A GUIDE TO SWELLING SOILS FOR COLORADO HOMEBUYERS AND HOMEOWNERS

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Colorado Geological Survey
Department of Natural Resources
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INTRODUCTION

Swelling soils are a common problem in Colorado. homes will be costly responsible for the cost of damage and disruption. In general, homes of older construction houses have more damage likely, in suburbs, the damage is more likely to be caused by swelling soils. Although risks from lifting and damage to houses, roads, and other structures, swelling soils are capable of causing severe damage to homes, roads, and other infrastructure.
This book replaces two other publications from the Colorado Geological Survey:

**CGS Publications Replacement of Older Works on Water and Construction in General**

By using this resource, you are helping to preserve and protect our natural resources. This book replaces two other publications from the Colorado Geological Survey:

**How to Use This Book**

If you have any questions or comments, please feel free to contact us. We are always looking for ways to improve our publications and make them more accessible to the public.

[Special Publication 46]
(Summar of Chapter I)

The Geology of Swelling Soils

Swelling soils and bedrock contain clay minerals that attract and absorb water as a result, they swell in volume when they get wet and shrink when they dry (refer to Figs. 4, p. 18). Swelling soils and bedrock may be found throughout Colorado, with the greatest exception of the highest mountain areas (refer to Fig. 4, p. 18). Swelling soils and bedrock contain some swelling characters.

The swelling pressure of the surfound layer charge that can occur around the soil's density can affect the amount of moisture the type and concentration of minor elements can swell, inducing

There are many factors that control swelling characters.

Some swelling soils may have extremely high swelling. Since it has been weathered to clay, this type is a silty loam soil that is often referred to as bench mossy swelling.

"Bench mossy" is a term that is often used synonymously with "swelling bench mossy." Swelling soil to include both soil and bedrock. Swelling soils and bedrock have extremely high swelling characters, and builders use the term "swelling" to refer to Figs. 1-3, p. 16 and 17. Many swelling soils shrink when they dry (refer to Figs. 1-3, p. 16 and 17). Swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain swelling soils and bedrock contain
SUMMARY OF CHAPTER 2

SUBSURFACE MOISTURE

Wellings swells, and may cause shifting. Soil swells and may cause shifting. Surface water infiltration and development oftenresults in the increase in soil moisture followed by a decrease in surface moisture. Subsurface moisture has a major impact on swelling soil behavior. An increase in moisture will result in swelling, while a decrease will result in shrinking. Wells may be deeper than groundwater and can influence swelling and shrinking, and may cause shifting. Swelling and shrinking are significant increases in the amount of moisture in the ground, and can significantly increase the amount of urbanization and land development. The relative increase or decrease in swelling can be significant, and may cause shifting and swells.
Construction on Swelling Soils

Starting on p. 29, to learn more about
See Chapter 3 and Figures 12-29,

House

By lo swelling soils damage to a
situation quality can add significant.
- design for swelling soils. Poor con-
- the key to the success of any special
Quality control during construction is

builder

many of the decisions made by the
not be the primary consideration in
However, swelling soils may or may
Swelling Potential of Swelling Soils

in part, on the potential security
structure used for a house depends.

The exact type of design and con-

SUMMARY OF CHAPTER 3

CONSTRUCTION ON SWELLING SOILS

Integrates into the ground next to the
reducing the amount of water that
parts with minimal damage and/or
bear and move relative to other

leaving certain parts of the structure
load of the house onto pads or piers.
the potential of the soil, concentrating the
be spread throughout reducing the swell

number of different ways. They may
Basic swelling soil designs work in a

Where swelling soils are present,

and subsurface drainage systems for
Foundation, loess, building interiors,

methods have been developed for
Special designs and construction

Special Publication 43
Landsaping on Swelling Soils

...
(Summary of Chapter 5)

Home Maintenance on Swelling Soils

This is one of the most important.

Contrary to the lack of proper main...

Reduce potentially costly repairs.

Damaged by swelling soils and help prevent a house from being practices are absolutely necessary to prevent main and irrigation...

and landscaping.

Surfaces and surface drainage slopes, damage, including slab's, walls, slab's systems that were designed to protect the house from swelling soils and maintain all of the different furnishings should be routinely...
Summar of Chapter 6
Swelling Soils and Homeowner Risk

The soil report should include the swelling characteristics of the soil at the site of the property. A summary report for each lot or parcel should be included in a summary of soil characteristics. This information should be used to design and construct buildings that are resistant to swelling soils. The soil report should include:

1. A description of the swelling soils
2. Recommendations for design and construction
3. A summary of the site's swelling characteristics

Colorado residents, particularly those living in areas prone to swelling soils, should be aware of the potential risks associated with these soils. The Colorado Geological Survey has published a guide that provides information on how to identify and mitigate the effects of swelling soils. The guide includes guidelines for building inspectors, developers, and homeowners.

The statute requires developers to disclose to potential buyers the potential risks associated with swelling soils. The disclosure must be in writing and must be provided to the potential buyer at the time of the sale. The disclosure must include:

1. A description of the potential risks associated with swelling soils
2. Recommendations for mitigating these risks
3. A summary of the site's swelling characteristics

Colorado residents should be aware of the potential risks associated with swelling soils and take steps to mitigate these risks. This may include:

1. Hiring a qualified soils engineer to perform a soil test
2. Consulting with a qualified architect to design a building that is resistant to swelling soils
3. Using appropriate building materials that are resistant to swelling soils

Colorado law requires that the presence of swelling soils be disclosed in the sale of a new house. This requirement applies to real estate brokers and sellers. The disclosure must be in writing and must be provided to the buyer at the time of the sale. The disclosure must include a description of the potential risks associated with swelling soils and recommendations for mitigating these risks.

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Swelling soils and foundation risk.

See Chapter 6 and Figure 7, starting on page 61, to learn more about

the factors such as location and cost

seriously along with other common

Swelling soils should be considered

Homestories.

The decision to purchase a

The final decision to purchase a

House

when you are thinking of buying a

whether or how that is expected due

The design of the house should be

potential severity of swelling soils.

Designs for houses are based on the

Recommendations.

determining the site's building

used by the builder or developer to

include the most specific information

should be the most specific information

provided the information provided

potentially, observations, and recom-

Adapted from: Homeowners Guide to Swimming Pools by A. J. Dumas, P.E.
PART II

GUIDE TO SWELLING SOILS
Chapter 7

Swelling Soils and Swelling Bedrock

Swelling Soils

The Geology of...
between clay plates to collapse on a microscope.

When water is added, the clay plates expand, which increases the volume of the water. The clay plates then swell, and water is expelled from the soil. This swelling behavior is known as swelling behavior. When the water is removed, the clay plates contract and the soil shrinks, which decreases the volume of the water. This shrinking behavior is known as shrinking behavior.

**Swelling and Shrinking Behavior**

High swelling clays are common in coastal regions. These clays are highly expansive and can cause significant problems in foundations and building foundations. To prevent this, it is important to understand the behavior of these clays and to take measures to mitigate the effects of swelling and shrinking.

In this section, we will discuss the behavior of swelling clays and how to design structures that are resistant to swelling and shrinking.
Chapter 2

Subsidence development activities are discussed in this chapter. Subsidence activities initially involve the development of water sources near the subsidence water in natural saline-alkali. The water is then taken out of the ground and used to develop subsidence areas. The water is used to develop subsidence areas and cause subsidence damage. The effects of subsidence are usually dry in the natural condition. The effects of water subsidence are usually dry in the natural condition. The water subsidence effect is most likely to cause damage to settlements and roads in Colorado. Colorado subsidence effects are usually dry in the natural condition.
COLORADO

Swellable soils in Colorado

Occurrence of

How to Recognize

1. Swellable soils expand when they are placed under pressure. These soils are known as swelling soils because of their ability to expand.

2. Swellable soils may not have swelling characteristics, but they may have swelling potential. These soils are located in areas of previous swelling soils.

3. Swellable soils are widespread throughout Colorado. They occur primarily in the eastern regions of the state, where they are frequent near populated centers.

4. Moisture change has a significant impact on swellable soils. When wet, these soils expand and may cause structural damage. When dry, they shrink, causing cracks and other problems.

5. Swellable soils can be identified by their characteristic behavior under pressure. They are sensitive to moisture changes, which can cause significant changes in their volume and structure.

6. Swellable soils may also be characterized by their ability to swell when exposed to water. This swelling can lead to damage in buildings and other structures.

7. Swellable soils are important to consider when planning construction projects in areas where they may be present. Proper engineering design and construction methods can help mitigate the effects of swelling soils.

8. Swellable soils can be harmful to infrastructure, including roads, bridges, and buildings. They can cause cracks, settlements, and other structural damage.

9. Swellable soils can be found in a variety of environments, including desert areas and mountainous regions.

10. Swellable soils are important to consider when planning and constructing buildings and other structures in areas where they may be present.
 Herculean.

Special Publication 42
Figure 3. This "peaks-and-valleys" road is the result of uneven swelling and heaving of bedrock areas.

Steeply Dipping Bedrock Layers

Bedrock layers, each having a different swell, may occur due to uneven swelling of individual mountainous areas. Proportionally compliant, the heaving that occurs in areas of bedrock can be measured to determine the amount of vertical and lateral stress. In the case of the ground surface, the heave is shown in Figure 2. In such areas, the bedrock layers are affected by differential swelling, which is shown in Figure 3. In certain areas of Colorado near the base of steeply dipping bedrock, areas of distinct bedrock layers are observed.
Figure 9. Different types of heave beds. (A) Symmetrical heave feature caused by uneven settlement of individual bedrock layers. (B) Asymmetrical heave feature caused by shear failure of failure planes and/or fracture surfaces. (Modified from Hoge and Podoson, 1995.)
Chapter 6

MOISTURE
SUBSURFACE
 Impermeable soil on pediments is a result of subduction.

Perched water tables may develop on top of sandstone or shale, leading to a groundwater table. The upper saturated surface of the water table is called the phreatic. The upper surface of the water table is called the water table. The water above the water table is called the phreatic water table.

Rock that has sand and gravel in the topsoil is saturated, and ground moisture where the rock is saturated is called ground water. These are factors that affect the soil at this point. If the ground water table is not at the soil, then it exists beneath the ground surface in two ways.

**Types of Subsurface Moisture**

Soils are generally dry during much of the year, and the near-surface moisture is characterized by an overall depth of water and soil. The lower-latitude areas of the state, like the surface evaporation, are warmer and wetter.

In the deserts, moisture for May–October is lower and has high evaporation (30 cm). The western region, on average, has lower temperature and precipitation (10 inches), which varies depending on climate conditions. Swelling soils are made up of several types of clay, which can result in higher levels of precipitation and cold conditions.

The mountainous areas of Colorado usually have an annual precipitation of over 20 inches. The Colorado River, which flows through the mountainous areas, is a major source of water in the state.

**The Hydrologic Cycle**

Water exists in various forms in the atmosphere, as a liquid in rivers and streams, and as a solid in the form of snow and ice. The cycle of water is significant in the environment, as it influences the weather and climate.

**Figure 1:** The hydrologic cycle.
How Subsurface Moisture Affects Swelling Soils

The presence of subsurface moisture can cause swelling soils, leading to heaving and damage. Nearly all subsurface water is surface water at some time. Natural sources of subsurface water include infiltration from rainfall, snowmelt, and percolation from underground sources such as wells, ponds, ditches, and buried water and sewer lines. Other significant sources are leaks and seepage, and evapotranspiration and crop irrigation, and escape from manmade elements of human activities, such as lawns and streets. Other significant sources are leaks and seepage, and evapotranspiration and crop irrigation, and escape from manmade elements of human activities, such as lawns and streets.
techniques to avoid this type of problem by using proper landscaping foundation. Chapter 3 gives tips on how to avoid foundation failure due to heavy rains or snow accumulation. This chapter will explain techniques to reduce the amount of damage caused by freeze/thaw cycles and improve the foundation's stability.

The first step in preventing foundation failure during dry periods is to ensure that the foundation is properly designed and constructed. This involves selecting the right type of foundation and ensuring it is properly installed. The foundation must be able to support the weight of the building and provide adequate drainage to prevent water from accumulating around the foundation.

The second step is to monitor the soil moisture levels. This can be done using a variety of methods, including soil moisture meters and visual inspections. If the soil is too dry, it is important to add water to the foundation before construction begins. If the soil is too wet, it is important to remove excess water to prevent the foundation from settling.

The third step is to use proper drainage systems. This involves installing french drains, catch basins, and other drainage systems to ensure that water is effectively directed away from the foundation.

The fourth step is to use proper fill materials. This involves selecting fill materials that are strong enough to support the building and have a low water content. This will help to reduce the risk of foundation failure due to freeze/thaw cycles.

The fifth step is to use proper construction practices. This involves ensuring that the foundation is properly installed and that the construction process is done in a way that minimizes the risk of foundation failure.

The sixth step is to use proper maintenance practices. This involves regularly inspecting the foundation and making necessary repairs as needed. This will help to ensure that the foundation remains in good condition and that foundation failure is prevented.

By following these steps, you can significantly reduce the risk of foundation failure during dry periods and ensure that your foundation remains stable and strong.

Shrinking Soils and Droughts

The chapter on shrinking soils and droughts will provide valuable information on how to design and build foundations that are resistant to shrinkage and expansion. It will cover the types of shrinking soils and the effects of drought on foundations. The chapter will also provide tips on how to design foundations and building systems that are resistant to shrinkage and expansion.

In summary, designing and building foundations that are resistant to shrinkage and expansion is essential to ensuring the long-term stability of your building. By following the steps outlined in this chapter, you can minimize the risk of foundation failure and ensure that your building remains safe and functional for years to come.
Chapter 3

Swellling Soils

Construction on

The process of construction is crucial for each step of the construction. Surface drainage systems, quality control of soils, excavation, and preparation of the site, as well as the design and construction of foundations, have significant potential swell effects. These effects influence the house construction, the various defects or cracks in the foundations, and some of the subtle factors of certain specialized designs used.

This chapter describes the advantages and some...
Ground Preparation

The design and construction of a house and its foundation are influenced by the ground conditions. Proper preparation and installation of the foundation are crucial to ensure the stability and durability of the structure. The type of soil and its physical properties significantly impact the foundation's performance.

Soil Classification:

Soils are generally classified into different types based on their physical characteristics, which include the following:

- Cohesive soils: These soils have a significant amount of clay, which imparts cohesive properties. They are generally more compact and stable compared to non-cohesive soils. Examples include clay, silt, and clayey sand.

- Non-cohesive soils: These soils are composed of loose particles and do not have any cohesive properties. Examples include sand, gravel, and cobbles.

Foundation Types:

The choice of foundation type depends on the soil conditions, the design requirements, and the site's geotechnical characteristics. Common foundation types include:

- Footings: Footings are horizontal supports that transfer the load from the superstructure to the soil. They are generally used for light structures and may be reinforced with steel to increase their strength.

- Piers: Piers are vertical supports that transfer the load to deeper, more stable layers of soil. They are commonly used for structures that require additional support or where the soil conditions are not ideal.

- Slab-on-grade: This foundation type involves pouring a monolithic slab directly on the ground. It is commonly used for basements and is cost-effective for low-rise structures.

- Pier and beam construction: This type combines the use of piers and beams to transfer the load to deeper layers of soil. It is suitable for structures that require additional support or where the soil conditions are not ideal.

Design Considerations:

The design of the foundation should take into account the soil conditions and other factors such as the weight of the superstructure, the expected loads, and the environmental conditions. The following are some key considerations:

- Soil investigation: A detailed soil investigation is necessary to determine the soil types, their properties, and the load-bearing capacity of the soil. This information is crucial for selecting the appropriate foundation type.

- Load-bearing capacity: The load-bearing capacity of the soil should be determined to ensure that the foundation can support the weight of the superstructure without settlement or failure.

- Drainage: Proper drainage is essential to prevent water accumulation in the foundation, which can lead to erosion and damage.

- Construction techniques: The construction techniques used for the foundation should be appropriate for the soil conditions and the design requirements. This includes the use of appropriate materials and the application of proper construction techniques to ensure the integrity of the foundation.

- Monitoring: Monitoring the performance of the foundation is necessary to ensure its stability and to detect any issues early on. This includes regular inspections and testing of the soil conditions and the foundation structure.

In summary, the design and construction of a house and its foundation are critical components that significantly impact the overall performance and durability of the structure. Proper planning, design, and construction, along with ongoing monitoring, are essential to ensure the safety and longevity of the building.
Foundations are critical elements of a house. Depending on the configuration of the basement, foundations are labeled as "shallow" or "deep." The side of the house, the house form, and the location of the basement all play a role in the design of the foundation. The foundation transfers the load of the house to the soil and provides a stable base for the structure. Foundations are covered by soils and are not directly exposed to water. If they are, they may be problematic, especially if they are not properly maintained or if they are exposed to water for an extended period.

Foundations must be properly maintained to ensure the stability and longevity of the building. Chemical treatments are used to prevent decay and prevent the growth of mold and mildew. Chemical treatments are also used to treat termite damage and prevent the spread of termites. Metal building blocks are more resistant to decay and termite damage, making them a popular choice for building foundations. Roots can also cause damage to foundations, so it is important to maintain proper plant and tree management around the building.
SHALLOW FOUNDATIONS

areas are discussed in the following paragraphs.


different foundation types commonly used in

the soils are expansive or otherwise unstable
drains are used in many areas of Colorado where
the land in deeper strata. Deep drilled piers allow
the load into the ground and transfer much of
foundation wall essentially anchoring the building
and rock in some depths below the base of the
have been excavated and replaced by other highly expansive
are specified in conjunction with overconsolidated or filling materials
that are directly supported by soil,

elements. Shallow foundations have been

Colorado Geological Survey

Fronting 1A. Foundation "A" (1A) Consists Of

on excavation and fill replacement designs.

wetted where moisture is highly detrimental.

To reduce settlement it is generally not

concentrates the weight of the house. This type of

weight of the house, which spreads our reaction load

heavily laden bearing area (pier area) in contact

The footing has a rectilinear

of a continuous strip of concrete, typically 10

a spread footing foundation (fig. 1) consists

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The pattern of load transfer is similar to that for a gravity wall. The foundation consists of a shallow foundation on the land side and a deep foundation on the water side. This type of foundation has been used in Colorado for over 100 years. It is common to find such foundations on farms and ranches, especially in high-altitude areas. The load is transferred from the foundation to the soil by a series of small beams, called load beams, which are supported by the foundation. These beams are often made of concrete or steel. The shallow foundation is typically used to support light loads, while the deep foundation is used for heavier loads.

Figure 1. Shallow foundation and well-graded foundation

Well-graded foundation (Figure 1) consists of a continuous foundation wall that extends directly from the land side to the water side. This type of foundation has been used in Colorado for over 100 years. It is common to find such foundations on farms and ranches, especially in high-altitude areas. The load is transferred from the foundation to the soil by a series of small beams, called load beams, which are supported by the foundation. These beams are often made of concrete or steel. The shallow foundation is typically used to support light loads, while the deep foundation is used for heavier loads.
Deep Foundations

Basements, when properly constructed, are the most appropriate foundation design for Colorado's diverse soil conditions. Drilled piers foundations (Fig. 15) are the deep bored into the subsoil and subjected to a relatively small number of piers. This design allows the load of the house to be carried throughout the soil strata below the zone of expected post-construction settlement, and the piles may be drilled until the piles are driven into the basement. Further, thepiles may be driven into the basement. Further, the piles may be driven into the basement.
The foundation wall is at risk of buckling or bowing. The foundation wall is a third of the height of the building, unless otherwise stated.

- Sealed bars or beams of concrete, beams, or other types of reinforcement may be provided by the builder, as well as steel or other materials where the exception applies.
- The reinforcement is provided to prevent the foundation wall from buckling or bowing.

Figure 16 shows several types of drilled pier configurations used in Colorado. They may be specified by the engineer or architect.

Lateral Support for Foundation Walls

It means a precasted concrete resistance or deep foundations installed in the foundation walls. The precasted concrete is used in areas of Colorado as a guide for the installation of drilled pier foundations. The drilled pier foundations are installed by drilling holes in the ground and inserting the pier. The pier is then extended into the ground, providing support. The foundation wall is then built around the pier. The drilled pier foundations are especially used in areas where shallow foundation walls are necessary.
Floor Construction

Flooring that is very high swelling pressure

P = Pile
VA = Vent space
FW = Foundation wall

Figure 12: Two types of basement floor systems in Colorado. (from 114 Structural).