Effect of Fibers on Permeability of Sand- A Case Study

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ABSTRACT

Over the last few years, environmental and economical issues have stimulated interest in the development of alternative materials and reuse of industrial waste/by-products that can fulfill specification of naturally existing materials such as sand with improvement in strength bearing properties and simultaneously reduction in permeability. The results usually should include saving in construction cost and reduction of implementation time. It can be attained by the various techniques available in Geotechnical Engineering for improving the mechanical and engineering properties of the soil.

However, each technique has some limitations and suitability to get maximum improvement in the soil conditions with minimum effort. During the construction of embankments, abutments, earthen dams and other retaining structures a huge amount of soil is needed. It can be done by partially replacing soil with some alternative materials like sand. As compared to the natural soil, the permeability of sand is very high and it has self-draining capability. It is necessary to know the strength characteristics of sand before its successful application in various fields. In the present study, the possibility of using sand for permeability study was investigated experimentally. Besides this effect of fiber inclusion in the mixture of sand was studied. It was found that it can act as a substitute for reduction in permeability of sand and at the same time gain in strength.

Keywords: Sand, Permeability, fibers, strength

1. INTRODUCTION

Soil specially cohesion less material like gravel, sand and coarse silt cannot take even low stress in tension and fails instantaneously with large values of permeability. The early man has known this phenomenon from intuition. Over the last few years, environmental and economical issues have stimulated interest in the development of alternative materials and reuse of industrial waste/by-products that can fulfill specification of naturally existing materials such as sand with improvement in strength bearing properties and simultaneously reduction in permeability. The results usually should include saving in construction cost and reduction of implementation time. It can be attained by the various techniques available in Geotechnical Engineering for improving the mechanical and engineering properties of the soil. However, each technique has some limitations and suitability to get maximum improvement in the soil conditions with minimum effort.The concept of soil reinforcement is an ancient technique and demonstrated abundantly in nature by animals, birds, and the action of tree roots. Constructions using these techniques are known to have existed in the fifth and fourth millenniums B.C. This concept is used for the improvement of certain desired properties of soil such as bearing capacity, shear strength (C and φ), permeability, etc.

This concept and principle was first developed by Vidal, in which he demonstrated that the introduction of reinforcing elements in a soil mass increases the shear resistance of the medium. Recently, the soil reinforcement technique is well established and is used in various applications like improving the bearing capacity, filter, and drainage control. Conventional reinforcement methods comprise continuous inclusions of strips, fabrics, and grids into the soil mass. Also the random inclusion of various types of fibres is considered to be modification of the same technique. These fibres act to interlock particles and aggregates in a unitary coherent matrix.This work investigates the use of polypropylene fibre for similar purpose. Mostly, the discrete fibres are simply added and mixed with the sandy soil. One of the main advantages of randomly distributed fibres is the maintenance of strength isotropy and absence of potential failure plane, which can develop parallel to the oriented reinforcement.

This paper presents the experimental results of the influence of polypropylene fibres on permeability response of a typical sandy soil. Tests were conducted using different fibre contents in various proportions, namely 6 mm, 12 mm and a mixture of 6 mm and 12 mm. A series of permeability tests were conducted on sandy soils for various combinations.

2. MATERIALS PROPERTIES AND EXPERIMENTAL STUDY

Experimental program consisted of exhaustive testing to explore the possibility of improving the engineering properties of sandy soils with inclusion of polypropylene fibre. The following tests were performed to achieve the various objectives

a. Proctor Compaction test.
b. Constant head permeability test

Soil used: It is proposed to use sand. The basic properties of soil were found out by performing various test i.e. particle size analysis, optimum moisture content, specific gravity etc. The soil is classified as SP as per Indian standard. Physical properties of sand are presented in table

Table.1 :Properties of Sand

Specific gravity	2.65
Optimum moisture content (%)	14.3
dry unit weight	17kN/m^3
Maximum dry density	1. 72g/cc

FIBERS: It is proposed to use commercially available poly-propylene fibers of length 6mm and 12 mm. The physical properties of fibers, as supplied by the manufacturer are in Table 2.

Table 2. Physical Properties of Fibres

Property	Values	Property	Values
Colour	White	Specific Gravity	0.91
Cut length	6mm, 12mm	Equivalent diameter (µm)	32-55
Denier (d)	1.5	Water absorption (%)	85.22
Tensile Strength (MPa)	600	Acid resistance	Excellent
Melting Point (°C)	>250	Alkali resistance	Good

3. MODIFIED PROCTOR COMPACTION TEST

The tests were performed in accordance with ASTM D 1557. The specimens were of 102 mm and 116 mm height. The degree of compaction of soil influences several of its engineering properties such as CBR value, compressibility, stiffness, compressive strength, permeability, shrink, and swell potential. It is, therefore, important to achieve the desired degree of relative compaction necessary to meet the required soil characteristics. The optimum moisture content (OMC) and maximum dry unit weight found in these tests were used for the various permeability tests conducted their after.

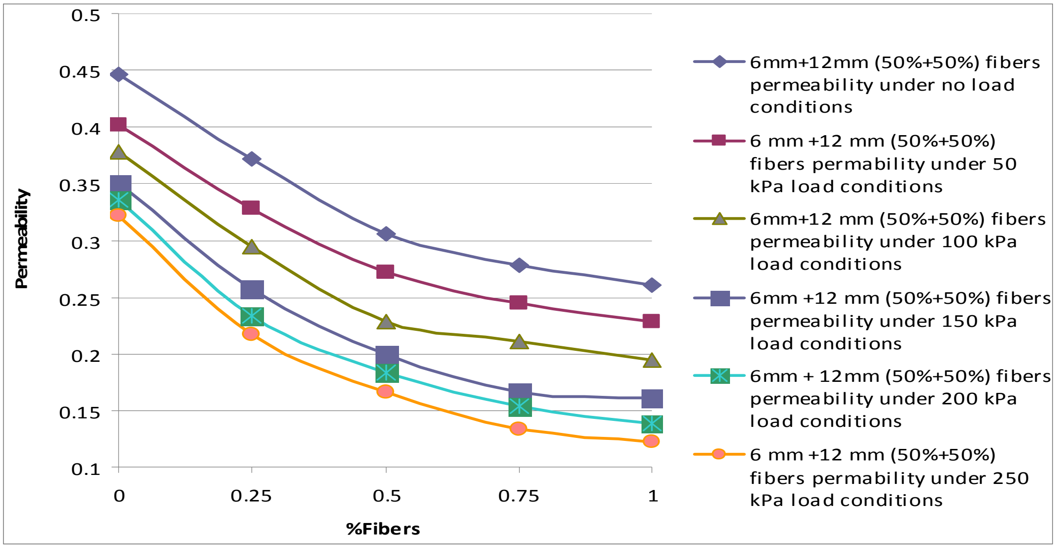
4. PERMEABILITY TESTS

The constant head permeability tests were performed in accordance with IS 2720 part 17-1986 for both horizontal and vertical permeability cases. The sample sizes were of 600 mm length, 300mm width and 300mm height. At the optimum moisture content (OMC) and maximum dry unit weight, the tests were performed. The tests were performed under no load conditions as well as under different loading conditions. Moreover the tests were performed without any reinforcement and with fibre reinforcement of 6mm, 12mm and mix of 6mm and 12mm fibres(in equal proportions). In order to evaluate the equivalent coefficient of permeability of the soil–system, permeameter tests were carried out by varying the fibers in various ratios with sand as given in above table. This test was conducted for both horizontal and vertical cases. The soil system was surrounded by geotextile sheet on open sides so that the pores in the system does not get clog while passing the water through the system.

After completion of saturation of the sample, the permeameter was mounted on the existing consolidation loading frame in the laboratory for applying normal stress increments. Normal stresswas increased in intervals of 50 kPa up to 250 kPa from 0 kPa. About 25–35 min are required to attain a stabilized value of transmissivity of compressible geosynthetics under the influence of load (Shukla and Sharma, 2006) and hence 1 h loading time was maintained for an increment of each stress level before the commencement of readings. Simultaneously the dial gauge readings were also recorded for each set of readings and each increment of stress with time. In this paper, the volume collected in 2 min was recorded in a measuring cylinder and the equivalent coefficient of permeability of soil system was determined by using equation for determination of coefficient of permeability as per IS codes.

5. RESULTS AND DISCUSSION

The equivalent coefficient of permeability of soil–geosynthetics system was determined by varying the percentage of fibers and mixture of sand. Fig. 1 presents variation of equivalent coefficient of permeability with normal stress for sandy soil. With an increase in normal stress a decrease in equivalent coefficient of permeability of the soil can be noted. Considerable increase in the equivalent coefficient of permeability of soils with the inclusion of fibers can be noted from Fig. 1. Fig1. depicts data when permeability is allowed through horizontal layers whereas Fig. 2 represents the same under vertical permeability conditions.



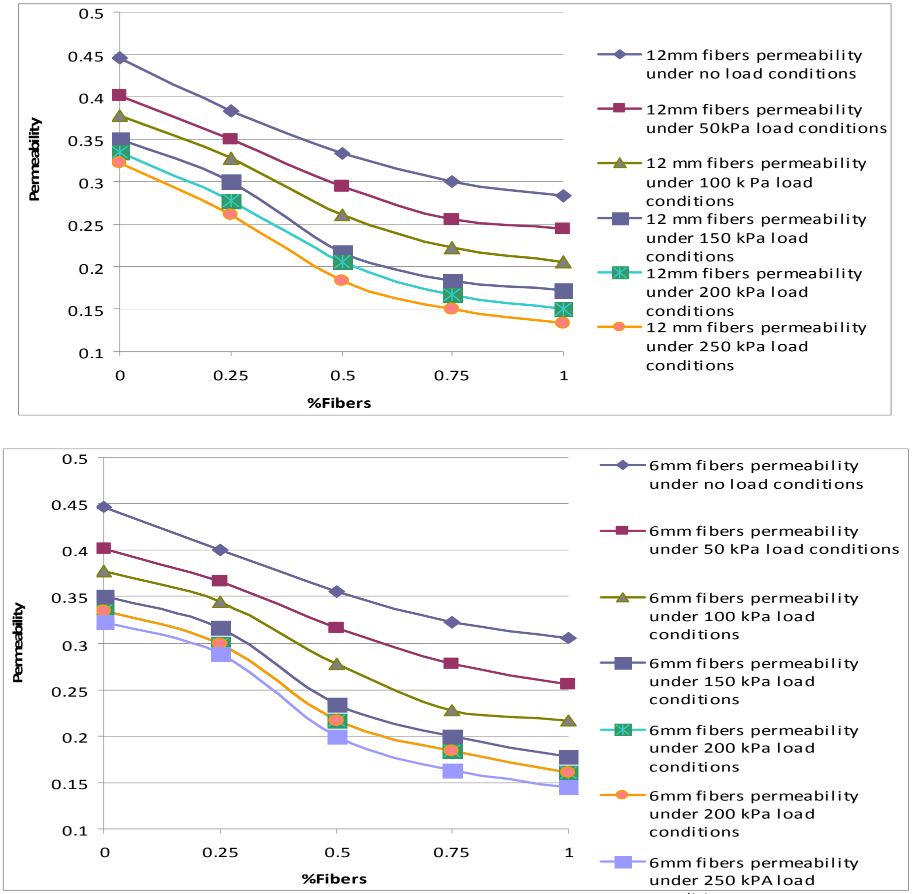
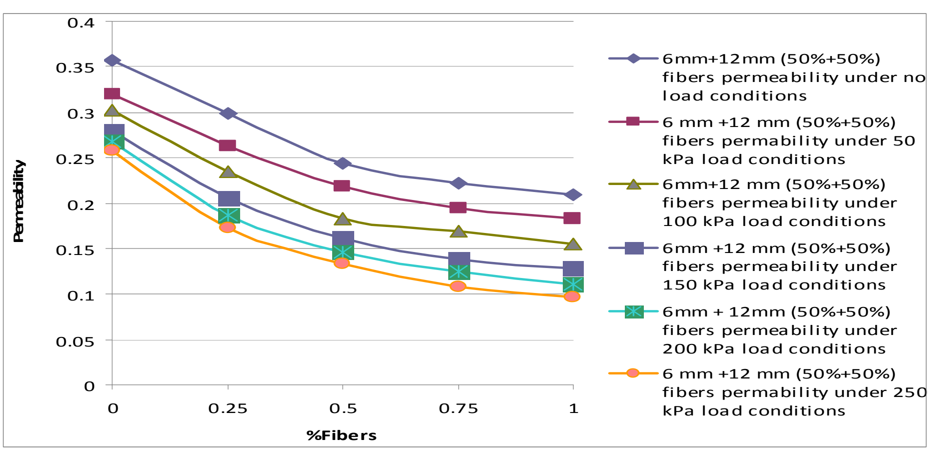


Fig.1: Horizontal permeability of sand with various loading conditions



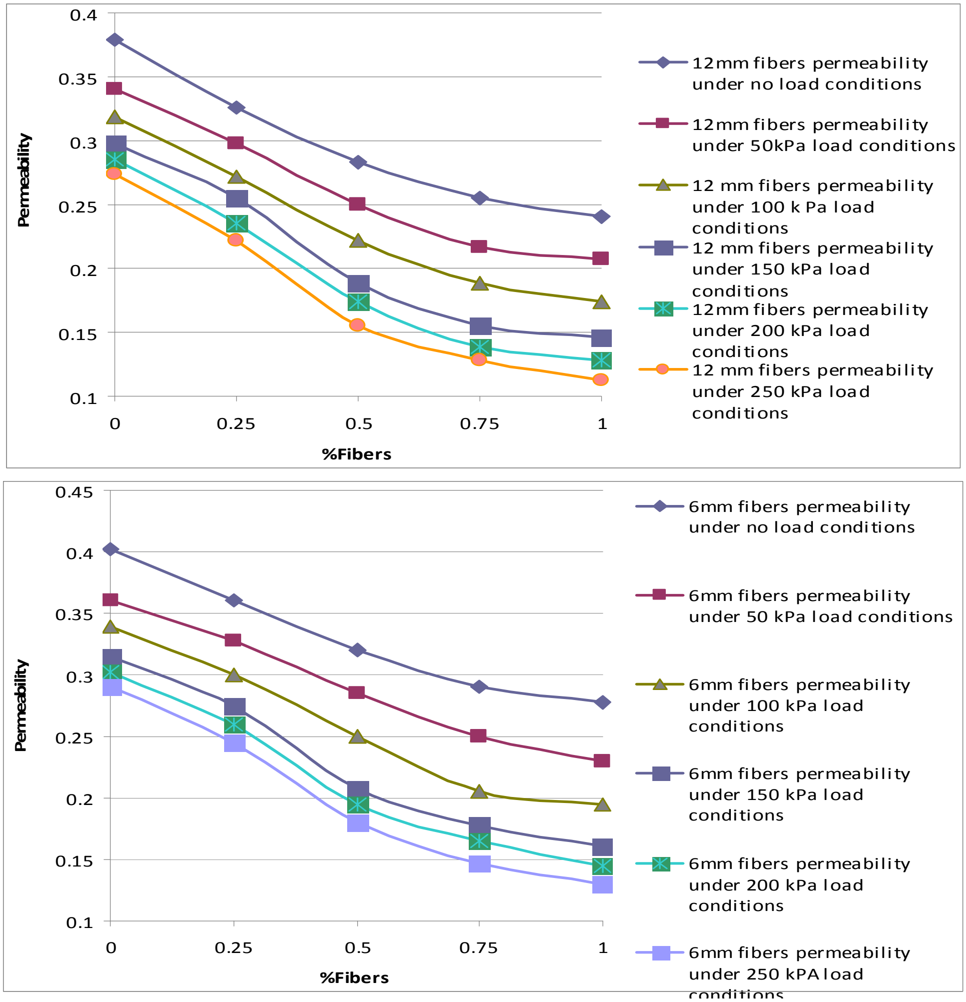


Fig.2: Vertical permeability of sand with various loading conditions

However, increase in equivalent in-plane permeability calculated at all normal stresses was found to be higher for higher percentage of fibers and higher stress level. The variation of equivalent coefficient of permeability has been studied for five levels of loading conditions for soil mix for both horizontals well as vertical cases of permeability. Moreover, with an increase in normal stress, equivalent coefficient of permeability of soil–fibers mix was found to decrease gradually for all the tests with various combinations of fibers more in case of vertical permeability study. To some extent, this was observed in the present study through readings obtained from dial gauges placed on top of the loading plate that confirmed that soil has settled down in a more compressed form with more addition of fibers.

6. CONCLUSIONS

The computed values of equivalent coefficient of perm abilities at zero normal stress for all the tests are higher than the measured values. The measured coefficient of permeability of soil–pond ash mix system appears to be a function of fibers mixed in the soil mix and the overburden stress of the soil acting on it. However, further work in this direction is warranted in the direction of strength of soils with and without fibers.

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