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Foundations in Expansive Soils

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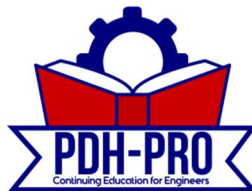
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Chapter 1 Introduction

Learning Objectives

By the end of this chapter, you will be able to:

- Identify the mechanisms that cause foundation movement in expansive clay soils
- Evaluate patterns of heave and their effects on structures
- Apply fundamental design principles to reduce structural distress

Executive Summary:

Changes in soil moisture are the primary cause of damaging foundation movement in expansive soils. Effective foundation performance depends on controlling moisture variation and limiting differential movement to tolerable levels.

1.1 Purpose

This course provides guidance for geotechnical investigation and foundation design in expansive clay soil environments. It applies to heavy and light military type buildings and is also applicable to residences, warehouses, and multistory structures.

Design emphasis is placed on maintaining constant moisture conditions in foundation soils during and after construction. Differential movement, rather than total movement, is the primary cause of structural damage and must be controlled through investigation, design, and construction practices.

Although the guidance significantly reduces the risk of severe damage, complete prediction of future moisture changes is not always possible. Engineering judgment remains essential.

1.2 Scope

This course presents guidelines for the investigation and analysis required to select and design foundations for buildings constructed in expansive clay soils.

Topics include:

- Recognition of expansive soil conditions
- Field exploration methods
- Laboratory testing programs
- Prediction of soil volume change
- Foundation type selection



Chapters 2 through 5 address investigation and analysis methods. Chapter 6 discusses foundation selection and design details. Chapters 7 through 9 cover construction practices, inspection, and remedial repair.

Guidance is not specifically provided for highways, canal linings, reservoir linings, retaining walls, or hydraulic structures. Frost heave and chemically induced soil volume changes are also not directly addressed, though many principles remain applicable.

1.3 Background

Expansive Soil Behavior

Expansive soils experience volume change due to moisture variation. These soils include highly plastic clays, clay shales containing montmorillonite minerals, marls, clayey siltstones, sandstones, and saprolites.

Differential Movement and Damage

Differential movement redistributes structural loads and produces increased bending moments and shear forces. These effects are often not accounted for in conventional design and can lead to significant damage.

Occurrence of Damage

Damage may occur shortly after construction, develop gradually over several years, or appear long after construction following changes in site moisture conditions. Risk increases when climate, construction activities, or building use promotes moisture variation beneath the structure.

Structures Most Susceptible

Structures commonly damaged include:

- Residential buildings
- Light one or two story buildings
- Warehouses
- Pavements
- Canal and reservoir linings
- Retaining walls

Light structures are particularly vulnerable because they cannot suppress differential soil movement.

Types of Damage

Typical damage includes:

- Cracking and distortion of slabs on grade
- Cracks in grade beams, walls, and drilled shafts
- Misaligned doors and windows
- Failure of plinths supporting grade beams
- Buckling of basement and retaining walls

Repair costs can exceed the original foundation cost and reduce structural functionality.

Example of Damage



Figure 1-1. Examples of cracks in an exterior wall.

This example illustrates damage caused by slab heave and lack of construction joints. Failure to isolate slabs from grade beams and absence of voids aggravated cracking and excessive movement.

Causes and Patterns of Heave

Causes

The primary cause of heave or settlement is change in soil moisture due to environmental conditions, construction activities, and building use.

Differential movement is influenced by:

- Nonuniform moisture distribution
- Variations in soil thickness and composition
- Structural geometry
- Nonuniform loading

Patterns of Heave

Doming Heave

Doming heave develops slowly and is characterized by greater uplift near the center of the structure. Reduced evapotranspiration and deep water tables commonly contribute.

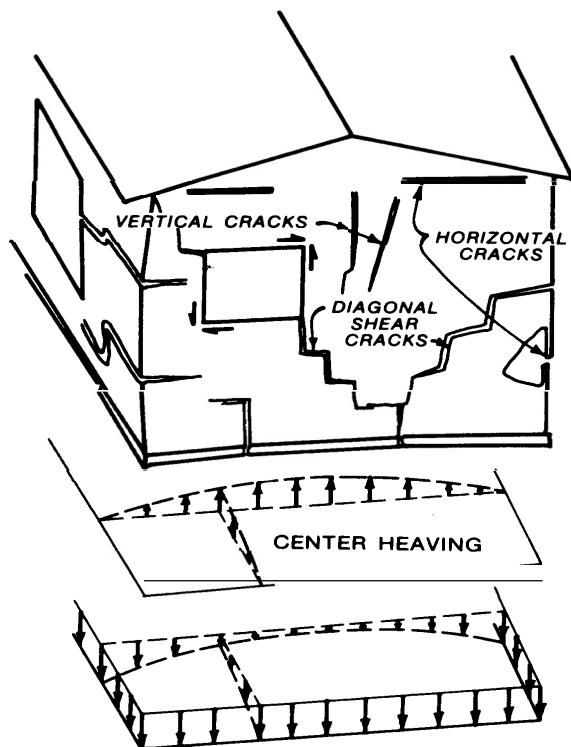


Figure 1-2. Examples of wall fractures from doming heave of swelling and shrinking foundation soils.

Doming heave often causes outward wall rotation and cracking near the roofline.

Cyclic Heave

Cyclic expansion and contraction occur near structure perimeters due to seasonal rainfall and evapotranspiration. Localized heave may result from leaks or ponding.

Shrinkage during dry periods can extend inward 8 to 10 feet and may reverse during wet conditions.

Edge Heave

Edge or dish shaped heave may occur soon after construction, especially in semiarid climates where vegetation removal and poor drainage increase soil moisture.

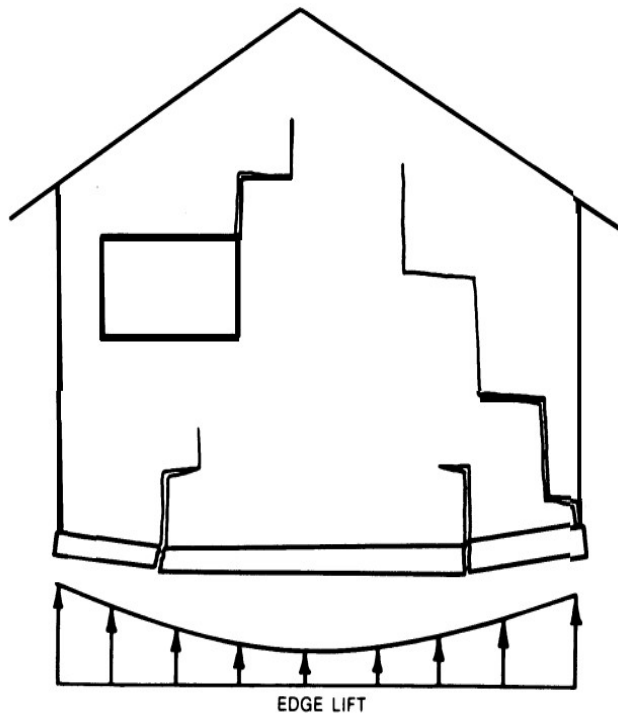


Figure 1-3. Examples of fractures from dish-shaped lift on swelling foundation soils

Structures with deep foundations and slabs on grade are particularly vulnerable if slab movement is not isolated from perimeter elements.

Lateral Movement

Expansive soils can exert significant lateral pressure, leading to bulging and fracture of basement and retaining walls. Structures on slopes greater than 5 degrees may also experience downhill soil creep, which can shear shaft foundations.

1.5 Elements of Design

Foundations must:

- Protect against swelling and shrinkage
- Transmit loads without excessive movement
- Resist freeze thaw effects in cold climates
- Withstand chemical attack from soil constituents



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the technical materials.