EFFECT OF LIME, FLY ASH AND MAT FIBER ON STRENGTH AND PERMEABILITY CHARACTERISTICS OF SUBBASE MATERIAL

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The efficient pavement performance depends on the stability of the supporting layers. Road failures mostly occur due to poor selection of material and insufficient drainage arrangements. Subbase layer is an essential component of the pavement alongwith base, subgrade and surface wearing course. This research work is related to investigating the effect of Lime, Fly ash and Mat fiber on the strength and permeability characteristics of Subbase material. Results show that the maximum dry density and soaked California bearing ratios (CBR) values are increasing with the increase of lime and fly ash ratio in subbase. Whereas, maximum dry density and soaked California bearing ratios (CBR) values are decreasing with the increase of Mat fiber in the subbase. The increase in content of Mat fibers also resulted in increase in permeability of subbase material. It is also observed that higher content of fly ash results in swelling of the subbase material as compared with lime content.

Keywords: *subbase; lime; fly ash; CBR; mat fiber*

1. Introduction

Road pavement failure mostly occurs due to poor selection of material or poor compactive effort. Roads and highways are the most important components of infrastructure development. Pavement is a structure that is a combination of different superimposed layers above the natural soil called subgrade. The main function of these layers is to transfer the loads of vehicles efficiently to the subgrade. The structure of pavement must provide a surface with comfortable riding quality and well skidding resistance. In addition to that, it must have a low reflecting characteristic and should be free of noise pollution. The unbound granular subbase layer has a significant role in pavement performance for both flexible and rigid pavement. More than 60-70% of road pavement failures occurs due to poor selection of construction material. Subbase layer accounts for about 45% of the entire pavement structure for stability against failure condition

The roads are mostly constructed worldwide as flexible pavement. Flexible pavements are layered structure. The supporting layers are properly arranged in such a way that good quality materials are provided in topmost layer [1]. Flexible pavement layers are composed of subgrade layer, subbase layer, base course and surface layer as shown in Figure 1.

Upper most layer is the surface course which become in contact with axel load directly. It is constructed with dense graded asphalt concrete. It helps to avoid the penetration of water into the pavement and it also provides smooth riding surface. Base course is laying under the surface course and it is provided for load distribution to the subbase layer. It consists of compacted stone. Subbase course is laying under the base course and its key purpose is to provide support to structure, improve drainage, and also reduce the interference of fines from the subgrade layer. Subgrade is the bottom most layer, which is overlain by Sub base. The subbase layer can be divided into two parts i.e. upper and lower subbase layer. Upper layer acts as drainage layer, whereas lower subbase layer soil acts as filter layer to prevent intrusion from subgrade to subbase.

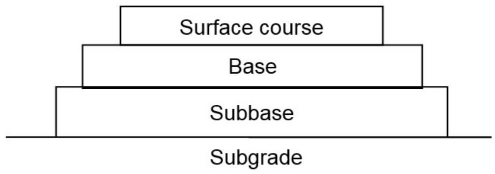

Fig. 1 - Typical layered structure for flexible pavement.

Sometime Subbase course can also work as a filler in between subgrade and the base course. The top natural surface soil called subgrade whose primary function is to efficiently distribute the stresses from the above provided layer to the ground underneath. It must be compacted according to the required density and at the optimum moisture content.

Rain and flood water infiltration badly affect the performance of flexible pavements. It may enter into the pavement layers through cracks and joints. Ditches on road can become filled with rain water which can quickly saturate pavement structure and subgrade soil. When cracks form in asphalt, it resulting in damaging to the base beneath it. The fluctuation of groundwater table also affects the pavement structure.

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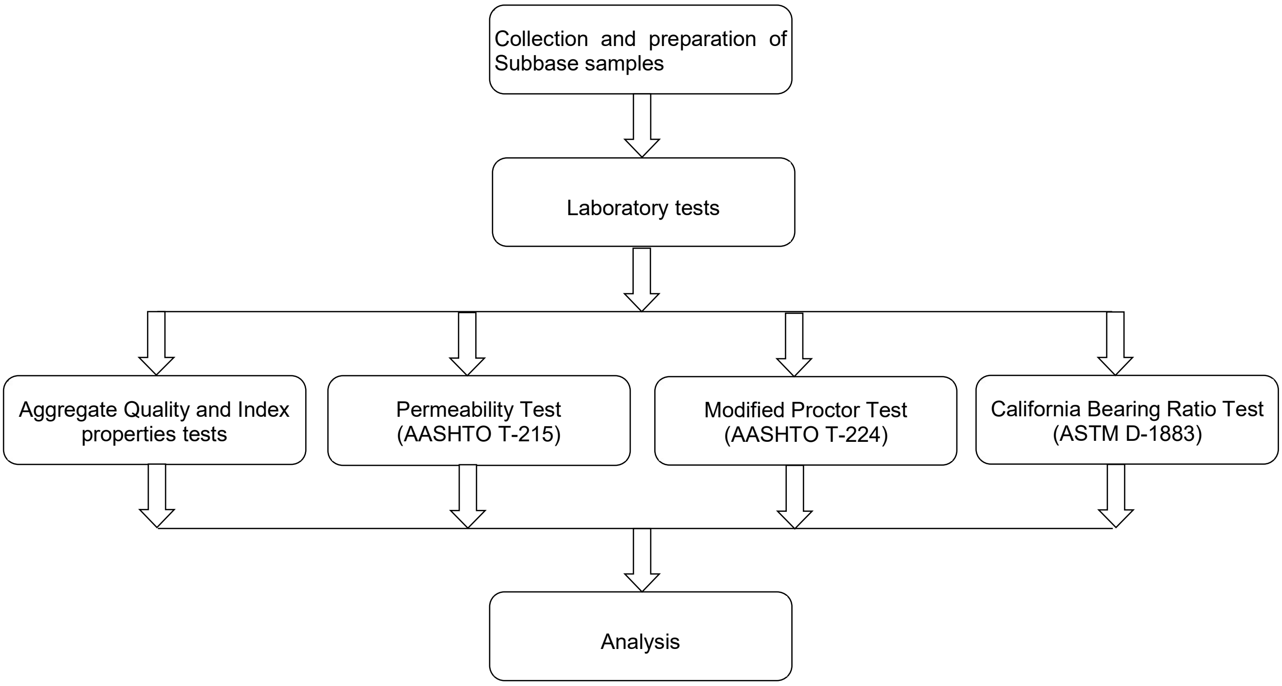


Fig. 2 – Testing Scheme

The trapped water within pavement structure can have adverse effects like reduction in strength of subgrade and subbase, movement of fine particles in subbase resulting in reduction of permeability etc. Raw materials are used by the researchers for ground improvement. Soil and fly ash combination can improve the CBR of sandy soil as compared to other types of soil [2]. Fly ash is an abundantly available environmental friendly by-product which is a potential stabilizer for improving the pavement characteristics [3]. CBR value is increased by 47%, once fly ash alongwith rice husk ash was used for stabilization of expansive soils [4]. The supplementary cementitious materials is also found beneficial in enhancing the frost durability of concrete. The use of lime as a supplementary cementitious materials is proven beneficial [5]. Lime was used as a common binding material two centuries ago [6]. The lime effect are more dominant in fine sandy soil as compared with medium grained sand. The sub-rounded particle also has more effect then the sub-angular particles of sand [7]. The polypropylene fiber can also increase toughness, shear strength and plasticity especially for cohesive soil [8]. The polypropylene fiber can also be used in combination with fly ash and lime and researchers have observed remarkable increase in the unconfined compressive strength [9]. The difference in length of fiber can lead to variation in failure strain of the composite specimens [10]. The reservoir dredged materials which lacks geotechnical properties can be stabilized by using cement, fly ash and fiber. Such composite material can be used in road subbase layer [11]. The subbase strength is generally evaluated by using Proctor, CBR and Unconfined compression test in the laboratory [12]. Correlations between CBR and the soil properties have been developed by the researchers [13]. The lime is used to stabilize the subbase material. The CBR values of lime stabilized subbase is higher than the untreated soil [14]. Subbase plays a key role in the performance of pavement. In this research, strength and permeability properties of subbase having Lime, Fly ash and Mat fiber as a stabilizer materials is evaluated.

The purpose of this research is to characterize the subbase material performance, through various laboratory tests and to increase the strength of subbase by adding lime, fly ash and mat fiber.

2.Material and methods

2.1 Materials

Lime, flyash and mat fiber is used to improve the subbase behaviour. The CBR values for subbase material with lime, fly ash and mat fiber is also calculated. Finally permeability of subbase having lime, fly ash and mat fiber is also evaluated. Figure 2 shows overview of the testing scheme.

2.1.1. Sample Collection.

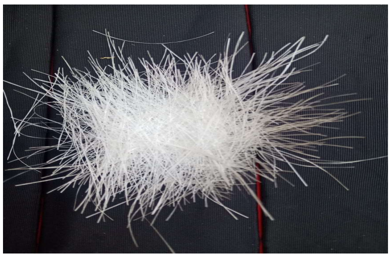
Subbase trial mixes were prepared with varying ratios of filler, lime, mat fiber and fly ash. Aggregates that are used in preparation of subbase mixes were taken from Sargodha quarry source, Pakistan. These aggregates are mostly used in local construction industry within province of Punjab, Pakistan. Lime, fly ash, mat fibers were purchased from Gujranwala City, Pakistan. Hydrated lime was used as it imparts binding characteristics once mixed with the fly ash.

2.1.2. Mix proportions.

The subbase characteristic are evaluated by adding lime, fly ash and mat fiber in variable proportions (Figure 3). Mat fiber is 1, 1.5 and 2 % of mix. Lime and fly ash is 2, 3 and 4% of mix. The chemical composition of flyash used is given in Table 1.

(a)

(b)



(c)

Fig. 3 - a) Lime, b) Fly ash, c) Mat Fiber

Table 1

Chemical composition of flyash

Chemical Composition	
Compound	Quantity (%)
SiO_2	57 to 65
Al_2O_3	28 to 32
Fe_2O_3	1 to 4
CaO	1 to 2
MgO	0.5
SO_3	Maximum 4
Na_2O	Maximum 1.5
Cl	0.01
LOI	1.30

2.2 Methods

Different tests are performed in the laboratory to assess the effectiveness of lime, fly ash and mat fiber.

2.2.1. Soil Classification Test

Soil classification tests included grain size distribution, specific gravity, water absorption and atterberg limit tests [15]. Series of seive analysis test on different samples were perfomed alongwith liquid limit determination through casagrande apparatus.

2.2.2. Aggregate Quality Test

Aggregate quality tests contain Los Angles Abrasion Test, Flakiness and Elongation Index. Aggregates wear and tear was checked through Los Angles Abrasion machine.

2.2.3. Compaction Test

Compaction test [16] is the most significant test used to assess the behaviour of material subject to compactive effort. It is the most essential parameter used in the construction of highways. Modified proctor test is performed in this study.

2.2.4. California bearing ratio (CBR) Test

3-point soaked CBR test [17] is performed and swell properties are also evaluated. CBR test was performed on 1000kN Universal testing machine using load controlled option.

2.2.5. Permeability Test

The reduction in permeability of subbase material is assessed through constant head permeability test [18].

3.Results and discussions

3.1.Grain size distribution, Liquid and Plastic limits.

Sieve analysis or Grain Size Distribution is a significant aspect used in the classification of soil. It is related with various engineering properties like swelling, shear strength, permeability, etc. Gradation is computed by sieve analysis in which finer and coarser particles are graded. Particles having coarser size (greater than 0.075 mm or retaining on sieve #200) are recommended to be used in subbase [19]. The selected material gradation curve is shown in Figure 4.

For soil classification determination of atterberg limits are also very important. Plasticity index can be calculated from liquid and plastic limit. The soil used in the subbase is Non-Plastic.

3.2. Specific Gravity and Water Absorption

Aggregate are consider weaker if they have lesser specific gravity and consider strong if they have maximum specific gravity. Water absorption provides an idea on the internal structure of aggregate. Specific gravity and water absorption tests were conducted as per AASHTO 85 [20] and ASTM D2216 standard respectively [21].

The specific gravity of coarse aggregate used is 2.6. The water absorption of coarse aggregate used is 0.81%.

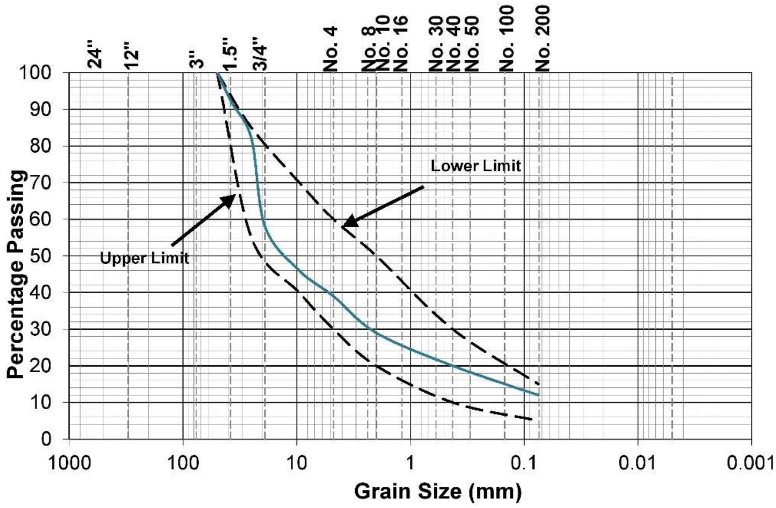
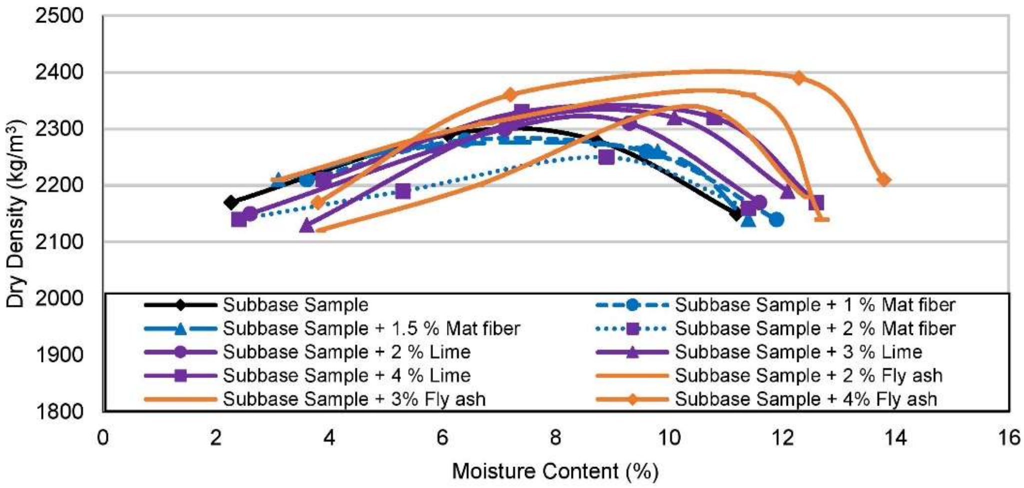
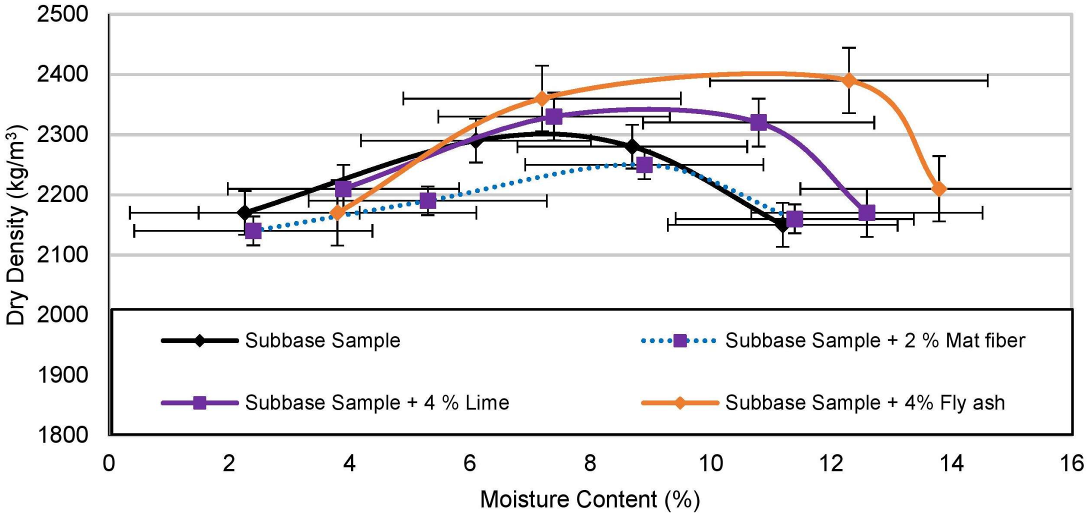


Fig. 4 - Grain size distribution



(a)



(b)

Fig. 5 – a) Effect of addition of lime, fly ash and mat fiber on Modified proctor test of subbase material, b) Maximum replacement content with error bars

3.3.Los Angles Abrasion Test.

Two tests are performed for Los Angles Abrasion test in order to attain the abrasion value of the aggregates. The test are performed as per AASHTO standard [22]. The average value of abrasion is 22.5%.

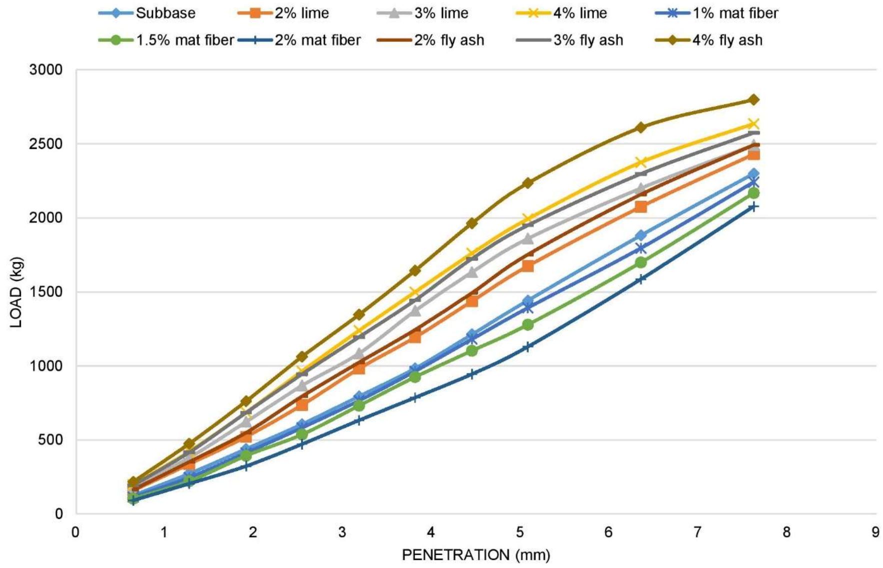
3.4.Flakiness and Elongation Test

The presence of flaky and elongated particles in base or subbase are unfavorable as it cause weakness and there are chances of break down because of the heavy traffic load. Therefore flakiness and elongation of the particles is essential in the construction of pavement. Flakiness index can be calculated as the ratio of weight of aggregate passed through different gauges to weight of sample taken. Whereas, Elongation index is the ratio of weight of aggregate retained on different gauges to the total weight of the aggregate taken. The Flakiness Index and Elongation Index of the aggregate used is 34.4 and 41.1 % respectively.

3.5.Compaction and CBR Test

Modified proctor test is carried out to assess the compaction characteristics of subbase material. The results of subbase material without addition of lime, fly ash and mat fiber and with addition of different percentages of fly ash, lime and mat fiber is is shown in Figure 5.

3-point soaked CBR test is performed. The test results of subbase material without addition of lime, fly ash and mat fiber and with addition of different percentages of fly ash, lime and mat fiber is shown in Figure 6. The results of CBR and Proctor tests are given in Table 2.



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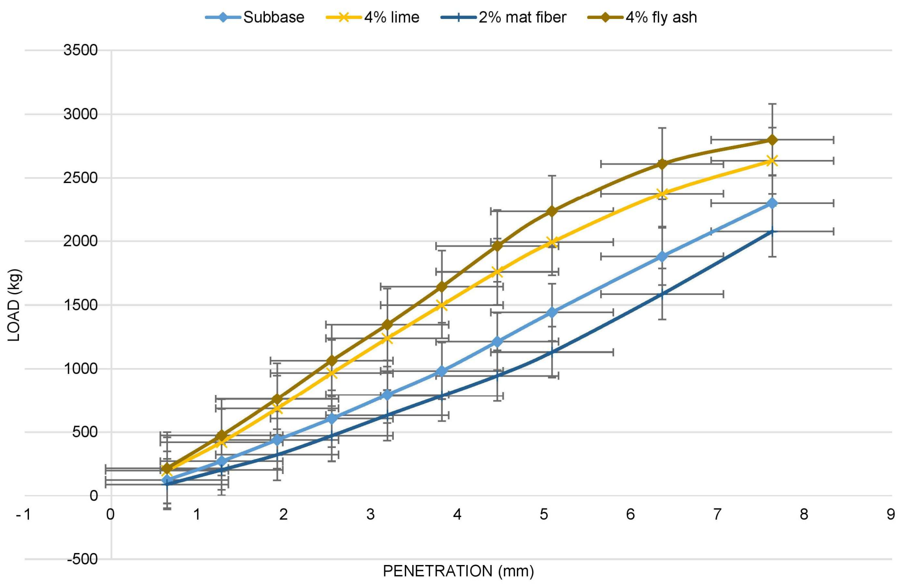

(b)

Fig. 6- a) Effect of addition of lime, fly ash and mat fiber on CBR test of subbase material, b) Maximum replacement content with error bars

Table 2

Test Results

Sample Name	Max. Dry Density (kg/m^3)	CBR (%)	
		0.1"	0.2"
Actual Subbase	2295	44.5	70.5
Subbase + 2% lime	2322	54.1	82.1
Subbase + 3% lime	2332	63.8	91.2
Subbase + 4% lime	2342	70.9	97.7
Subbase + 1% Mat Fiber	2288	42.8	68.3
Subbase + 1.5% Mat Fiber	2276	39.5	62.7
Subbase + 2% Mat Fiber	2255	34.7	55.4
Subbase + 2% Fly ash	2339	58.4	85.9
Subbase + 3% Fly ash	2369	69.5	95.6
Subbase + 4% Fly ash	2395	78.2	109.5

Variation in CBR and dry density values are observed with varying content of lime, fly ash and mat fiber.

3.6. Permeability Test

Constant head permeability test is performed and results are summarized in Table 3.

Table 3

Permeability test

Sample #	Sample Name	Coefficient of permeability m/sec
1	Actual Subbase	0.000052
2	Lime + Subbase	0.000031
3	Fly ash + Subbase	0.000040
4	Mat fiber + Subbase	0.00063

It is observed that addition of mat fiber, results in increase of permeability of subbase. Lime and fly ash imparts binding properties thereby results in reduction in permeability of subbase.

4.Conclusions

Based on the Gradation, Proctor, CBR and Permeability test on subbase material with addition of lime, fly ash and mat fiber, following conclusion can be drawn:

- CBR and maximum dry density is increasing with the increase of content of lime and fly ash in subbase. Whereas, CBR and maximum dry density is decreased with the increase in content of mat fiber. Lime and fly ash imparts binding characteristics to the subbase materials thereby increasing the CBR value whereas if only mat fiber is used dry density decreases because of its lighter mass.
- CBR value is increased to 27.2% by addition of 4% lime in the subbase sample. CBR value is increased to 39% by addition of 4% fly ash in the subbase sample. CBR value is decreased to 15.1% by addition of 2% mat fiber in the subbase sample. It was observed that if only mat fiber is used, it has adverse effect on CBR value because of its non cohesive properties.
- Maximum CBR value was achieved with 4% fly ash, but addition of fly ash in the subbase results in swelling. This swelling can disturb the pavement. Therefore, 4% lime is better to use as at 4% lime, CBR value was maximum with no swelling.
- Permeability is decreased by addition of fly ash and lime in the subbase sample, while permeability is increased with the addition of mat fiber as it has non cohesive properties.
- For better performance and durability of pavement structures, parameters like Gradation, Plasticity index, Los angles abrasion, Flakiness & Elongation index and CBR values must be properly evaluated. The performance characteristics of pavement can be enhanced by addition of lime and fly ash in the subbase.

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