Fly Ash

Soil Sample-3:

Based up on the experimental investigation evaluated on soil replaced with different percentages of partial replacement of Plastic Waste on optimum water content and the maximum dry density values are graphically represented below.

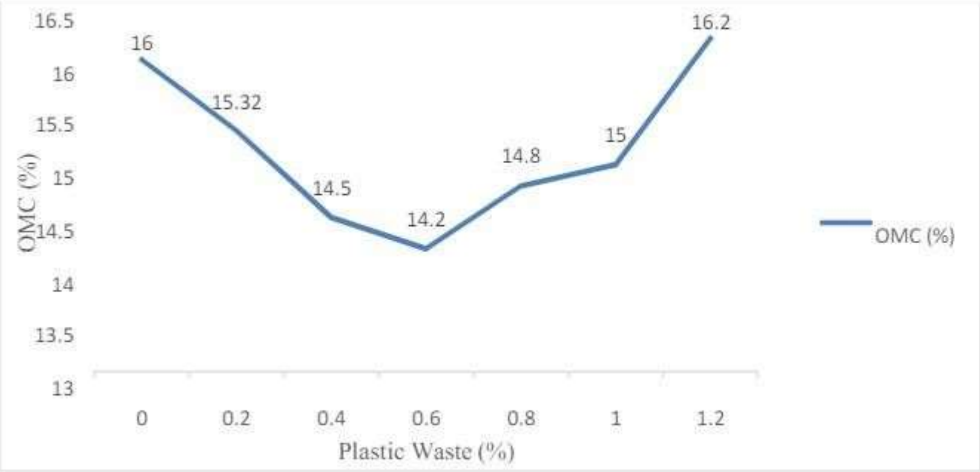


Figure 7.11: Compaction Curve for OMC and Percentage of Plastic Waste

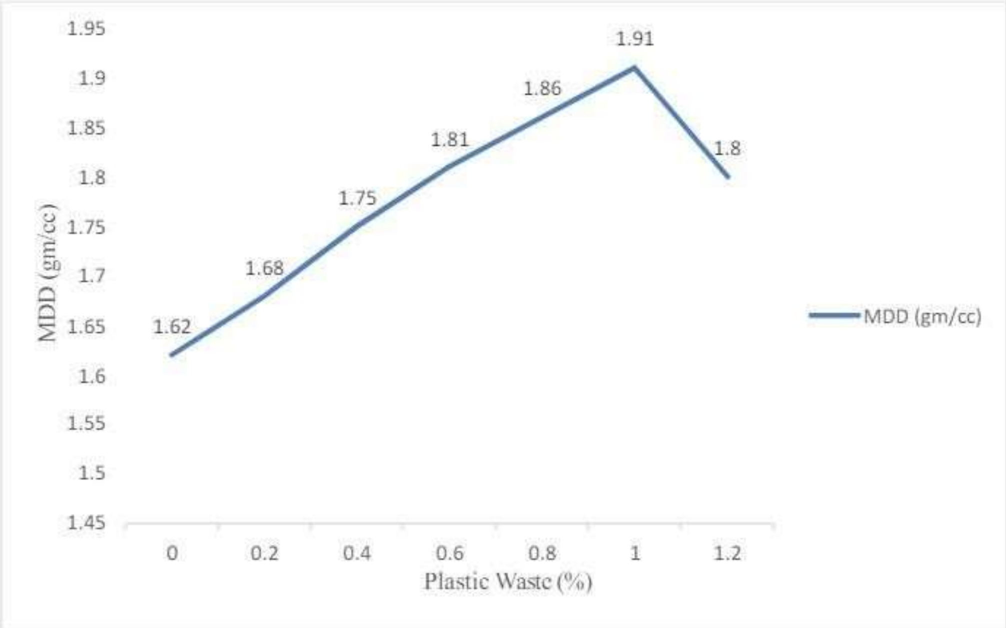


Figure 7.12: Compaction graph for MDD with Percentage of Plastic Waste

From the above graphs, the water content of unmodified soil is 16% and that of the dry density is 1.62 respectively. After the addition of plastic waste in the soil, the water content decreases and its dry densities increases up to certain extent. The maximum dry density value is found to be 1.91 gm/cc and is obtained at an optimum moisture content of 1% replacement of plastic waste in the soil. So, this maximum value of dry density, optimum moisture contents are considered for the CBR, California Bearing Ratio and UCS, Unconfined Compressive Strength tests. The retardation in the water content in soil is because of the absorption of moisture by plastic.

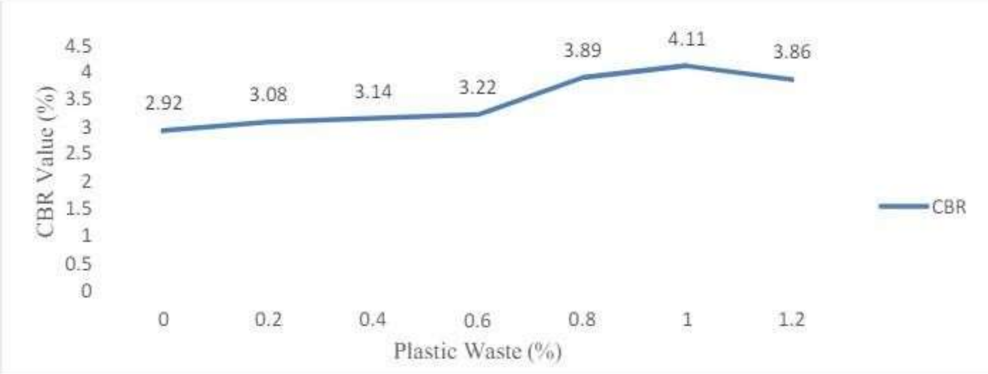


Figure 7.13: Variation of CBR values at different percentages of Plastic Waste

At 1% plastic waste replacement in soil, the greatest CBR value of 4.11% was achieved, while the natural soil CBR is 2.92%. The graph shows that the CBR value increases up to 1% replacement and then begins to decrease. Thus, the plastic trash stiffens the soil, leading to an increase in the CBR. Comparing the unaltered material's UCS value to that of the one that contains one percent plastic waste reveals a maximum value of 0.178 MPa for the unconfined compressive strength. From these results, we can deduce that a 1% substitution of plastic trash results in higher CBR and UCS values.

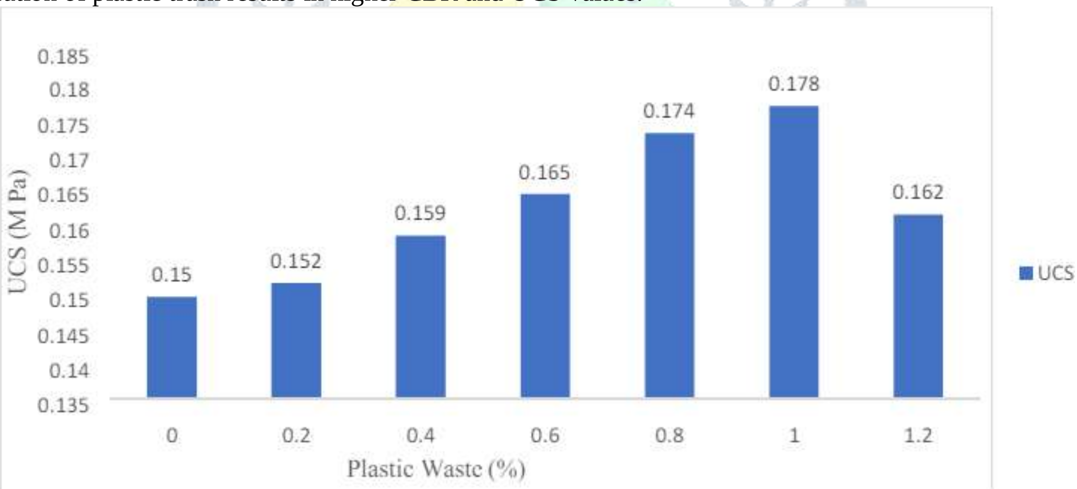


Figure 7.14: Variation of UCS values at varying percentages of Plastic Waste

Conclusion

Important design considerations for flexible road work were covered in this project, with a focus on the subgrade's behaviour as the model's foundation. For the strength and durability of a flexible pavement, it is necessary to reinforce, stabilise, or compact the soil subgrade prior to its installation, as expansive soils typically contain high percentages of silt and clay. Substituting bitumen-coated chicken mesh, bamboo mesh, plastic trash, fly ash, or other reinforcing materials for the subgrade soil can accomplish this.

References

1. Abdel–Aziz, G., & El Sayad, H. I. (2002). Effect of Retempering on Consistency, Compressive Strength and Durability Related Properties of OPC, Silica Fume and Fly Ash Concrete in Egypt. Civil Engineering Research Magazine, Civil Eng. Dept., Al-Azhar University, Cairo, Egypt, 24(4), 1460- 1477.
2. Abdel–Aziz, G., & El Sayad, H. I. (2002). Effect of Retempering on Consistency, Compressive Strength and Durability Related Properties of OPC, Silica Fume and Fly Ash Concrete in Egypt. Civil Engineering Research Magazine, Civil Eng. Dept., Al-Azhar University, Cairo, Egypt, 24(4), 1460- 1477.

3. Abrishami, H. H., & Mitchell, D. (1996). Analysis of bond stress distributions in pullout specimens. Journal of Structural Engineering, 122(3), 255-261.

4. ACI Committee 408, 2003 ―Bond and Development of Straight Reinforcing in Tension ACI 408R-03),‖ American Concrete Institute, Farmington Hills, MI, , 49 pp

5. Ahmad, S., & Alghamdi, S. A. (2014). A statistical approach to optimizing concrete mixture design. The Scientific World Journal, 2014.

6. Alnaki, A. A., Wegian, F. M., Abdalghafar, M. A., Alotaibi, F. A., Ali, I. A., Almurshed, M. M., & Alwan, A. B. (2014). Assessment of the Strength of Remixed Concrete Structures. Jordan Journal of Civil Engineering, 8(2), 227- 238.

7. Baigrai, N.K. arid Kar, J. N.(1970) "Effect of pre setting of cement on the mortar strength" Cement and Concrete, Apr-June, pp 25-29.

8. Bairagl, N.K. and Jhaveri (1977). "Strength variation of composite mixes by pure selfing theory" Indian Concrete Journal, March,pp 87-89.

9. Bairagi, N., Strength Variation of Composite Mixes by General Selfing Theory, Int. Conference on Materials of Construction for Developing Countries, Bangkok. August 22-28, 1978 at AIT-Bangkok, Thailand.

10. Bairagi, N.K., Goyal,A.S.and Joshi,P.A.(1989) "Strength of Composite Mixing Using General Crossing Theory" ICJ, Vol.63, No.12,pp 600-604. 232 | P a g e

11. Bairagi, N.K. ,Goyal, A.S, and Ramachandra RAO,M. (1990). "Selfing and Crossing Theories on Cumulatively Cured Strength", ICJ, Vol. 64, No.11, Nov., pp 527-534.

12. Bayrak, M. B., & Ceylan, H. (2008). Neural network-based approach for analysis of rigid pavement systems using deflection data. Transportation Research Record, 2068(1), 61-70.

13. Bezabih, A. G., & Chandra, S. (2009, July). Comparative study of flexible and rigid pavements for different soil and traffic conditions. In Journal of the Indian Roads Congress (pp. 153-162).

14. Buch, N., & Zollinger, D. G. (1996). Development of dowel looseness prediction model for jointed concrete pavements. Transportation research record, 1525(1), 21-27.

15. Byrum, C. R. (2013). Falling Weight Deflectometer Evaluation of Pavement Joint Looseness and Differential Slab Edge Settlements in Jointed Concrete Pavements. In Airfield and Highway Pavement 2013: Sustainable and Efficient Pavements (pp. 243-261).

16. Chen, D. H., Won, M., & Hong, F. (2009). Investigation of settlement of a jointed concrete pavement. Journal of performance of constructed facilities, 23(6), 440-446.