

Stabilization of Fine Sand using Square Pieces of Waste Plastic as Admixture for Construction of Embankments for Road

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ABSTRACT: This research is concerned with the stabilization of fine sand using square pieces of waste plastic as admixture. The work is regarding, how to make fine sand which has low compressive strength and thus has nil cohesion and high permeability, useful for construction of embankments for roads. This analysis discusses the potential of fine sand stabilization with square pieces of square plastic as admixture. Present work has been taken up by addition of 5mm×5mm square pieces of waste plastic as admixture. The varying percentage 0.15%, 0.25, 0.50%, 0.75%, 1% of square pieces of plastic waste were mixed with fine sand of different densities 1.51gm/cc, 1.54gm/cc and 1.58gm/cc (M.D.D.). All the Direct Shear Tests were conducted at different mix compositions of square pieces of plastic waste and fine sand of different dry densities as arrived from Standard Proctor Test. Falling-Head Permeability Tests were also performed on different mix compositions. On the basis of the experiments performed, it is determined that the stabilization of fine sand using square pieces of plastic waste as admixture improves the strength characteristics of the fine sand so that it becomes usable as construction of embankment.

KEYWORDS: Direct shear, fine sand, permeability, square pieces of plastic.

I. INTRODUCTION

In many countries all-over the world, fine sand is found in ample. It is being unnoticed for the use of construction of embankment of roads because of its low bearing capacity and greater compressibility. The advancement of a soil at a site is necessary due to rising cost of the construction of the road in this situation the properties of soil can be advanced by soil stabilization.

Soil stabilization is the alteration of soil to make it serve better its intended engineering purpose. Stabilization can increase the shear strength of soil, thus improving the load bearing capacity of a sub-grade to support and foundations embankment. Soil stabilization can be utilized on roadways, parking areas, site development projects, airports and other situation where sub-soil are not suitable for construction.

The new technique of soil stabilization can be effectively used to meet the challenges of society, to reduce the quantities of waste, producing useful materials from non-useful waste materials. Since the use of plastic in diversified forms such as chairs, bottles, polythene bags, etc., has been advancing speedily and its disposal has been a problem all the time regarding the environmental concern, using square pieces of waste plastic as soil stabilizer would reduce the problem of disposing the plastic as well as increases the bearing capacity of soil in an economical way. The laboratory tests studies have been done on by direct admix of fine sand with pieces of plastic waste. Many researchers like Purohit D.G.M. et al. (2009), Awad ALKarni et al. (2012), jain O.P. et al. (1979), V. Mallikarjuna et al. (2016), Kevin M. (1978) and Wayal A.S. et al. (2012) have worked on stabilization of soils.

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II. RELATED WORK

Various stabilization techniques available are mechanical stabilization with special stabilizers, chemical stabilization, thermal stabilization, electrical stabilization, complex stabilization, stabilization by grouting and geotextiles. At surface, soil stabilization with waste material as admixture is more economic than any other method; hence we have selected plastic waste as our admixture in stabilization technique.

III. MATERIALS USED FOR PRESENT STUDY

A. FINE SAND

Fine sand is found in abundance in Western Rajasthan. The fine sand has similar characteristics which are found in various Towns of Jodhpur. Hence the sand used in present study was brought location near Dangiyawas-Banar villages, at about 30-35 kms away from Jodhpur on Jodhpur-Jaipur Road. Fine sand has nil cohesion and poor compressive strength and hence need stabilization. Fine sand is uniform clean sand as per Unified Soil Classification System. Particles size ranges between 75μ to 1 mm that is fine coarse sand, round to angular in particle shape as per Indian Standard Classification System.

B. PLASTIC WASTE

Plastics are considered as one of the important invention which has remarkably assisted in different aspects of life whether it might be in scientific field or others. The use of plastic has been enormously increasing these days. But now, plastic has become the significant pollutant of Environment because of the Use and Throw mechanism and everyone should think about this in the present scenario. The admixture used in present study was Polyethylene or polythene, as it is also known, as a polymer, produced by the polymerisation of ethylene gas, a derivative of the petroleum industry. The polymer consists essentially of long-chain molecules of very high molecular weight, made up of many thousands of the $-CH_2-$ repeating unit. The plastic waste used is of 4th type that is LDPE (Low Density Polyethylene) left after domestic, industrial etc. The plastic waste brought for the research work is a square of 5mm x 5mm pieces cut from plastic sheets by scissor and shredding machine. This plastic waste was availed from a manufacturing unit near Jodhpur Rajasthan (India). Fig.1 shows the square pieces of plastic waste admixture which is used for present research. Physical and engineering properties of plastic waste material are shown in table 1.



Fig.1. Square Pieces of Plastic Waste Admixture

Table 1: Summary of the Physical and Engineering Properties of the Tested Plastic Waste Material

Physical and Engineering Properties	
Density	0.910-0.925 gm/cm ³
Water Absorption	Slight
Crystallinity	50-65%
Yield strength	4-16 MPa
Melting temperature	115°C

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IV. TEST PROGRAM AND PROCEDURE

The laboratory investigation on fine sand stabilization with square pieces of plastic waste as admixture was performed. This work is done for beneficial utilization of plastic waste and a mix proportion that can be mixed with fine sand as a best stabilizer with limited detrimental effects.

The objective of the present study is to evaluate the use of fine sand as a construction material after stabilizing it with plastic waste as admixture. The present study has been undertaken with the following objectives:

1. To study the effect of moisture content on dry density of fine sand.
2. To study the changes in shear stress of fine sand of different dry densities mixed with square pieces of plastic waste in different proportions.
3. To study the changes in permeability of fine sand by mixing with square pieces of plastic waste in different proportions.

A. TEST PROGRAM

The test program included the preliminary tests for fine sand and mix compositions of fine sand with square pieces of plastic waste. Following tests were carried out:

1. Determination of particle size distribution of fine sand.
2. Standard Proctor Test (Proctor Compaction Test) for determining different dry densities for fine sand.
3. Direct Shear Test to determine shear stress of fine sand and mix compositions with square pieces of plastic waste.
4. Permeability by Variable Head Permeability Test of fine sand and mix composition with square pieces of plastic waste.

Table 2 shows the variables which are investigated in present study.

Table 2: Variables Investigated

S. No.	Effect of	Variables	Range Investigated
1	Moisture content in sand	Dry density	1.51 gm/cc, 1.54 gm/cc and 1.58 gm/cc
2	Square pieces of Plastic on different properties of sand	Square size	Plastic are 5mm square size
3	Mix Square pieces of Plastic waste by dry weight of sand	Proportion percentage	0.15%, 0.25%, 0.50%, 0.75% and 1%

i. Particle Size Distribution or Gradation Test of Fine sand

The particle size distribution test or gradation test was carried out with Indian Standard Sieve size 4.75 mm, 2.36 mm, 1.18 mm, 600 μ , 425 μ , 300 μ , 150 μ , 75 μ , pan and weigh balance in the laboratory.

A typical sieve analysis involves a nested column of sieve with wire mesh cloth (screen). A representative sample of 1000 gm is poured into the top sieve which has the largest screen opening of 4.75 mm. Each lower sieve in the column has smaller opening than the one above. The base is a round pan, called the receiver. The sample was shaken vigorously for 10 minutes on sieve shaker. After the shaking, the weight of material retained on each sieve was weighed. Percentage passing through each sieve was calculated and plotted against particle size. Since percentage passing 75 μ is within 1% only, hydrometer analysis was not done.

$$\text{Percentage (\%) Retained} = \frac{W_{\text{sieve}}}{W_{\text{total}}} \times 100\%$$

Where W_{sieve} is the weight of aggregate in the sieve in gm

W_{total} is the total weight of the aggregate in gm

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The cumulative percentage passing of the aggregate is found by subtracting the percent retained from 100%.

Percentage (%) Cumulative Passing = 100% - Percentage (%) Cumulative Retained

The results of particle size distribution have been shown in table 3, table 4 and figure 2.

Table 3: Particle Size Distribution of Fine Sand

S.No.	Sieve Size	Weight Retained (gm)	% Weight Retained	Cumulative % Weight Retained	Cumulative % Weight Passing	% Finer
1.	4.75 mm	2.0	0.2	0.2	99.8	99.8
2.	2.36 mm	2.0	0.2	0.4	99.6	99.6
3.	1.18 mm	2.0	0.2	0.6	99.4	99.4
4.	600 μ	1.0	0.1	0.7	99.3	99.3
5.	425 μ	2.0	0.2	0.9	99.1	99.1
6.	300 μ	2.0	0.2	1.1	98.9	98.9
7.	150 μ	904.0	90.4	91.5	8.5	8.5
8.	75 μ	82.0	8.2	99.7	0.3	0.3
9.	Pan	3.0	0.3	100	0	0

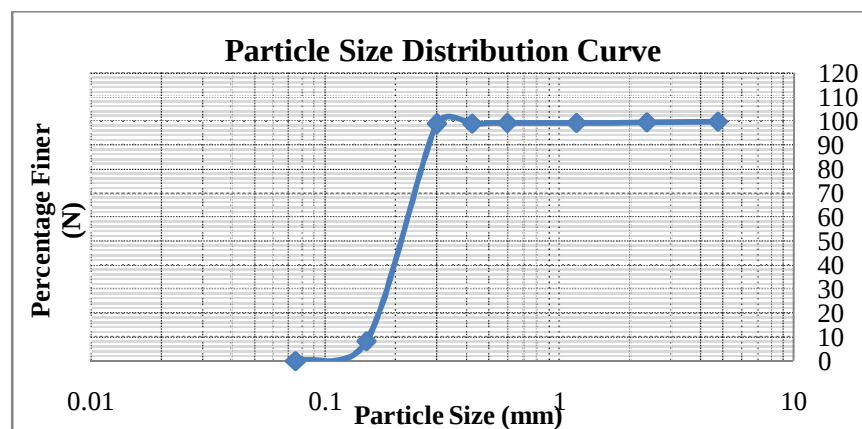


Figure 2: Particle Size Distribution Curve

Table 4: Results of Particle Size Distribution

S. No.	Property	Test Media (Fine Sand)
1.	Coefficient of Uniformity (C_u)	1.31
2.	Coefficient of Curvature (C_c)	1.08
3.	Mean Diameter (D_{50}) mm	0.20
4.	Effective Size (D_{10}) mm	0.16
5.	Fine Soil Fraction (75 μ)	0.10%

ii. STANDARD PROCTOR TEST

Standard proctor covers the determination of the relationship between the moisture content and density of soils. The standard proctor test was performed in accordance with IS 2720 (Part VII) on fine sand. In this test, a standard mould of 100 mm internal diameter and an effective height of 127.3 mm, with a capacity of 1000 ml are used. The mould had

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a detachable base plate and a removable collar of 50 mm height at its top. The soil was compacted in the mould in 3 equal layers; each layer was given 25 blows of 2.6 kg rammer falling through a height of 310 mm. The result tabulated in figure 3 shows that on increment of moisture content, dry density first decrease and then increase. In the curve dry density first decrease due to bulking of sand. After reaching maximum dry density on optimum moisture content, dry density decreases. The variation of dry density with moisture content shows that the required dry densities 1.51 gm/cc, 1.54 gm/cc and 1.58 gm/cc for the experiments occur at 4%, 12% and 18% moisture content.

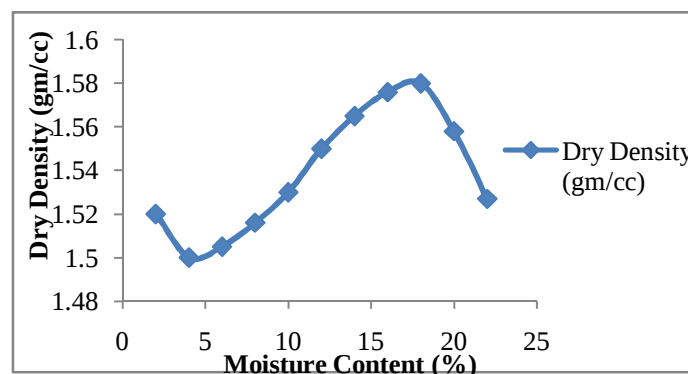


Figure 3: Dry Density v/s Moisture Content Curve

iii. Direct Shear Test

The Direct Shear Test is used to determine the shearing strength of the fine sand using the direct shear apparatus. Direct shear tests were performed on mix composition of fine sand of 1.51 gm/cc, 1.54gm/cc and 1.58 gm/cc density with square pieces of plastic waste of 0.15%, 0.25, 0.50%, 0.75% and 1% by dry weight of sand. Tests were carried out with a strain controlled shear apparatus at rate of 1.25 mm/min to determine failure stress and angle of internal friction (ϕ) of different mix composition in accordance with ID 2720 (Part XIII).

4.1.4.1 Comparative Study

A comparative study of variation of stresses has been made from the test results. The variation of shear stress graphs, showing on X-axis corresponding normal stress 0.1 kg/cm², 0.2 kg/cm², 0.3 kg/cm² and Y-axis corresponding shear stress at 1.51 gm/cc, 1.54 gm/cc and 1.58 gm/cc dry density sand mixed with 0.15%, 0.25, 0.50%, 0.75% and 1% admixture have been tabulated in following tables and figures.

The value of shear stress linearly increases for different dry density, different percentage of admixture and different normal stress. It has been found from the study that on keeping dry density as constant, the shear stress value of the mix composition increases as the normal stress increases. Also for the same normal stress, as the quantity of the admixture increase, the shear stress value of the mix composition increases as the dry density increases.

From the results obtained it can be concluded that angle of internal friction (ϕ) increases with increase in dry density in mix composition. For the same dry density, the angle of internal friction ϕ increases with increase in percentage or quantity of square pieces of plastic waste.

Table 5: Variation of Shear Stress for 1.51 gm/cc Dry Density Sand with 0.15%, 0.25, 0.50%, 0.75% and 1% Admixture

Normal Stress (kg/cm ²)	Shear Stress (kg/cm ²)					
	Mix Composition					
	0% Admixture	0.15% Admixture	0.25% Admixture	0.50% Admixture	0.75% Admixture	1%Admixture
0.1	0.1056	0.1452	0.1716	0.1716	0.132	0.1452
0.2	0.2046	0.264	0.264	0.2508	0.198	0.2046
0.3	0.3168	0.3894	0.3564	0.33	0.2636	0.2666

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Table 5 consist of variation of shear stress at dry density 1.51 gm/cc sand with mix composition 0.15%, 0.25%, 0.50%, 0.75% and 1% admixture of plastic waste and normal stress 0.1, 0.2, 0.3kg/cm². As we increase the percentage of plastic waste admixture there is an increase in the shear stress value. As shown in figure 4 the graph increases linearly in shear stress with increases in normal stress and mix composition.

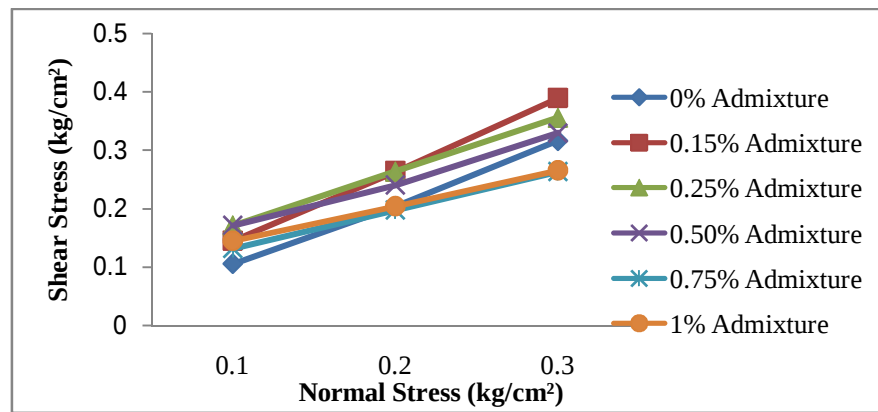


Figure 4: Variation of Shear Stress for 1.51 gm/cc Dry Density Sand with 0.15%, 0.25%, 0.50%, 0.75% and 1% Admixture

Table 6: Variation of Shear Stress for 1.54 gm/cc Dry Density Sand with 0.15%, 0.25%, 0.50%, 0.75% and 1% Admixture

Normal Stress (kg/cm ²)	Shear Stress (kg/cm ²)					
	Mix Composition					
	0% Admixture	0.15% Admixture	0.25% Admixture	0.50% Admixture	0.75% Admixture	1% Admixture
0.1	0.1056	0.1122	0.1188	0.1386	0.1452	0.2244
0.2	0.1914	0.2232	0.2244	0.264	0.2244	0.2904
0.3	0.2812	0.3432	0.3233	0.396	0.3036	0.366

Table 6 consist of variation of shear stress at dry density 1.54 gm/cc sand with mix composition 0.15%, 0.25%, 0.50%, 0.75% and 1% admixture of plastic waste and normal stress 0.1, 0.2, 0.3kg/cm². As we increase the percentage of plastic waste admixture there is an increase in the shear stress value. As shown in figure 5 the graph increases linearly in shear stress with increases in normal stress and mix composition.

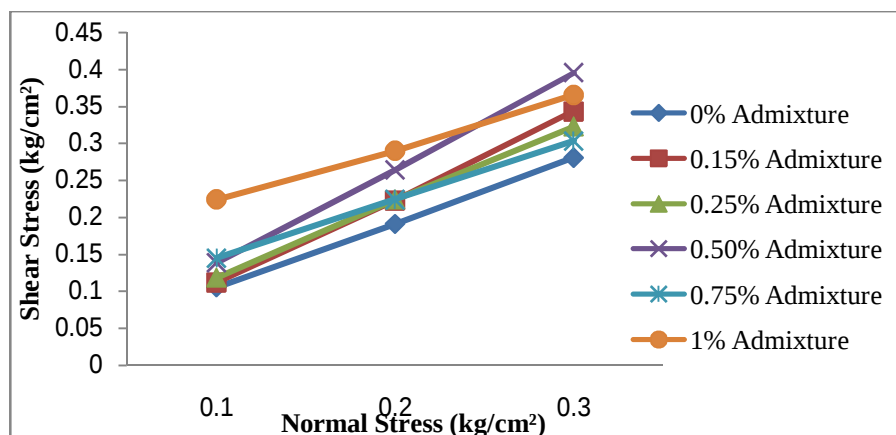


Figure 5: Variation of Shear Stress for 1.54 gm/cc Dry Density Sand with 0.15%, 0.25%, 0.50%, 0.75% and 1% Admixture

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Table 7: Variation of Shear Stress for 1.58 gm/cc Dry Density Sand with 0.15%, 0.25, 0.50%, 0.75% and 1% Admixture

Normal Stress (kg/cm ²)	Shear Stress (kg/cm ²)					
	Mix Composition					
	0% Admixture	0.15% Admixture	0.25% Admixture	0.50% Admixture	0.75% Admixture	1% Admixture
0.1	0.099	0.2112	0.1056	0.2112	0.1122	0.1584
0.2	0.1914	0.3498	0.22	0.3564	0.198	0.2376
0.3	0.2838	0.495	0.33	0.516	0.2772	0.3164

Table 7 consist of variation of shear stress at dry density 1.58 gm/cc sand with mix composition 0.15%, 0.25%, 0.50%, 0.75% and 1% admixture of plastic waste and normal stress 0.1, 0.2, 0.3kg/cm². As we increase the percentage of plastic waste admixture there is an increase in the shear stress value. As shown in figure 6 the graph increases linearly in shear stress with increases in normal stress and mix composition.

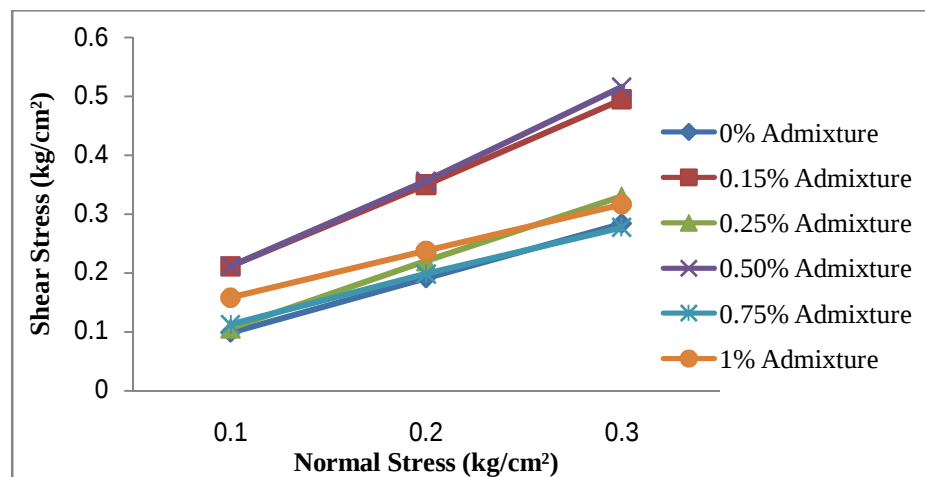


Figure 6: Variation of Shear Stress for 1.58 gm/cc Dry Density Sand with 0.15%, 0.25, 0.50%, 0.75% and 1% Admixture

Table 8: Variation of ϕ with Dry Density of Sand and % Admixture

Dry Density (gm/cc)	Angle of Internal Friction ϕ (Degree)					
	Mix Composition					
	0% Admixture	0.15% Admixture	0.25% Admixture	0.50% Admixture	0.75% Admixture	1% Admixture
1.51	31.12°	33.18°	38.24°	42.42°	46.36°	50.42°
1.54	35.18°	38.24°	41.18°	45.36°	49.6°	52.6°
1.58	38.18°	39.3°	42.42°	48.18°	54.48°	56.42°

Table 8 consist of variation of angle of internal friction ϕ at dry density 1.51gm/cc, 1.54gm/cc, 1.58gm/cc sand with mix composition 0.15%, 0.25%, 0.50%, 0.75% and 1% admixture of plastic waste. As we increase the percentage of plastic waste admixture and variation in dry density there is an increase in the angle of internal friction value. As shown in figure 7 the graph increases linearly in angle of internal friction with increases in mix composition and dry density.

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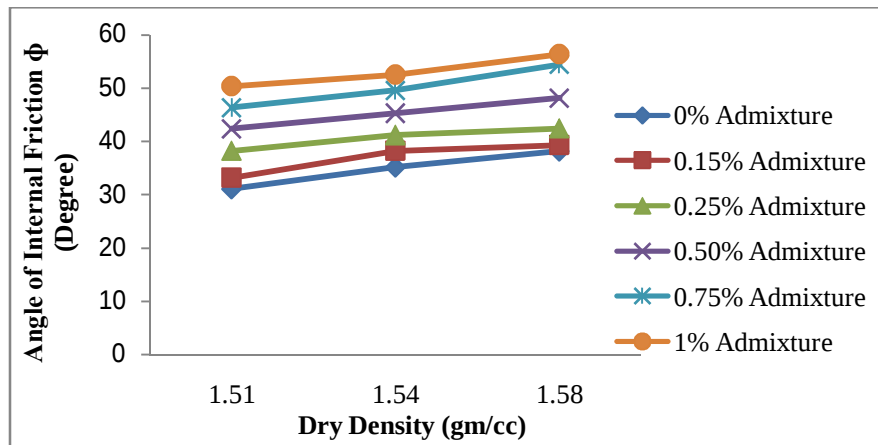


Figure 7: Variation of ϕ with Dry Density of Sand and % Admixture

v. Variable Head Permeability Test

Permeability is the measure of the ease with which water can flow through a soil sample. The tests were conducted in variable head permeameter according to IS 2720 (Part XVII). Test investigations were carried out on variable head permeameter with mix compositions of 1.58 gm/cc dry density fine sand and square pieces of plastic waste in varying percentages of 0.15%, 0.25, 0.50%, 0.75% and 1%.

A conclusion from the test results obtained that coefficient of permeability (k) increases with increase in percentage of square pieces of plastic waste as given in table 9 and figure 8.

Table 9: Variation of Coefficient of Permeability k (cm/sec) with Mix Composition

S.No.	Percentage (%) Admixture	Coefficient of Permeability (cm/sec)
1.	0.15%	1.51×10^{-3}
2.	0.25%	1.57×10^{-3}
3.	0.50%	1.76×10^{-3}
4.	0.75%	1.86×10^{-3}
5.	1%	2.04×10^{-3}

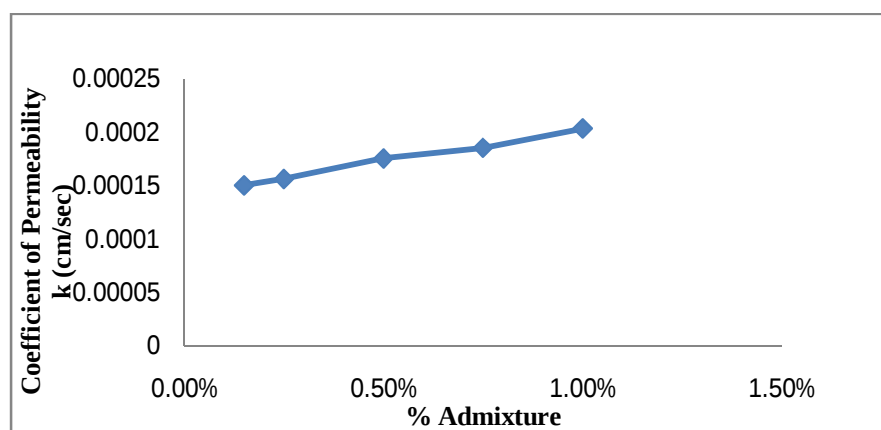


Figure 8: Variation of Coefficient of Permeability k (cm/sec) with Mix Composition

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V. CONCLUSIONS

In this investigation we have used square pieces of plastic waste in different proportions to study its effect on various geotechnical properties of fine sand of Western Rajasthan. The results of the testing program clearly show that the engineering properties of the fine sand improved considerably due to stabilizing with square pieces of plastic waste. In the present investigation, as we are increasing the quantity of admixture of square pieces of plastic waste, the angle of internal friction increases. So we have stopped the further increment of admixture. Further study can be done by addition of more amount of admixture.

A few generalized conclusions are summarized below:

1. The shear test were performed for mix compositions of fine sand of different dry densities 1.51 gm/cc, 1.54 gm/cc and 1.58 gm/cc with square pieces of plastic waste of varying percentage 0.15%, 0.25%, 0.50%, 0.75% and 1%. The angle of internal friction (shearing resistance) ϕ increases with increase in dry density of fine sand and quantity of the square pieces of plastic waste. As the ϕ is increasing, the required section for embankment is reduced.
2. Permeability Tests were performed for mix composition of 0.15%, 0.25%, 0.50%, 0.75%, and 1% of square pieces of plastic waste and fine sand of 1.58 gm/cc dry density. The coefficient of Permeability k (cm/sec) increases with increase in the percentage of square pieces of plastic waste mixed to fine sand. Greater the percentage of square pieces of plastic waste more was the mix composition permeable. Hence, the impermeable material should be used in the mix composition to reduce the permeability.
3. After this investigation we conclude that square pieces of plastic waste can successfully be used as admixture for fine sand stabilization. It can be used for the making embankment for construction of road.

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