Permeability

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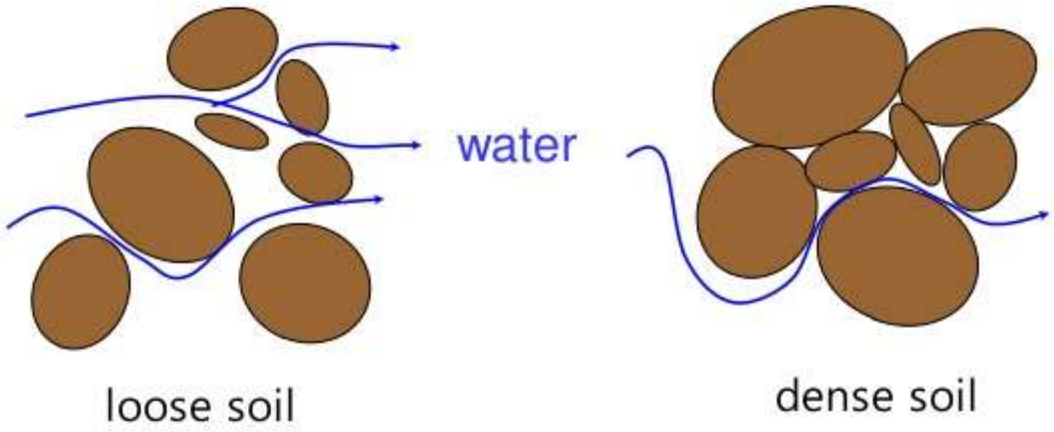
INTRODUCTION

Definition

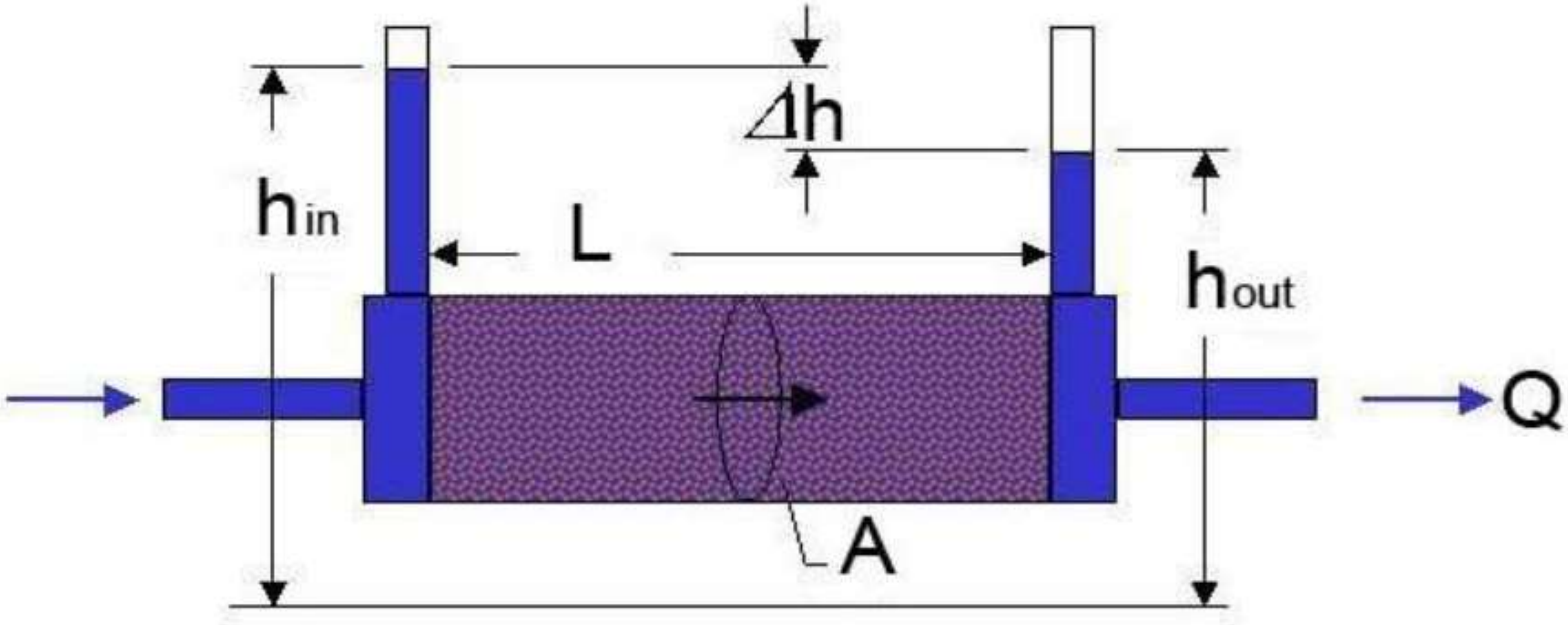
It is the property of soil which allows the flow of water through it.



Importance of Permeability

- The design of earth dams is very much based upon the permeability of the soils used.
- The stability of slopes and retaining structures can be greatly affected by the permeability of the soils involved.
- Filters made of soils are designed based upon their permeability
- Estimating the quantity of underground seepage

Darcy’s law



Where,

A is the cross section of soil sample
L is the length of the soil sample
h_{in} is the head at the inlet
h_{out} is the head at the outlet
Q is the discharge
q is the rate of discharge per unit time (t) = Q/t

Darcy’s law

It states that “In a saturated soil, under laminar flow condition, the rate of flow of water through given sample of soil is directly proportional to hydraulic gradient”

$$V=q/A=ki$$

$$q=kiA$$

Where,

V is the superficial velocity (m/sec)
k is the co-efficent of permeability (m/sec)
i is the hydraulic gradient= $(h_{in}-h_{out})/L$

Superficial velocity

It is defined as discharge per unit cross section area of soil

$$V=q/A$$

Where,

V is the superficial velocity (m/sec)
q is the discharge per unit time
A is the area of the soil sample

Seepage velocity

It is defined as discharge per unit cross section area of voids to the direction of the flow soil

$$V_s=q/A_s$$

Where,

V_s is the seepage velocity (m/sec)
q is the discharge per unit time
A_s is the area of voids

Relationship between superficial velocity and seepage velocity is

$$V_s = V/n$$

n is the porosity

Factors affecting permeability

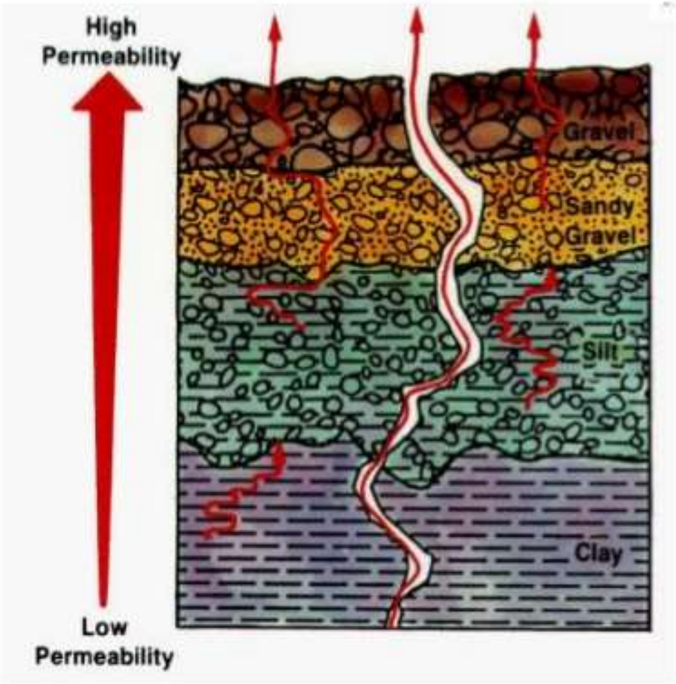
- Particle size
- Properties of pore water
- Degree of saturation
- Presence of entrapped air & other foreign matter
- Structural arrangement
- Stratification of soil

Factors affecting permeability

Particle size

The Permeability varies approximately as the square of diameter of the soil

$$k=100D^2_{10}$$



Where,

D_{10} is the effective diameter of the soil

Factors affecting permeability

Property of pore water

The Permeability of the soil varies directly with density & inversely proportional to the viscosity of the water

$$k \propto \gamma_w/\mu$$

$$k=1/\mu$$

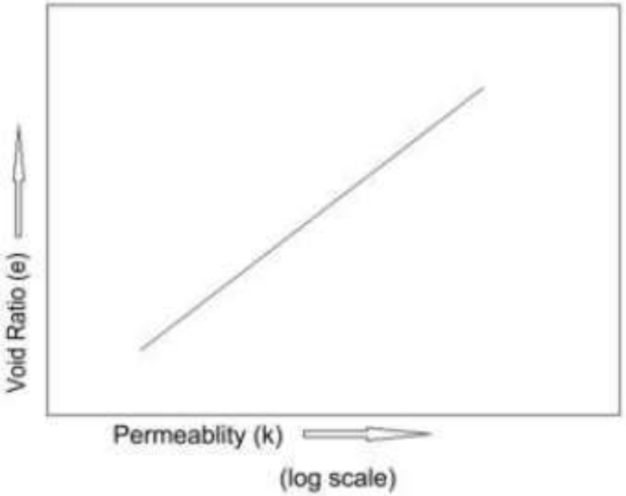
$$k\mu=\text{constant}$$

Factors affecting permeability

Void ratio

Increase in the void ratio increases the area available for flow hence permeability increases.

$$k \propto e^3/1+e$$



Where,

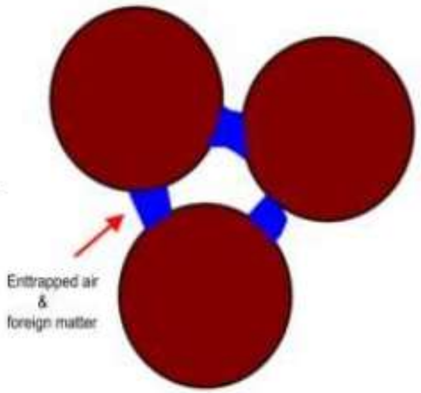
e is the void ratio for the soil
permeability k

Factors affecting permeability

Degree of saturation

Higher the degree of saturation, higher will be the permeability.

Presence of entrapped air & Other foreign matter

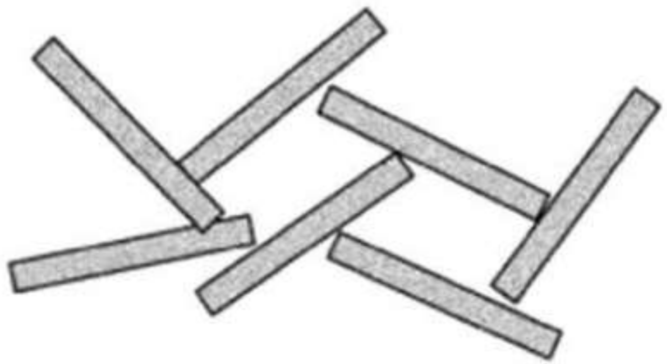


The entrapped air and foreign matter will block the voids in soil results in decreasing in permeability

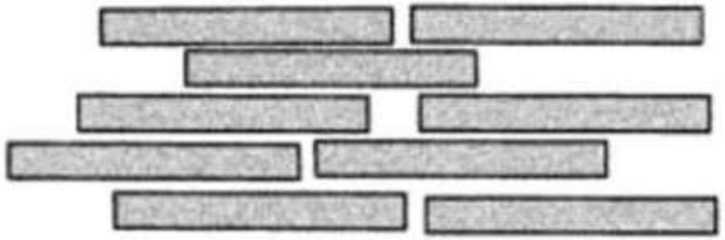
Factors affecting permeability

Structural arrangement

For same void ratio the permeability of the soil will be more in flocculated structure as compare to Dispersed structure.



Flocculated structure

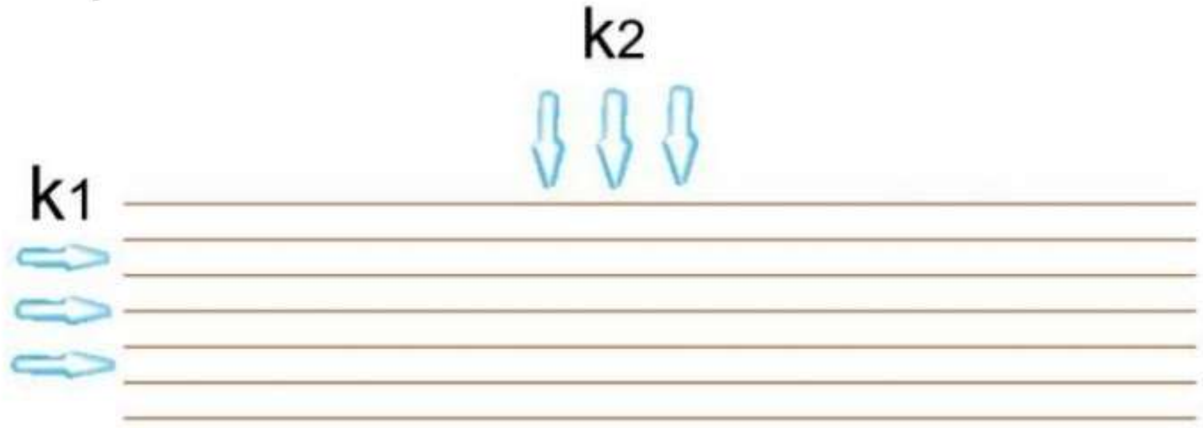


Dispersed structure

Factors affecting permeability

Stratification of soil

Stratified soil deposits have grater permeability parallel to the plane when compare to perpendicular to the plane.



k1>k2

Laboratory Testing to find coefficient of permeability

Two standard laboratory tests are us to determine the coefficient of permeability of soil

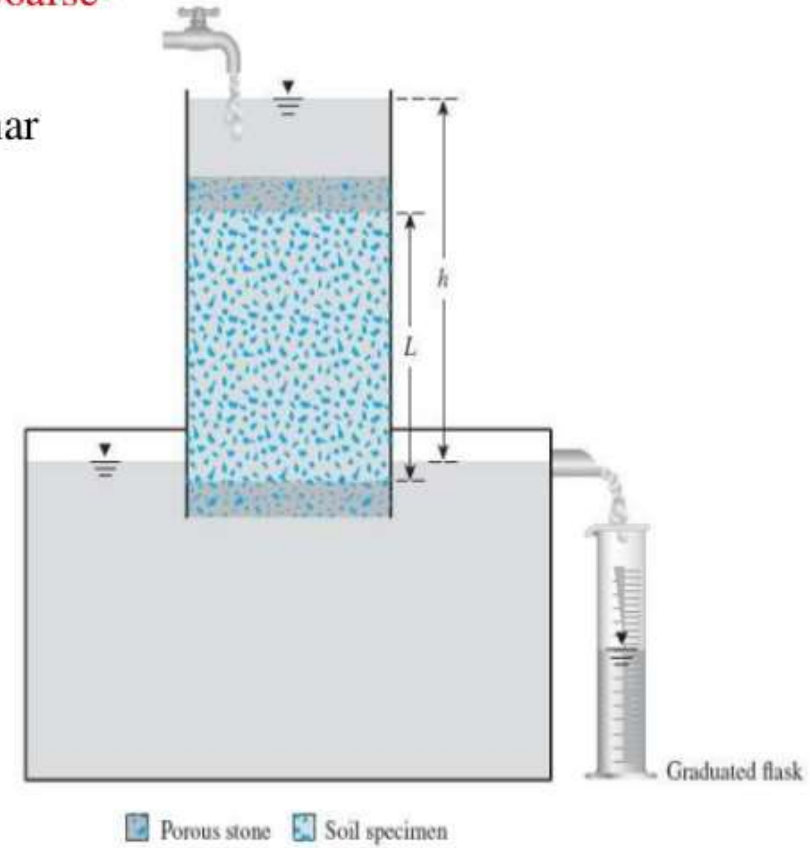
- The constant-head test
- The falling-head test.

Laboratory Testing to find coefficient of permeability

The constant-head test

- The constant head test is used primarily for coarse-grained soils.
- This test is based on the assumption of laminar flow (Darcy's Law apply)

$$k = \frac{V \cdot L}{h \cdot A \cdot t}$$



Where:
Q = volume of water collection
A = cross section area of soil specimen
t = duration of water collection

Laboratory Testing to find coefficient of permeability

The constant-head test

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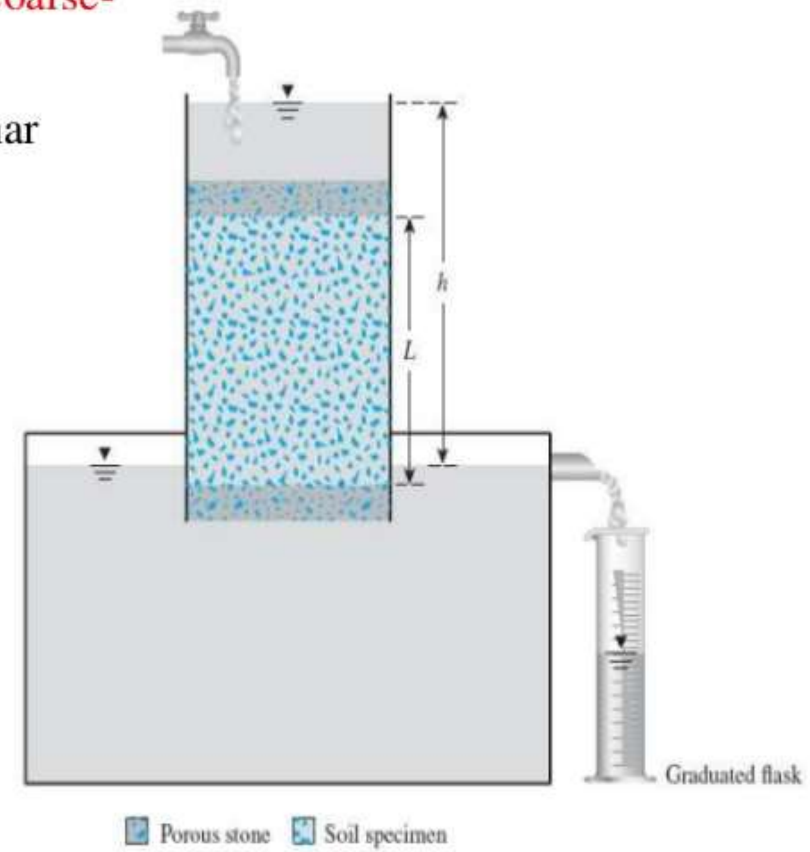


Stress distribution of soil

Introduction

- Stress are induced in a soil mass due to self weight of the soil and due to applied structural loads.
- Estimation of vertical stresses at any point in a soil mass due to external vertical loadings are of great significance in prediction of settlement of buildings, bridges, etc.

Geostatic stress

- Vertical stress in soil due to self weight of is called **geostatic stress**.
- Vertical stress
- Horizontal stress

Theories regarding stress distribution

- Boussinesq theory
- Westergaard's analysis
- Newmark's influence chart
- Janbu's chart
- Pressure bulb concept
- Contact pressure concept

Boussinesq’s solution

- He gave the theoretical solutions for stress distribution in a elastic medium subjected to a concentrated load on its surface.

Point Loads (P)

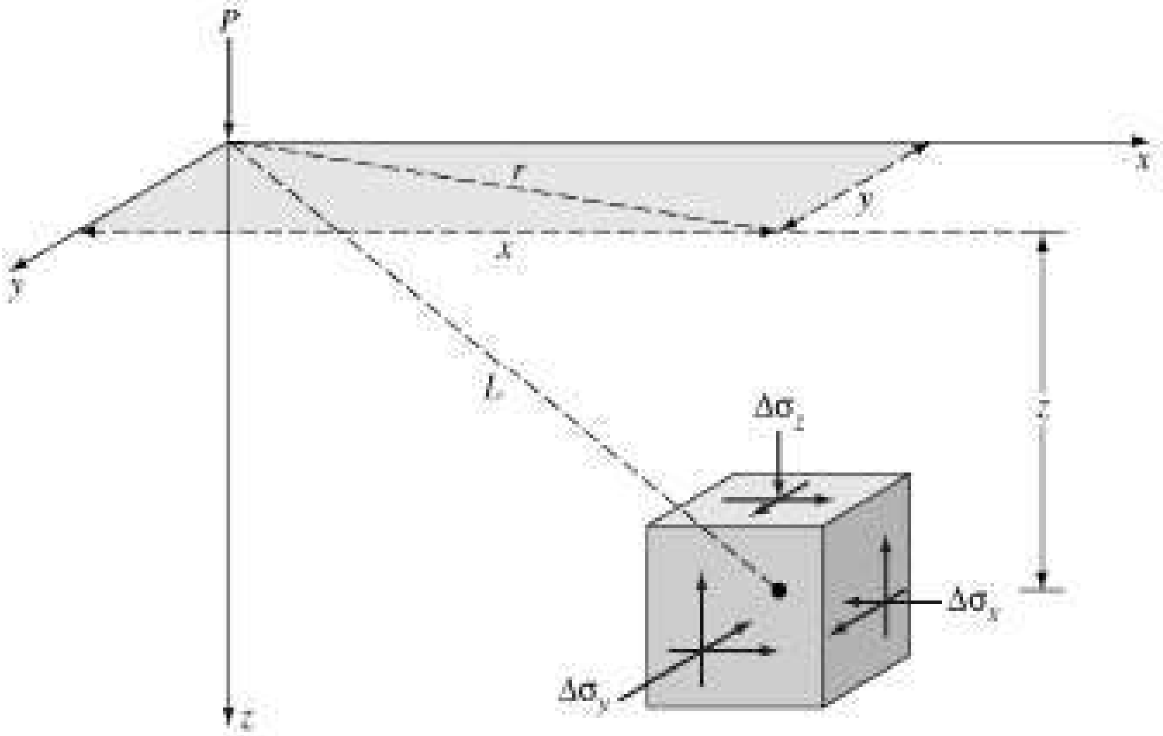


Figure 6.11. Das FGE (2005).

Assumptions:

- Elastic medium
- Homogeneous
- Isotropic
- Semi- infinite self weight is neglected
- Soil is initially stress free
- Change in volume of soil upon application of load is neglected
- Top surface is free of shear stress

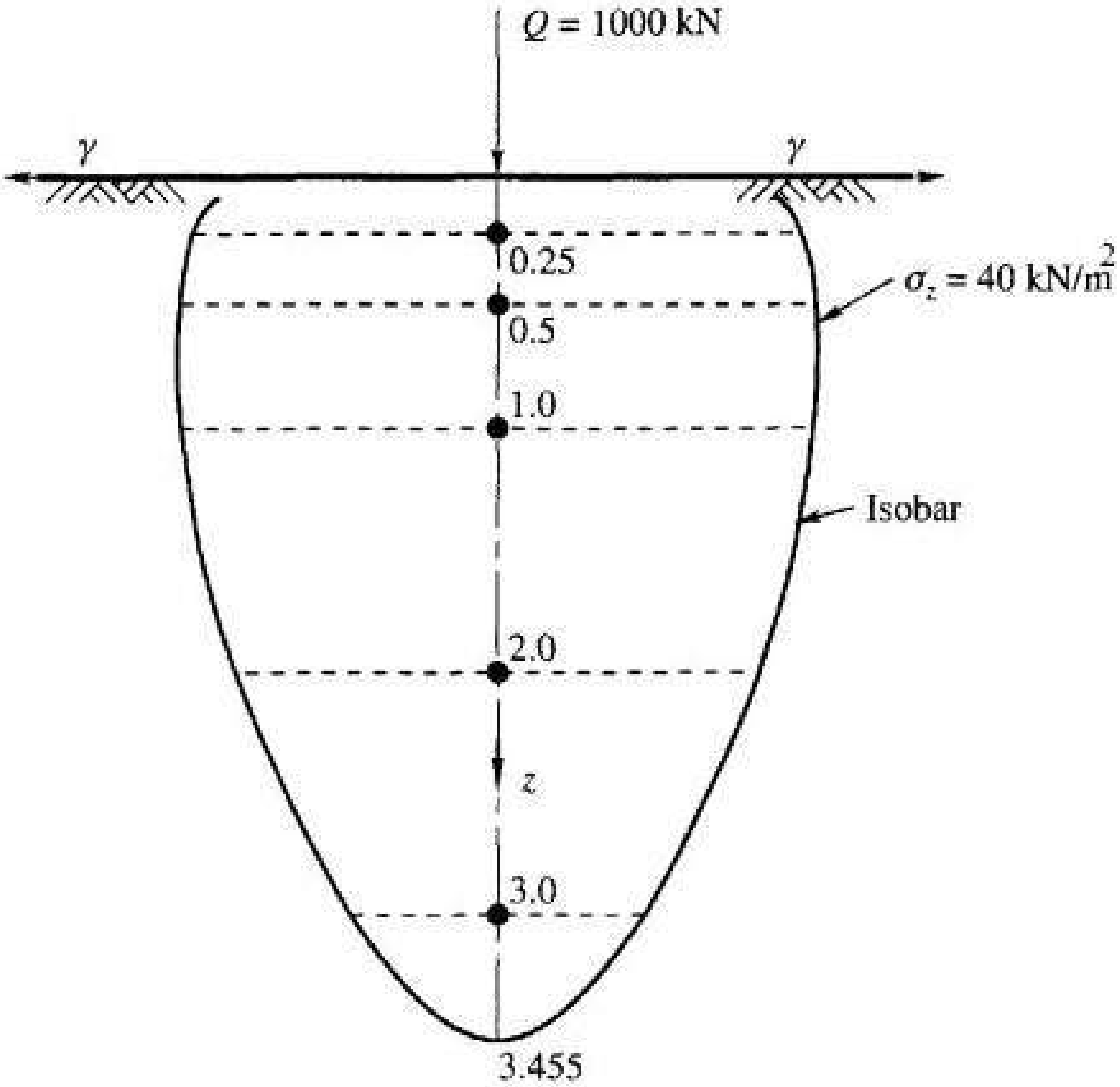
Limitations

- It is assumed that soil mass is an elastic medium.
- It is applicable when there is constant ratio between stress and strain.
- Theory can be use for only homogenous soil only.
- Point load applied below ground surface causes somewhat smaller stresses than that are caused b y surface load.

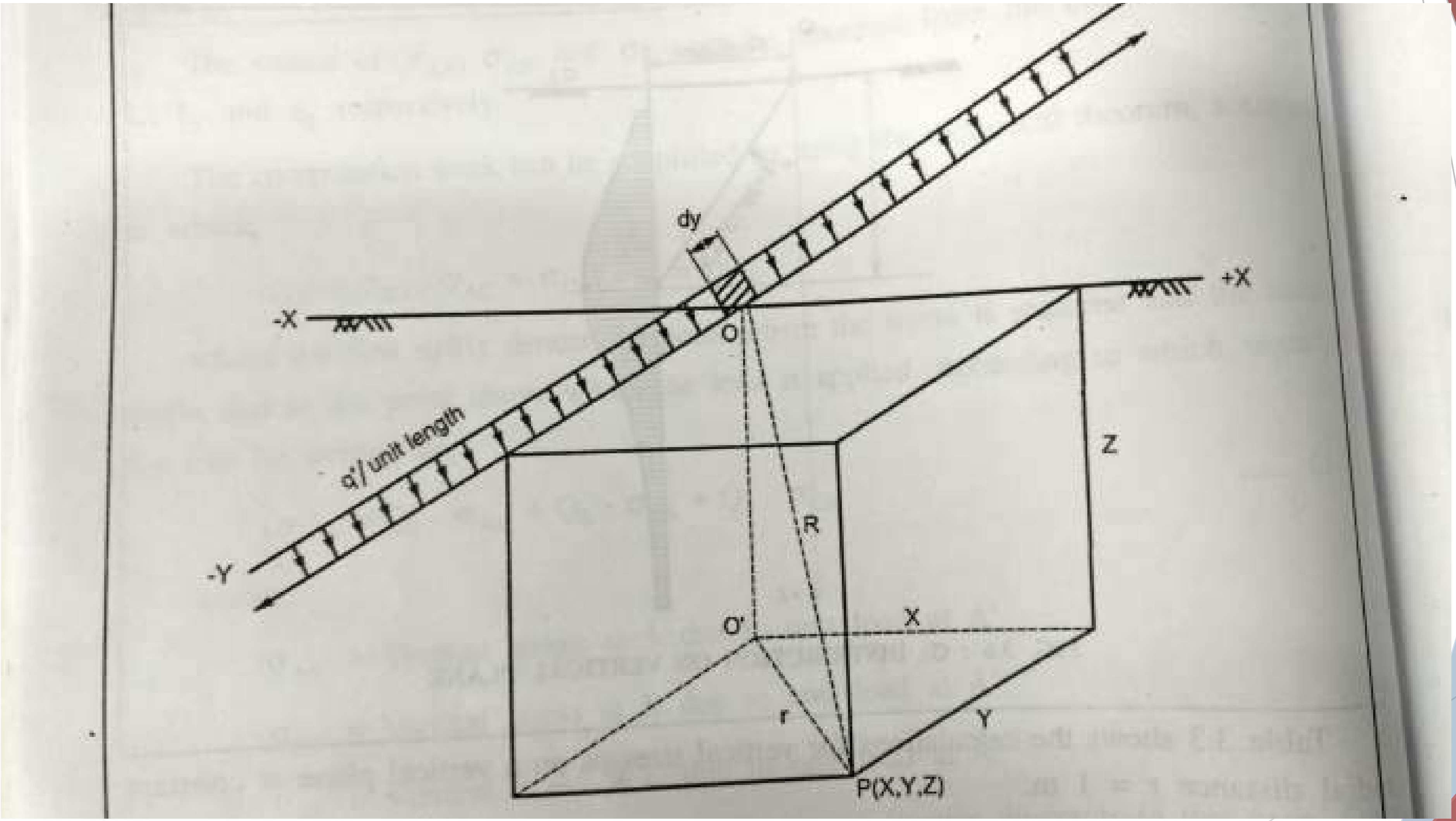
Isobars

- An isobar is a curve or contour connecting all the points below the ground surface of equal vertical pressure.
- It is a contour of equal vertical stress.
- The zone in a loaded soil mass bounded by an isobar of given vertical pressure intensity is called pressure bulb.

z (m)	r (m)
0.25	1.34
0.50	1.36
1.0	1.30
2.0	1.04
3.0	0.60
3.455	0.00



Vertical stresses due to a line load



Consider a small length dy of the line load. The load can be taken as a point load of $(q' \cdot dy)$ and Boussinesq's solution can be applied to determine the vertical stress at P (x, y, z) from equation 3.4,

$$d\sigma_z = \frac{3(q' \cdot dy)}{2\pi} \cdot \frac{z^3}{(r^2 + z^2)^{5/2}} \quad \text{..... (a)}$$

or $$d\sigma_z = \frac{3q'}{2\pi} \cdot \frac{z^3 \cdot dy}{(x^2 + y^2 + z^2)^{5/2}}$$

The vertical stress at P due to the line load extending from $-\infty$ to $+\infty$ is obtaine by integration.

Consider a small length dy of the line load. The load can be taken as a point load of $(q' \cdot dy)$ and Boussinesq's solution can be applied to determine the vertical stress at P (x, y, z) from equation 3.4, 3Q cosβ/ 2*R*R*π

$$d\sigma_z = \frac{3\,(q' \cdot dy)}{2\pi} \cdot \frac{z^3}{(r^2 + z^2)^{5/2}} \qquad \text{..... (a)}$$

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The vertical stress at P due to the line load extending from $-\infty$ to $+\infty$ is obtained by integration.

$$\therefore \quad \sigma_z = \frac{3q'z^3}{2\pi}\left[\int_{-\infty}^{\infty} \frac{dy}{(x^2 + y^2 + z^2)^{5/2}}\right]$$