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# Modification of Darcy's law for sea bed sand

**Omkar Kopnar[#1], Amol Ghuge[#2], Niyati Bagad[#3], Bhakti Jadhav[#4], Indrajeet M. Jain[#5]**

*[#1-4]UG Students, Civil Engineering Department, Savitribai Phule Pune University, Pune*
*[#5]Assistant Professor, Civil Engineering Department, Savitribai Phule Pune University, Pune*
*[1] omkar.kopnar1@gmail.com*

*[2] ghugeamol100@gmail.com*

*[3] jadhavbhakti007@gmail.com*

*[4] niyatibagad1406@gmail.com*

*[5] prof.indrajeetjain@gmail.com*

***Abstrac***

*A soil consists of different size of particles and it has different permeability characteristics theoretical equation based on Darcy's law are often used to determine the coefficient of permeability in layered soil. Moreover, there is a very limited body of literature available on the validity of Darcy's law. This paper study the rate of permeability, when water contains salt flows in oceanic sand. In this paper, we examine the effect of porosity and size of sand on coefficient of permeability. Also, we study the effect of salt concentration and permeability on shear strength of sea sand.*

*Keywords—Permeability, Darcy's Law, Salt Concentration, Oceanic Sand*

## I. INTRODUCTION

### A. Darcy's Law

As soil sample has different characteristics, theoretical equation based on Darcy's law are often used to find coefficient of permeability. Darcy's law is the most fundamental law in ground water science .It was proposed by Henry Darcy. It is one of the first mathematical relationships proposed for water flow through saturated porous media. The simplicity of the mathematical expression in Darcy's law facilitates its widespread use in qualification of groundwater flow. Permeability is defined as the property of a porous material which permits the passage or seepage of water (or other fluids) through its interconnecting voids.

Q = KiA

$v$ = k i

Where k = Darcy's permeability, i = hydraulic gradient, $v$ = Discharge velocity or Superficial velocity

V is not actual velocity because water is passing only through the pores.

It is calculated as follows $V_S = v\frac{A}{A_v} = \frac{vV}{V_v} = \frac{v}{\eta}$

Where η= Porosity of soil



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Darcy's law is valid for laminar flow through sediments. In fine-grained sediments, the dimensions of interstices are small and thus flow is laminar. Coarse-grained sediments also behave similarly but in very coarse-grained sediments the flow may be turbulent. Hence Darcy's law is not always valid in such sediment.

**B. Validity of Darcy's Law**:

In accordance with the Darcy's Law, the velocity of flow through soil mass is directly proportion to the hydraulic gradient for laminar flow condition only. It is expected that the flow to be always laminar in case of fine-grained soil deposits because of low permeability and hence low velocity of flow.

However, in case of sands and gravels flow will be laminar upto a certain value of velocity for each deposit and investigations have been carried out to find a limit for application of Darcy's law.

According to researchers, flow through sands will be laminar and Darcy's law is valid so long as Reynolds number expressed in the form is less than or equal to unity as shown below –

$$\frac{v\, D_a\, \gamma_w}{\eta\, g} \leq 1$$

Where v = velocity of flow in cm/sec

$D_a$ = size of particles (average) in cm.

It is found that the limiting value of Reynolds number taken as 1 is very approximate as its actual value can have wide variation depending partly on the characteristic size of particles used in the equation.

Darcy's law which governs the free flow of water through soils is inadequate for extremely fine grained soils because variation in porosity was not incorporated into its formulation. Thus, the statement of the law which implies that zero seepage velocity, v, is attainable only at zero hydraulic gradient, i, is not always true. The aims of this work were to modify Darcy's law to include variations in porosity. Samples of sand from sea-bed were used as porous media Porosities of the different samples were determined using constant head method.

Sea sand can become a potential resource capable of supplying fine aggregate material for domestic civil engineering and construction usage. In addition, using sea sand is economic than using river sand because river sand is more expensive. If the salt is not treated and sea sand is directly utilized for civil engineering and construction concrete project, the durability of the structural may be affected and as the result the concrete might be swelling, precipitating, sulphating and other adverse consequences.

Motive of this project is to find out coefficient of permeability with the variation in porosity and salinity for sea bed soil. As we all know that the structures near the coastal region are fails due to erosion in concrete, this concrete eroded due to salinity which is present in sea sand as well as water which flows through interconnected soil voids.

In this project after finding the permeability we are calculate the shear strength of same soil sample. After getting various results from different tests we analysis all data. From all these we are going to derive how permeability and salinity of sea sand affects the shear strength of soil. We are trying to study the behavior of sea sand according to variation in permeability and how this permeability affects the shear strength.



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## II. LITERATURE REVIEW

The following review gives the interrelationship between the permeability and shear strength. V. Koi and A. S. Guimaraes [1] have studied various damage mechanisms to porous building materials induced by salt action. The importance of pre-treatment investigations is discussed as well in combination with the knowledge of salt and moisture transport mechanisms they can give useful indications regarding treatment options. Another important cause of building pathology is the rising damp and, in this phenomenon, it is particularly severe considering the presence of salts in water. When treating the damage caused by salts in building materials, avoiding the source of damp is found often enough to lead to the solution of the problem. M. D. Ahmed and H. A. Mohammed [2] analysed the soil water characteristic curve (SWCC) which defines the relationship between the amount of water in the soil and soil suction. The physical properties of these soils were studied by conducting a series of tests in the laboratory. For each sample, the SWCC is measured by the filter paper method. Fitting methods are applied through the program (Soil Vision), after identifying the basic properties of the soil such as Atterberg limits, particle size distribution, specific gravity, void ratio, porosity and wet and dry unit weights.

Popoola O.I. and Adegoke J.A. [3] observed the permeability of porous media and its capacity for transmitting a water under influence of hydraulic gradient. When flow is laminar the velocity of flow increases in direct proportion to the hydraulic gradient. When water is flowing in highly permeable material the condition can vary from laminar flow at small gradient to semi turbulent gradient. The result of this experiment shows the permeability increases with increasing porosity, but decreases with increase in hydraulic gradient. Popoola O.I. and Adegoke J.A.[4] studied the statement of Darcy's the law which implies that zero seepage velocity (V) is attainable only at zero hydraulic gradient (i) is not always true .The aim of his work were to modify Darcy's law to include variations in porosity .It has been observed that detailed knowledge of soil physical properties and processes in an environmental engineering perspective is very essential to respond to increasing problems of soil contamination in most urban areas . F. Adeyemi and Amusan[5] are presents the experimental investigations on the effect of sea water on the compressive strength of concrete. Concrete in marine environment suffer deterioration which may be due to the effects of chemical reaction of seawater constituents with cement hydration products, alkali-aggregate expansion which occur when reactive aggregates are present, crystallization pressure of salts within concrete when one face of the structure is subject to wetting and others to drying conditions, frost action in cold climates, corrosion of embedded steel in reinforced or prestressed members, and physical erosion due to wave action and floating objects.

H. Mansouri and A. H. Sadeghpour[6] have been studied the effect of water salinity on geotechnical properties of fine grained soil used in Korchay dam core. In the laboratory, several tests such as Atterberg limits, compaction, consolidation, direct shear and dispersion (pinhole and chemical) were done with distilled, half saline and saline wate. Tests results showed Atterberg limits, compression index, swelling index, coefficient of volume compressibility (mv) and coefficient of compressibility (av) have decreased and consolidation of coefficient and shear strength parameters have increased as water salinity increased. Mohammed Al-Bared and Aminaton Marto[7] analysed the geotechnical and engineering characteristics of marine clay. Marine clay is a soft soil that could be found widely at the coastal and offshore areas. This type of soil is usually associated with high



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settlement and instability, poor soil properties that are not suitable for engineering requirements and low unconfined compressive strength of less than 20 kPa. The review through many research studies on the geotechnical properties of marine clay show that marine clay is a very soft soil that has low strength and high compressibility. Marine clay usually exists in a natural moisture content that is higher than its liquid limit which is the main reason of its weak behaviour. In addition, this paper serves as a guideline for the design and construction of projects on marine soils. Leon A. van Paassen1 and Laurent F. Gareau[8] Investigated the shear strength, compressibility and moisture content of a recent marine clay in the Caspian Sea and result showed soil profiles with a lower shear strength and higher moisture content, than expected for a normally consolidated soil. A research project was carried out to study the effect of pore fluid salinity on shear strength and compressibility of remoulded clays. Preben Terndrup Pedersen[9] studied the trends associated with the future development of marine structures. Its main focus is on ways to improve the efficiency of energy-consuming ships, and on design challenges related to energy-producing offshore structures.

## III. METHODOLOGY

### A. Sieve Analysis:

A sieve analysis (or gradation test) is a practice or procedure used to assess the particle size distribution (also called *gradation*) of a granular material by allowing the material to pass through a series of sieves of progressively smaller mesh size and weighing the amount of material that is stopped by each sieve as a fraction of the whole mass.

A sample of Sea Sand is taken1Kg.

TABLE I

FINENESS MODULUS BY SIEVE ANYALSIS

| Sieve Size (μ) | Mass Retained (Kg) | (%) Mass Retained | (%) Cumulative Retained | (%) Finer |
|---|---|---|---|---|
| 710 | 0.054 | 5.4 | 5.4 | 94.6 |
| 250 | 0.700 | 70 | 75.4 | 24.6 |
| 212 | 0.020 | 2 | 77.4 | 22.6 |
| 125 | 0.114 | 11.4 | 88.8 | 11.2 |
| 90 | 0.074 | 7.4 | 96.2 | 3.80 |
| 75 | 0.026 | 2.6 | 98.8 | 1.20 |
| Pan | 0.012 | 1.2 | 100 | 0 |

$$C_u = \frac{D_{60}}{D_{10}} = \frac{0.39}{0.12} = 3.25$$

$$C_c = \frac{D_{30}^2}{D_{60}D_{10}} = \frac{0.26^2}{0.39 \times 0.12} = 1.4$$



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**B. Specific Gravity by Pycnometer method:**

The major measuring equipment in this test is Pycnometer. This is a glass jar of 1 litre capacity that is fitted at its top by a conical cap made of brass. It has a screw type cover as shown in figure. There is a small hole at its apex of 6mm diameter. The leakage is prevented by having a washer between the cap and the jar. While closing the jar, it is screwed till the mark so that the volume of the pycnometer will remain constant throughout the calculation.

Fig1.Pycnometer Jar

TABLE II

SPECIFIC GRAVITY BY PYCNOMETER

| Type of sample | 1 | 2 | 3 |
|---|---|---|---|
| M1 (kg) | 0.502 | 0.480 | 0.502 |
| M2 (kg) | 0.800 | 0.780 | 0.802 |
| M3 (kg) | 1.254 | 1.266 | 1.289 |
| M4 (kg) | 1.090 | 1.098 | 1.088 |
| Specific gravity | 2.67 | 2.5 | 2.72 |

$$G = \frac{M_2 - M_1}{(M_2 - M_1) - (M_3 - M_4)}$$

$$= \frac{0.8 - 0.502}{(0.8 - 0.502) - (1.254 - 1.090)}$$

$$= 2.67$$

**C. Water Content by Pycnometer**

TABLE III



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WATER CONTENT BY PYCNOMETER

| | |
|---|---|
| Type of sample | 1 |
| M1 (kg) | 0.5 |
| M2 (kg) | 1.006 |
| M3 (kg) | 1.308 |
| M4 (kg) | 1.09 |
| Water content (%) | 41.58 |

Water content is obtained by expression $W = \left\{\left(\frac{M_2 - M_1}{M_3 - M_4}\right)\left(\frac{G_s - 1}{G_s}\right) - 1\right\} \times 100$

$$= \left[\frac{1.006 - 0.5}{1.308 - 1.09}\left(\frac{2.63 - 1}{2.63}\right) - 1\right] \times 100$$

= 41.58%

**D. Permeability Test by Constant Head Test**

The constant head permeability test is a laboratory experiment conducted to determine the permeability of soil. The soils that are suitable for this test are sand and gravels. Soils with silt content cannot be tested with this method. The test can be employed to test granular soils either reconstituted or disturbed.

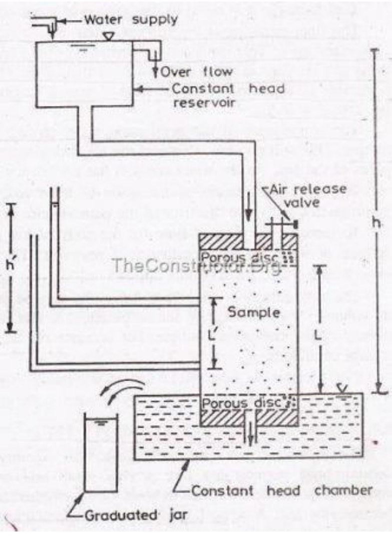


Fig.2: Constant Head Permeability Test

## IV. RESULT AND CONCLUSION

The type of soil is poorly graded sand. In this study, the effect of saline water on engineering properties of fine-grained soil (CL) is investigated. Tests results showed Atterberg limits,



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compression index, swelling index, coefficient of volume compressibility (mv) and coefficient of compressibility (av) have decreased and consolidation of coefficient and shear strength parameters have increased as water salinity increased. The main reason of these changes have been attributed to increasing attractive force between soil particles, establishing bonding between them and forming salt crystals in pores soil and role playing as cement. Regarding the low percentage of clay in the soil, small part of these changes is concerned with the reduction of double layer thickness. Although concentration of saline water is 50 times more than that of half saline water, but difference between soil properties is not noticeable with these two types of water. It seems that rate of variations on the soil properties decreases as water salinity increases. It can be said, excessive concentration of water causes cations in water to combine with anions to form salts before they influence on surface of clay minerals. Deposition these salt on the surface of the soil particles and in the soil pores have decreased the content surface soil particle with water. So, increase in concentration of water will not cause a significant difference in soil behaviour. Consolidation test showed soil behaviour with all three types of water is almost close together in high pressure. Its reason can be attributed to breaking interparticle bonding by high pressures. Although sodium concentration in half saline and saline water is high, but soil dispersion has not been observed with them. At the end, results show saline water of Korchay branch has not negative effect on engineering properties of the core soil. So it can be used in processing of dam core and prevent the additional cost for transferring water.

## V. FUTURE SCOPE

In future the settlement of saline sand can be measured with changing the parameters like grain size, concentration of salt and shear strength parameters.

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