Chapter 7
Seepage and Groundwater Flow

ABSTRACT

Water in soil exists in a variety of forms, affects its engineering properties, and plays a very important role in all soil mechanics problems. The effects caused by the presence of water whether at rest or when moving through the pores of the soil must therefore be properly understood. Capillarity and both saturated and unsaturated flows are considered. Methods of measuring soil suction and the hydraulic conductivity of soils in the laboratory and in-situ are highlighted. The chapter considers the permeability of stratified deposits, effective stress, and seepage pressures. Using Darcy's law and other assumptions, the basic flow equation is derived. Analytical and graphical (flow nets) methods for solving the Laplace equation are developed. Kozeny's analysis of seepage through earth dam sections using the basic parabola is introduced and the Casagrande constructions are illustrated for some homogeneous earth dams with different discharge slopes. Seepage in soils with transverse isotropy and through soils with nonhomogenous sections are analyzed. The chapter ends with a consideration of the mechanics of piping, filter, and its design.

7.0 SEEPAGE AND GROUNDWATER FLOW

Water is a naturally occurring inorganic chemical compound with a definite crystal lattice. It exists in three natural states: solid (ice), liquid (water) and vapor (water vapor). Subsurface water originates chiefly from infiltration of rain water, melted ice and snow and seepage from streams, lakes, oceans, ponds, channels, reservoirs and other bodies of water.

7.1.1 Importance of Water

Water is a very valuable resource. It is used for both human and stock consumption, for irrigation and for manufacturing and other industrial purposes. Water in soil affects its engineering properties and plays a very important role in all soil mechanics problems. Geotechnical engineers are often called upon to estimate the quantity of underground water under various hydraulic conditions. They often have to solve problems involving pumping of seepage water during construction excavations and have to analyze

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the stability of earth structures and retaining walls subjected to seepage forces. The effects caused by the presence of water whether at rest or when moving through the pores of the soil, must therefore be properly understood.

We study the flow of water in soils (porous media) for the following reasons among others, Harr (1962):

1. To estimate the quantity of underground seepage. For example it is important to know the amount of water that will enter a pit during construction, or the amount of stored water that may be lost by percolation through or beneath a dam.
2. To determine the quantity of water that can be discharged from a soil.
3. To determine the pore water pressure/effective geostatic stresses, and to analyze earth structures subjected to water flow.
4. To determine the volume change in soil layers (soil consolidation) and settlement of foundation.
5. The behaviour of soil is governed by the effective stress, which is the difference between total stress and pore water pressure. When water flows, the pore water pressures in the ground change. Knowledge of how the pore water pressure changes can be important in considering the stability of earth dams, retaining walls, etc.

7.1.2 Groundwater Table

Water in soil obeys the laws of hyraulics. When at rest, it exerts a pressure at any point consistent with the depth of water above that point. Atmospheric pressure is usually taken as the datum for pressure-head measurements. The level at which the pressure in the water is atmospheric is called the water table, or more correctly the phreatic surface, Kozeny (1930). The pressure of water at this level is taken to be zero. The area over which the pore-pressure is zero is normally found to follow the ground surface, but at a slightly flatter slope. However, there can be discontinuities in the water table in certain geological conditions and sometimes there may be more than one level on a single vertical section where the pore-pressure is zero and a water table exists. Small areas of zero pore-pressure lying above the general water table for a district or geographical zone are known as perched water tables. There are usually seasonal fluctuations in the water table in an area. The location of the ground water table is also affected by variations in precipitation, surface runoff and evaporation.

7.1.3 Modes of Occurrence of Water in Soils

Water in soil exists in a variety of forms, namely:

1. **Chemically Combined Water:** Water contained within the mineral particles of the soil in the form of hydrous oxides. This water is part and parcel of the soil structure. The presence of chemically bound water is of interest in the study of clay mineralogy.
2. **Adsorbed Moisture:** Water, which is held by the physical force of adhesion to the soil particles. It is sometimes called surface bound moisture. It is of significance in fine-grain soils. The adsorption of water to clay particles is brought about by the dipole effect of water molecules which are attracted to clay minerals by the physico-chemical forces within the clay matrix. These forces hold the water molecules to the clay in such a way that the movement of water is largely restricted to slow migration parallel to the mineral surface. This zone of water within the soil grains is sometimes referred to as the electrostatic or diffuse double layer.