International Journal of Scientific Research and Engineering Development-– Volume 7 Issue 6, Nov-Dec 2024
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Review Paper on Performance Evaluation of Flexible Pavement on Different Subgrades with Industrial Waste

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ABTRACT

The design of flexible pavements heavily relies on the behavior of the subgrade, which serves as the foundation for the entire pavement structure. Therefore, careful attention must be given to both the performance and design analysis during pavement construction. Expansive soils, which contain high percentages of silt and clay, require stabilization or compaction before laying the pavement. Stabilizing these soils can be achieved by replacing the subgrade with alternative materials.

Fly ash, an industrial waste with a current utilization rate of about 55%, presents an opportunity for such stabilization. By replacing a portion of the subgrade with fly ash and reinforcing it using bitumen-coated chicken mesh at varying percentages and layer placements, the stability of the pavement can be enhanced. This reinforcement has been shown to significantly improve the California Bearing Ratio (CBR), with maximum strength achieved when 15% of the soil is replaced with fly ash and four layers of bitumen-coated chicken mesh are used.

Keywords: - Unconfined Compressive Strength (UCS), CBR, Maximum Dry Density (MDD), and Optimum Moisture Content (OMC).

1.1 INTRODUCTION

The economy of any country depend upon a good infrastructure which covers roads, bridges, buildings, warehouses, airports, harbors, instrumentality terminals etc. In today's life, a good infrastructure is a major requirement for the growth of a country which seems impossible to attain without using cement. Cement is a powdery substance which is made up of calcining lime and clay. Mainly cement is used as a binding material which is mixed with water, sand and aggregates for the construction purposes (i.e. highways or building). Though, it is an environmental concern because of the emission of several hazardous gases at various stages of cement manufacturing process. In a previous study (Mehraj et al 2014), it was mentioned that consumption of cement in India is increasing with the rate of 10% per year. It is to note that the cement is the second most consumable material after water across the world.

Construction of road and highways is significant for the economic development of a country. Pakistan is lying in the center of South Asia; for better trading and a balance economy road links and networks are essential. A good transportation system provides an efficient means to carry different necessary products, agricultural and daily life necessities. Pavement is a multilayer system which distributes the vehicular load over a larger area. There are mainly two types of pavements, rigid and flexible pavement. The main difference between these two pavements is that the upper surface of the rigid pavement is made of concrete and the upper surface of flexible pavement is made of asphalt. The flexible pavement distributes the loading stress to the soil (subgrade) in less magnitude on which the soil will not shear or distort, i.e., from 150 psi to 3 psi. The asphaltic binders behave as visco-elastic material; its behavior changes as temperature increases. This behavior is mainly dependent upon the temperature and loading as well. At a colder temperature, the asphaltic binder behaves as stiffer material, so the ambient temperature is the primary parameter in design. At very low temperature (less than 0 °C) the asphaltic binder behaves as stiffer solid

1.2 LITERATURE SURVEY & BACKGROUND

Sweeping soils are known to cause harm for the most part to light structures, for example, private residences and street asphalts. The misfortunes because of broad harm to roadways running over sweeping soil sub levels are evaluated to be the billions of dollars everywhere throughout the world. Different therapeutic estimates for soil substitution, dampness control lime adjustment Bansal et al,1996, Robneet,1976; have been rehearsed under fluctuated level of achievement. Anyway, these strategies experience the ill effects of certain confinement regarding their versatility like longer time frames for initial wetting the exceptionally plastic material dirts, trouble in developing the perfect dampness boundaries pummeling and blending issues if there should be an occurrence of lime adjustment and significant expense for pulling appropriate top off material for soil substitution.

The favourable circumstances for utilization of Geosynthetics in structural building have been acknowledged by the scientists (Rao, 1996). Lion's share of the past investigations included the utilization of geosynthetics either as a separator at asphalt sub level interface (Jorenby and Hicks, 1986; AL Qadi and Bhutta, 1999) or at the asphalt overlay interface (Button, 1989; Pradeep Kumar, 1995). Be that as it may, a couple of instances of utilizing geo synthetics for fortifying one of the adaptable asphalt layers laid over traditional non-expanding subgrades (Hass et al, 1988) have likewise been accounted for.

Fly debris has been utilized in India for filling low lying territories, for development of street dikes and for development of dykes around debris lakes just as refilling behind holding structures. Aside from the utilization of fly debris as a geo-building material, it is being utilized in solid structures, block industry, in the assembling of asbestos sheets and furthermore as poultry feed. Different elective advances of using fly debris for the production of blocks, squares, tiles and so on., are accessible today, the advancement in embracing them isn't extremely palatable (Suryanarayana, 2000; Kuan-Yeow Show et al., 2003). So as to stay away from different related issues of fly debris transfer, the best cure is to utilize fly ash in mass amounts. Regardless of some inborn issues related with fly ash usage, the empowering designing material properties provoked building network which use in mass amounts for development, that arranges it off as well as to safeguard the top rich soil from utilizing it for a few purposes.

In the ongoing past, strengthened earth strategy has been attempted viably in taking care of dominant part of geotechnical designing issues (Hausmann, 1990). Under the presentation of Geo Synthetics, the strengthened ground strategy picked up its noticeable quality because of its versatility for various field conditions. Constrained examines are likewise carried out by setting support in the layers adaptable asphalt framework laid on the ordinary non-expanding subgrade layers. Be that as it may, the outcomes are not convincing in regard of the sort of the support operator for conquering the issues related with sweeping soil. In the light of above talks as for issues presented by sweeping soils and fly debris just as the arrangements attempted to contain them for better model research center asphalt execution, there seems, by all accounts, to be holes either with the materials utilized or the systems embraced. Endeavors are called for to connect the holes so as empower to prescribe a method that tends to the issues. Further, any method proposed must be approved with experimentation under field recreated conditions.

Mohammadinia et al. (2017) studied the effect when fly ash is mixed with crushed brick (CB) and reclaimed asphalt (RAP) in the subbase layer of flexible pavement. Aggregates of CB and RAP having size of 20 mm were accumulated from factory where recycling is done. Fly ash (FA) is added in different proportions. A number of compaction tests were conducted on CB and RAP to determine the OMC and MDD. To calculate the unconfined compression strength (UCS) test, dry aggregate were combined with relative moisture content for 2 hours before addition of FA. CB and RAP aggregates were blended with the range of 5%, to 30% of FA then tested for the maximum strength con achieved for which %. When 10% of FA is added then pores of RAP is filled and up to 20% it will get its maximum strength. All the tests were conducted by curing the samples in a humidity restricted box for 7 days. It was concluded that the 15% fly ash can be utilized for pavement bases as well as a cementitious material for the pavement.Wang et al. (2017) examined the effect on concrete when fly ash is added to mix. Fly ash was added to mix in replacement of cementitious material like cement. While preparing sample for testing w/c ratio have to kept .35 and .25 and replacement of cement from 8% to 15% can be done. Test to find compressive strength, chloride permeability and shrinkage of new concrete mix. After analyzing result it was found that 15% substitution give the optimum result. Shaikh and Supit (2015) calculate that by using 8% of ultrafine fly ash (UFFA) in the concrete, compressive strength porosity and durability get increased by forming extra C-S-H gel. Jerath and Hanson (2007) conducted the study to check the durability of concrete by increasing the gradation of aggregate with fly ash content. The usage of high quantity of fly ash decreases the water content of mix which gives high compressive and flexural strength. Dense graded aggregate with 45% of fly ash in place of cement reduces the specific gravity, permeability, absorption and voids in concrete mix which increase the durability of the rigid pavement in every climate conditions. Anupam et al. (2017) conducted the study by utilizing industrial waste in roads. Fly ash was mixed with soil to increase the bearing capacity of lower surface layer of pavement. Adding waste in ranging from 0 to 35% by weight of soil sample are made. Various test like California bearing ratio test, unconfined compressive strength test, triaxial test and micro structural investigation were performed. Results concluded that 25% mix sample increases the property of soil for the pavement.

Sujit Kumar Pal and Ambarish Ghosh (2009), has conducted shear strength parameters of all the nine fly ash samples, compacted at optimum moisture content and maximum dry density by standard Proctor compaction tests. The results showed with increase in confining pressure the deviator stress at failure (q¦) increases and the shear strength also increases, irrespective of variety of fly ash. The effect of confining pressure on deviator stress at failure is more prominent for the fly ash samples of low strength than for fly ash samples of high strength. Fly ash achieves most of its shear strength from internal friction and exhibits some amount of apparent cohesion. It implies that the fly ash is of mostly noncohesive in nature and internal friction is directly proportional to the shear strength values of fly ash. Maximum dry density of fly ash influences the shear strength parameter like, angle of internal friction. The strain to attain the peak deviator stress increases with increase in confining pressure

It is crucial for highway engineers to develop a subgrade with a California Bearing Ratio (CBR) value of atleast 10. Research has shown that if a subgrade has a CBR value less than 10 (Ayothiraman etal.2002) the subbase material will deflect under traffic loadings in the same manner as the subgrade and cause pavement deterioration. Stabiliing the weak soil with suitable waste material as stabilizers (Palaniappan, and Stalin, 2009) is an effective method. A lot of research work has been reported on the stabilization of soil by waste materials in powdered form. Ceramic dust (Ameta etal,2013). Quarry Dust (Sabat, 2012) , marble dust (Sabat,2011; Baser ,2009; Swami,2002), Foundry Sand and Fly Ash and Tile waste (Amrendra etal, 2014) are some of the prominent dust/powder like waste materials which have been successfully utilized for stabilization of subgrade. A large percentage of clay tile waste is produced during formation, transportation and placing of tiles. 55% of tile waste remains unutilized and its disposal is a problem which can be effectively utilised as a stabiliser in subgrade soil. The available literature shows that only a limited amount of experimentation is done with tile waste as an additive for soil stabilization.

Solid waste generation is one of the major impairment of the birth of a clean and green environment. Millions of tons of these wastes are

generated daily, and industrial and agricultural waste takes a very large percentage of these solid wastes. Fly ash has a lot of engineering benefits when used in soil stabilization Rajakumar and Meenambel, (2015), Turgeon, (1998), Ahmed et al, (2014), Indraratna et al, (1991),Saha and Pal, (2013),
Satyanarayan et al, (2013) and Verma and Maru, (2013) and . Fly ash, a typical example of industrial waste was used by Zumrawi, (2015) in improving the engineering and geotechnical properties of lateritic soil. According to the author, the Fly Ash was obtained from ignition of sub-bituminous coal at an electric power plant. It was used to stabilize soft, fine-grained red soils with bearing capacity of 10Kg/mm2 , CBR of 3.1% and plasticity indices ranging from 25 to 30 at an optimum water content of 9%. Fly Ash was added at different percentages ranging from 0 to 9%, but the most efficient and economical percent was 6%. After the stabilization using 6% Fly Ash, the bearing capacity increased to 35kg/mm2, and the CBR ratio increased to 4.82%. The required pavement thickness needed to be reduced from 305mm to 215mm for 'A' type traffic. Additionally, class 'F' type Fly Ash activated from the thermal power plant at different percentages (5%, 10%,15% and 20% by dry weight) with ordinary Portland cement at constant 5% to stabilize expansive soil at Almenshia in Khartoum, Sudan Zumrawi, (2015) [23]. The results showed that at 5% Fly Ash addition with constant cement percentage, the swelling potential and swell pressure values of the soil reduced from 18.7% to 4.5% and from 175 kPa to 75 kPa with a slower rate as more Fly Ash is needed. There were obvious strength improvements over the soaking periods due to stabilization reactions. The CBR chart shows a significant increase in soil strength from 0% to 15%, after which there was a reduction in strength. Also, the most obvious improvement was recorded at 5%. Research of Ayidelek and Arora, (2005) focused on comparative the use of cement and lime as activators on fly ash class F on stabilizing silty soil at 40%. From the results, cement as activator shows better improvements. The stabilized soil with cement as activator had a CBR value of 140%, MDD of 15.46 KN/m3 and USC of 3.2MPa. While, lime as an activator recorded, CBR value of 36%, USC of 0.4MPa and MDD in 15.36 KN\m3 Ayidelek and Arora, (2005) . Furthermore, Santos et al, (2011) compared the use of fly ash at 20, 40 and 60% on stabilizing low plasticity clay. The virgin clay had OMC of 14% and MDD of 17.9 KN/m3 . The highest CS WAS achieved at 60% (2.67 MPa), but the difference to that of 40% is minimal (2.65MPa). As the percentage increased, there was an increase in the OMC and decrease in MDD. The optimum percentage was achieved at 60%. Cistelo et al, (2012) [27] Compared the use of fly ash class 'F' and class 'C' at different percentages to stabilize fat clays at 28 and 84 days using Sodium Hydroxide and Sodium Silicate as an activator. It was observed that as curing days increase, the USC value increases as well. Also, fly ash class 'f' was more efficient. Also, the optimum percentage for the class was 20% Reyes and Pando, (2007) [28] Used CFBC fly ash at 10% and 20 % to stabilize High Plasticity Clay. Curing effects were observed at 28 days and 40 days. The research showed that as a percentage of CFBC and curing days increases as well as USC. Research carried out by Manu et al, (2015) [29] showed results close to that of Anthony et al, (2014) [30] but suggest CPHAcan be used in the production of Compressed Earth Bricks with CPHA not passing 10%. Their research showed that as the percentage of CPHA of dry weight increase, it increases the alkalinity of the Earth brick and any increase beyond 10% should result in a slight decline in engineering properties of the improved earth bricks. It also shows that CPHA cannot pass as a Pozzolanic material. In a bid to reduce solid waste in the environment a re-use for Shredded Rubber Tyre SRT which is a non-biodegradable waste has been found in road constructionHumprey and Nickel, (1997), Ghate et al, (2014), Gary et al, (1996), Ayothiraman and Abilash, (2011), Amin (2012) and Ajay and Jawaid, (2013) . Jagtar and Vinod (2017) Used (SRT) to stabilize a clayey soil collected from Banur near Chandigarh. SRT was cut in various sizes such as 10mm, 20mm, and 30mm in width and 20mm, 40mm, and 60mm in length. Different percentages ranging from 5%, 10%, and 15% was

used on the soil. The MDD and OMC results of all sizes indicate a reduction in MDD and the increase in the OMC as percentage increases due to the light weight of the rubber tire and water absorption respectively. From the CBR test, the optimum value was at 10mm by 20mm at 5%, which yielded 1.93% (28.66% increase) as against the virgin soil CBR value of 1.50%. This would reduce construction cost as pavement thickness will reduce. Plastic waste (made into strips) was used to stabilize Black Cotton Soil which has a CBR value of 1.0%, OMC of 20.5%, MDD of 1.62gm/cc, the Compressive strength of 90.8 kg/cm2 , Plasticity index of 35.2% and swelling Index of 65.3%. This research shows that plastic is a good stabilizing material, especially at 4% where CBR is 11.70%, OMC of 18.5% and MDD of 1.81gm/cc Ekta et al, (2017) [38]. Sewage sludge is also used in road construction as carried out by Lin et al (2007), Lin et al, (2005), Tay et al, (1991) and Yague et al (2002) [39, 40, 41 and 42] used Incinerated Sewage Sludge Ash (ISSA) to stabilize soft subgrade (low plasticity silty clay) using cement as an activator. The ratio of ISSA to cement is given as 4:1, this mixture was used at 2%, 4%, 8% and 16% to stabilize the soil. The introduction of the mixture at various percentages decreased the plasticity index. The admixture at 16% reduces swelling to 33.33% of the initial value. As the admixture percentages were increased, the UCS values also increased. UCS values increased as curing time increases due to the reaction between pozzolanic materials in the soil and ISSA. The CBR result also indicates an increase in CBR values as a percentage of admixture is increased. This study shows that ISSA is a good soil stabilizer. The optimum percentage for this admixture, IS 16%. The use of steel slag has been used by Li et al, (2009), Motz and Geiseler, (2001), Alexandr et al, (1993), Shen et al, (2009), Mahieux et al, (2009), Rhode et al, (2003) and Mohd et al, (2015) [43, 44, 45, 46, 47, 48 and 49]. Recently, Faisal et al, (2017) used steel slag to stabilize clay soils obtained from Mecca Street in Amman. The soil had a plasticity index of 24, OMC of15.6%, MDD of 18.02 KN/m3 . Different percentages of this admixture were used, ranging from 5 to 30%. The tests showed that as steel slag increase, the plasticity index also reduces but MDD is increased, therefore changing the soil classification from highly plastic clay and silt to low plastic clay and silt. This change is due to the nonplastic nature of steel slag. Also, as the steel slag increased, the swelling pressure also reduces. The initial swell pressure for the virgin soil is placed at 110kPa, while at 30%, the swell pressure is 25kPa. The UCS test indicated a reduction in strength as steel slag percentages increased. The natural soil had UCS value of 500kpa, while at 30%, the result showed 150kpa. The CBR value indicated that as steel slag as increased, the CBR value increased while free swelling reduced.

Furthermore, [51] used a combination of ground granulated blast furnace slag (GGBS) and fly ash (FA) to stabilize an expansive soil mixture with lime used at some point as an activator. The soil sample is a mixture of black cotton soil (80%) and commercial sodium bentonite (20%) by dry weight. The soil sample plasticity index is 33%, and free swelling index of 7.25. Results showed a decrease in the plasticity index as the percentages of the mixture is increased, but when 1% of lime is added, there is greater reduction. At 40% pure admixture, the plasticity index is 22, while addition of 1% lime gave 15. This is due to diffuse double layer thickness as well as flocculation of clay particles. From the study, OMC reduced while MDD increased as the admixture increased, it is a sigh of soil improvement. The strength of the soil plus admixture alone was not so desirable, but the addition of 1% of lime greatly increased the strength of the soil. The optimum percentage for the admixture is 20% plus 1% of lime. Granulated Blast Furnace Slag (GBFS) was used to stabilize soft soil by 52. The plasticity index of the soil is 17%, MDD of 17.6KN/m3 , OMC of 11%, soaked CBR of 2.05%, unsoaked CBR value 8.14%, free swelling index of 83% and swelling pressure of 41.8 KN/m2 . The result showed a reduction in the plasticity index as GBS increased. OMC was observed to reduce while MDD increased due to GBS acting as a filler, thereby, increasing the specific gravity in the voids. The swelling pressure and free swelling index tests revealed the optimum percentage of 9%

where there were 21% and 67% reduction respectively. The UCS test showed an increase in strength until 9% (28%) after which there was a drop in strength due to saturation of GBFS, which lead to weakening bonds between the soil and cementitious materials. The optimum percentage can be placed at 9%. The unsoaked CBR test indicated rise until 6% while soaked CBR values rise by 9% (400% improvement) and dropped at 12%. The optimum percentage for GBS usage is placed at 9%.

1.3 CONCLUSION

The performance evaluation of flexible pavements on different subgrades stabilized with industrial waste demonstrates significant potential for improving both pavement durability and subgrade strength. Incorporating industrial wastes such as fly ash, blast furnace slag, steel slag, and cement kiln dust not only enhances the engineering properties of weak subgrades but also offers a sustainable solution for managing industrial by-products.

The key findings of this review indicate that:

1. **Improved Subgrade Performance**: The inclusion of industrial waste in subgrades results in higher California Bearing Ratio (CBR) values, reduced plasticity, and better compaction, leading to a more stable foundation for flexible pavements.
2. **Enhanced Pavement Life**: Stabilized subgrades exhibit reduced deformation, rutting, and cracking, thereby extending the service life of the pavement.
3. **Economic and Environmental Benefits**: Utilizing industrial waste reduces the dependency on natural resources, lowers construction costs, and minimizes the environmental footprint by repurposing waste materials.

However, challenges such as variability in waste properties, long-term performance under diverse climatic conditions, and potential environmental impacts need to be addressed. Standardization of design methods, coupled with field trials and regulatory guidelines, is essential for broader adoption.

In conclusion, the use of industrial waste in subgrade stabilization represents a promising avenue for sustainable infrastructure development. Future research should focus on long-term monitoring, hybrid stabilization techniques, and life-cycle assessments to maximize the potential benefits and ensure widespread implementation in road construction practices.

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