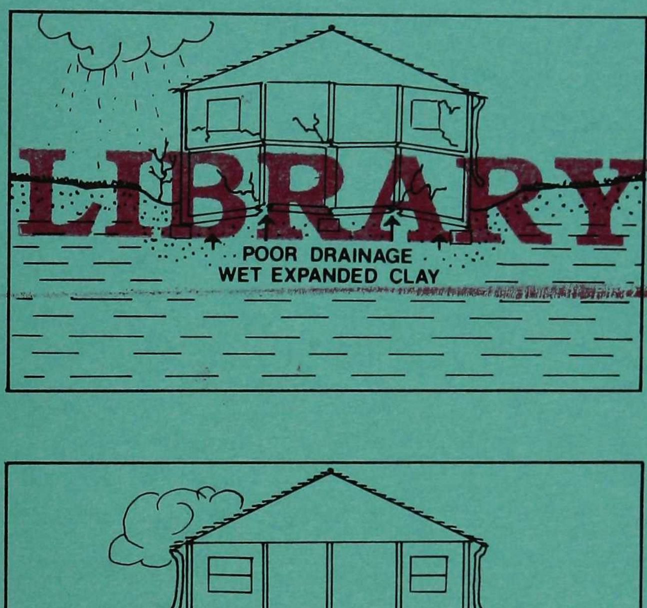
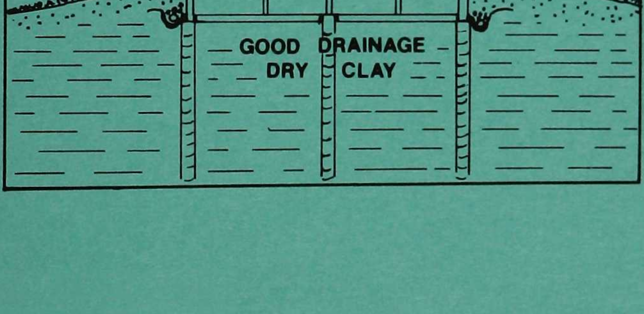
SPECIAL PUBLICATION 11

Information for the Colorado Homeowner...

HOME CONSTRUCTION ON SHRINKING AND SWELLING SOILS





HOME CONSTRUCTION ON
SHRINKING AND SWELLING
SOILS

BY

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for the
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INTRODUCTION

Each year in the United States, shrinking or swelling soils inflict at least $2.3 billion in damages to houses, other buildings, roads, pipelines and other structures -- more than twice the damages from floods, hurricanes, tornadoes, and earthquakes combined! Of the 250,000 new homes built on expansive soils each year, 60 percent will experience only minor damage, but 10 percent will experience significant damage -- some beyond repair.

Soil properties primarily determine the potential for swell, while environmental conditions producing soil moisture changes determine the actual amount and rate of swell or shrinkage beneath structures and pavements. Differential heave, rather than total movement, is generally responsible for major structural damage. Differential movements are usually caused by non-uniform changes in soil moisture and irregularities in the thickness and composition of the foundation clay strata. Variations in soil moisture may result from edge effects of wetting or drying on a covered area, which may involve seasonal or cyclic (long time) weather changes, drainage patterns, local watering, or drying of soils from evaporation and where shrubs and trees remove soil moisture by transpiration.

Colorado's semi-arid climate and geological setting combine to make it one of the most severely affected areas of expansive soils in the nation. One expert recently estimated that the annual cost of damage to public buildings, roads and schools in Colorado may exceed $16,000,000 in taxpayer funds. Damage to public buildings has been discussed very frequently by news media and is well documented.

Unlike news coverage of damage to public facilities, damage to homes from swelling soils has not received extensive publicity. The number of homes on the resale market with severely cracked sidewalks, garage floors, and basement walls and floor slabs is, however, an indication of the widespread nature of the problem. Several homes in the Denver area have received severe damage exceeding 50% of the value of the structure. However, most of the home damage would be classified as minor (Figure 1) to moderate (Figure 2),

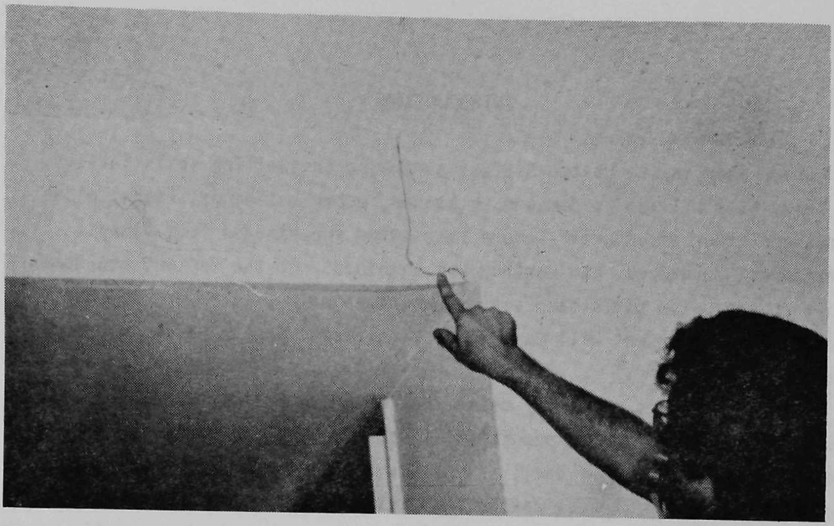

Fig. 1 MINOR DAMAGE

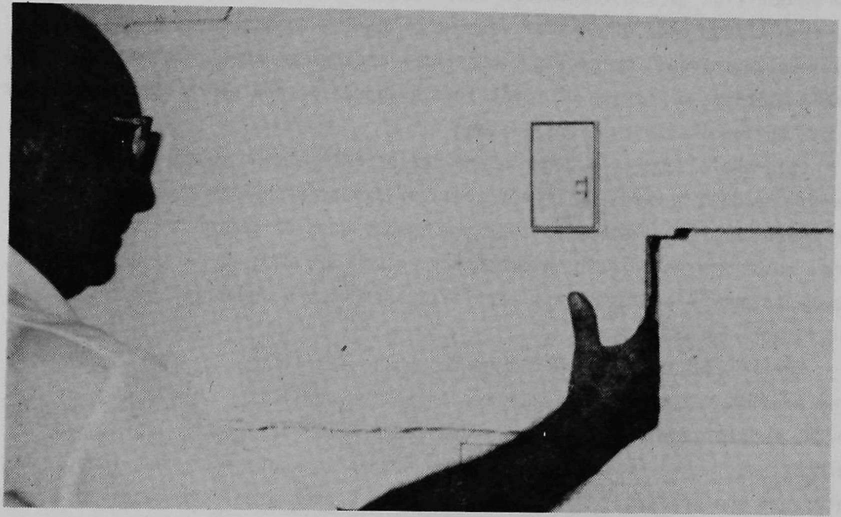

Fig. 2 MODERATE DAMAGE

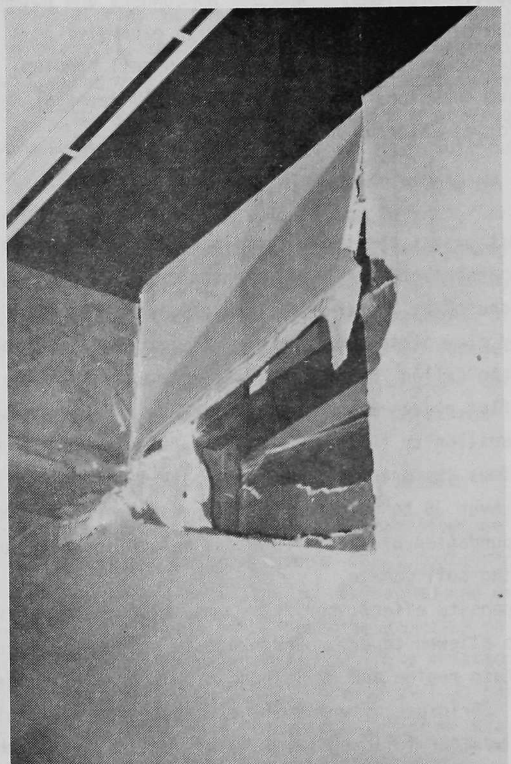

Fig. 3 MAJOR DAMAGE

rather than severe (Figure 3). Figure 4 is a sketch showing typical house damage occurring from swelling soils.

If you are new to Colorado, you may ask, "What is swelling soil, and where is it located?" If you are a homeowner experiencing expansive soil problems, you might ask, "How can my problem be solved?" A do-it-yourself homebuilder may be concerned with "How can I finish my basement without creating costly problems?" And all homeowners and potential homebuyers need to know "Who can I turn to for help with expansive soil problems?" Although no one solution exists for every swelling soil problem, providing answers to the above questions can lessen the costly remedial work that may fall upon uninformed Colorado homebuyers.

WHAT IS SWELLING SOIL?

In most cases, the clay minerals in rocks and soils are responsible for the expansion and shrinkage phenomenon. The change in rock or soil volume is caused by the chemical and physical attraction of water molecules to the tiny clay plates that make up the expandable, montmorillonite clay mineral often called "bentonite." As more water is made available to the clay, the flat plates are pushed farther apart (Figure 5). In a sample of pure montmorillonite the plates may expand so much that the sample increases up to 15 times its original volume. While most montmorillonitic soils will not expand over 35 to 50 percent, the pressure and movements created on a building foundation by this tremendous volume increase are responsible for most swelling soil damage.

The opposite effect, shrinkage, may also damage structures if a previously wet soil is allowed to dry. Shrinkage is not unlikely in the semi-arid Rocky Mountain region and buildings in this area have been damaged by soil shrinkage. Shrinkage often can be attributed to foundation construction during wet weather followed later by dry cycles, or to the presence of moisture-loving trees or shrubs near the foundation which remove soil moisture by transpiration. As an example of the effect of wet-dry climatic cycles on foundations, we may use the period of 1977-1978. Two homes constructed side-by-side on highly swelling soil during this period may behave differently.

This is due to the greater potential for damage from swell of a house built during the extremely dry spring or summer of 1977 and the greater potential for damage from shrinkage of a house built during the wet spring of 1978. It is obvious that clay soil foundations should not be allowed to dry during construction.

The amount of volume change that can take place depends upon 5 basic factors: the amount of clay in the soil, the type of minerals in the clay, the denseness of the soil, the amount of moisture change and the amount of structural load applied to the soil. Highly plastic clay soils containing montmorillonite, which are dense, lightly loaded and undergo major moisture changes develop the greatest volume changes and may cause heavy damage.

Swelling minerals other than clay also occur widely in semi-arid areas such as Colorado. Hydrated calcium sulfate, or "gypsum," and sodium sulfate, or "white alkali," may have moderate swell potential if they constitute more than 15 to 20 percent of a soil. This swelling is caused by the pressures developed during crystal growth rather than the expansion of flat plates. Although these sulfate minerals have caused swelling damage to structures, they are more generally considered a hazard due to their corrosive effects on certain types of concrete and on buried metal pipes and cables.

WHERE ARE COLORADO'S SWELLING SOILS?

More than 90 percent of Colorado's population lives on the eastern plains or the valleys on the Western Slope. Rocks containing swelling clay are generally softer and less resistant to weathering and erosion than other rock types, and, therefore, more often occur as deposits on the plains and in valleys than in the high mountain terrain. This relationship between population and geology means that every major population center along the Front Range and many of the cities on the Western Slope are underlain, at least in part, by swelling soils and/or swelling shales.

The primary bedrock formations having swelling potential are the Denver-Dawson, Laramie, and Pierre shales on the eastern plains and the Mancos and Lewis shales on the Western Slope. Most of the cities from Walsenburg and Canon City on the south to Ft. Collins and Cheyenne and Laramie, Wyoming, on the north are underlain by one or more of the three major eastern bedrock

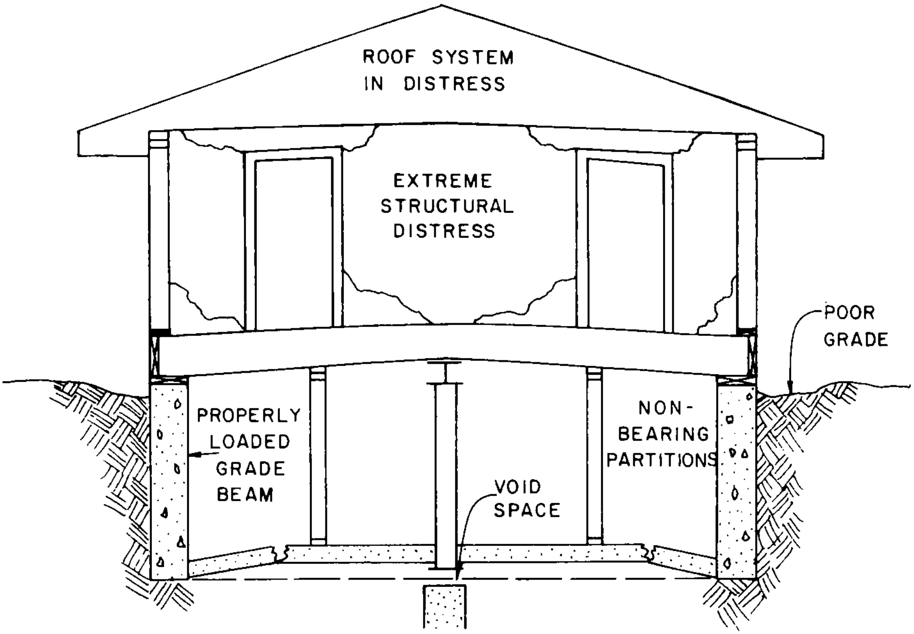

FIG. 4 TYPICAL MAJOR HOUSE DAMAGE

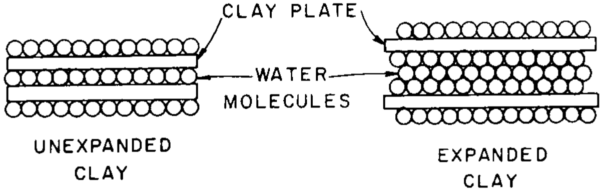

FIG. 5 SKETCH OF EXPANDING CLAY PLATES

units. Craig, Grand Junction, Montrose, Delta, Gunnison, Durango, and many smaller towns on the Western Slope are underlain by the Mancos or Lewis shales.

CAN THE PROBLEMS BE SOLVED?

Although engineers and builders cannot guarantee complete solutions for every swelling soil problem, several design and construction methods have been used successfully in the Rocky Mountain region to reduce the risk of severe damage. It is not the purpose of this publication to make recommendations for specific building sites or buildings. Site soil conditions and structural designs can vary considerably. It is the purpose of this publication to advise home buyers and owners, builders and others related to the home market of the damages that can be caused by shrinking and swelling soils and relate certain methods of design, construction and maintenance which have been used to mitigate or control structural damage. These methods include properly engineered foundations, segmented interior designs and carefully designed lot drainage and landscaping to minimize saturation or desiccation of the foundation soils.

Foundation Design. To be considered properly engineered and constructed, a foundation should be designed and inspected by a registered professional engineer specializing in soil and foundation engineering. In the areas of Colorado that contain moderately to highly swelling soils, drilled pier and grade beam, or "caisson," foundations are generally recommended (Figure 6a). Placing the bottom of piers well below the zone of seasonal moisture change minimizes the risk of changes in the soil moisture regime. Piers must be anchored in the non-swelling soil zone to minimize uplift. This can be done by belling the pier bottoms, grooving the pier hole near the bottom, or extending the piers to sufficient depth for anchorage. A three-to six-inch space must be left between the foundation soil and the grade beam in order to concentrate the weight of the building on the piers and not allow the soil to press upward on the grade beam. The pad and grade beam foundations (Figure 6b) or extended bearing wall (Figure 6c) are sometimes used in moderately to lowly swelling soils. These foundation designs are intended to concentrate the weight of the structure for a small depth below grade,

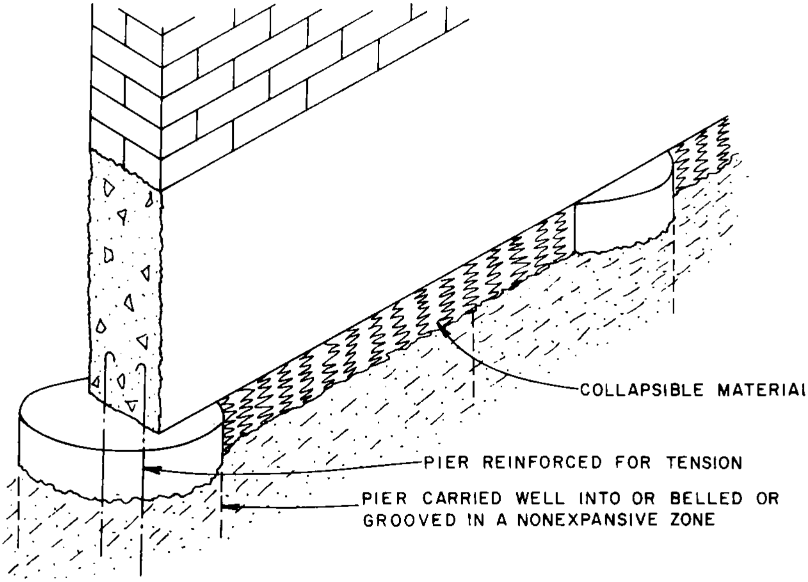

FIG. 6 TYPES OF FOOTINGS
A. FOUNDATION WALL ON DRILLED PIERS

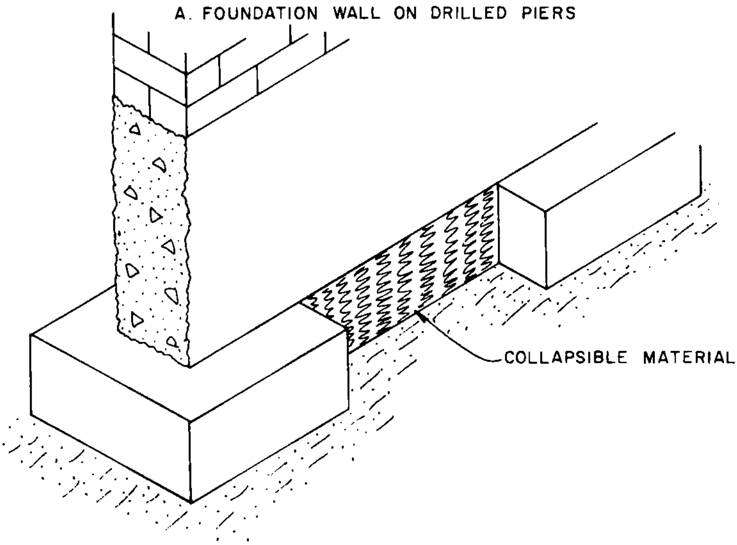

FIG. 6 TYPES OF FOOTINGS
B. FOUNDATION WALL ON PAD TYPE FOOTING

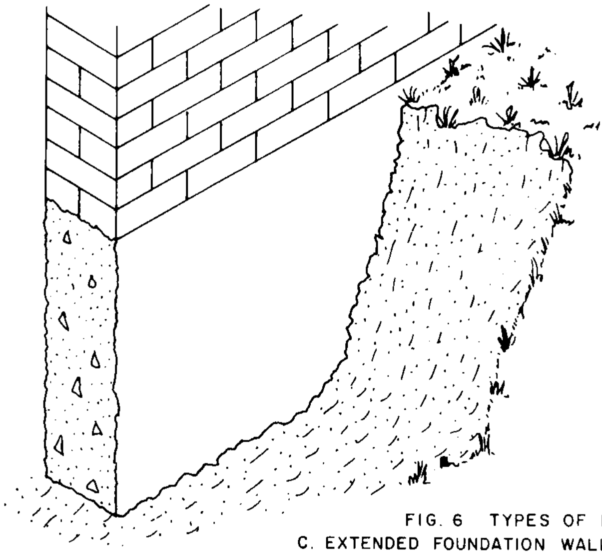

FIG. 6 TYPES OF FOOTINGS
C. EXTENDED FOUNDATION WALL WITHOUT FOOTING

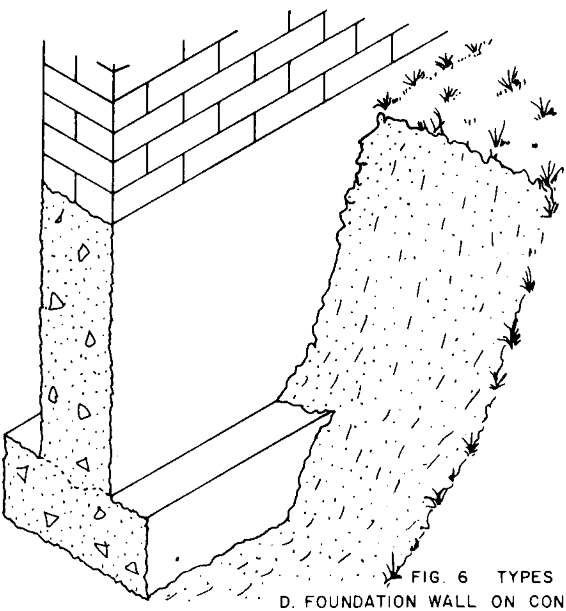

FIG. 6 TYPES OF FOOTINGS
D. FOUNDATION WALL ON CONTINUOUS SPREAD FOOTING

but they do not necessarily concentrate the load below the zone of seasonal moisture change, and should not be used in highly swelling soils. The most common design in areas of extremely low swell or non-swell potential is the continuous spread footing foundation (Figure 6d). In this design, the weight of the building is transmitted to the soils through reinforced concrete strips that are wider than the foundation wall. Special moisture control measures are often required for this design.

Ordinary concrete "slab-on-grade" foundation design that is used in other parts of the country is not recommended for use in Colorado on natural soils that have even slight swell-shrinkage potential. Some new designs of structural concrete slabs, such as post-tensioned reinforced concrete slabs, certain types of "BRAB" slabs and structural above-grade floorings are available for consideration under certain conditions. The more common spread footings and ordinary slabs can function properly if the expansive soils are removed to sufficient depth and are replaced with compacted, non-expansive soils or chemically treated on-site soils. The addition of lime or cement in adequate amounts can reduce the swell-shrinkage potential of most expansive soils in the Colorado area. Certain other chemical treatments are reported to be beneficial. In the above cases, experienced technical guidance is important.

Interior Design. Although a completely rigid box structure would tend to eliminate swelling soil damage, such a structure would be exorbitantly expensive. A segmented, or "flexible," rather than rigid, design is therefore normally used to minimize damage to the interiors of houses located in swelling soil. The major component of this type of design is the "floating" floor slab, used for basement, garage, and other floors resting on the soil (Figure 7). Complete isolation of the floor from bearing walls, columns, nonbearing partitions, stairs, and utilities allows the slab to move with minimum damage to the structural integrity of the building. Some cracking of the floor slab can be anticipated. Bearing walls should be founded similar to the exterior walls at the particular site. When soil movements are anticipated, nonbearing (nonstructural) walls can be suspended from the ceiling with a void space of several inches provided between the wall and the floor slab. Flexible jointing to the floor also may be used. The void

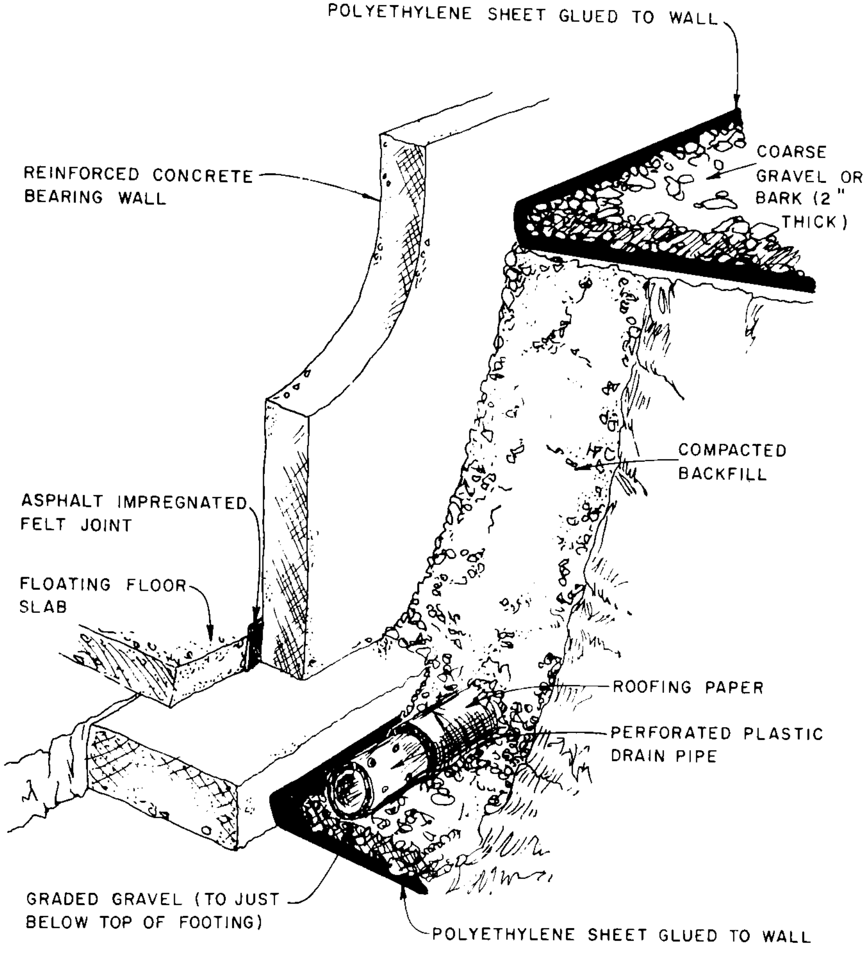

FIG. 7 DETAILS OF TYPICAL FLOATING FLOOR SLAB AND PERIMETER DRAINAGE

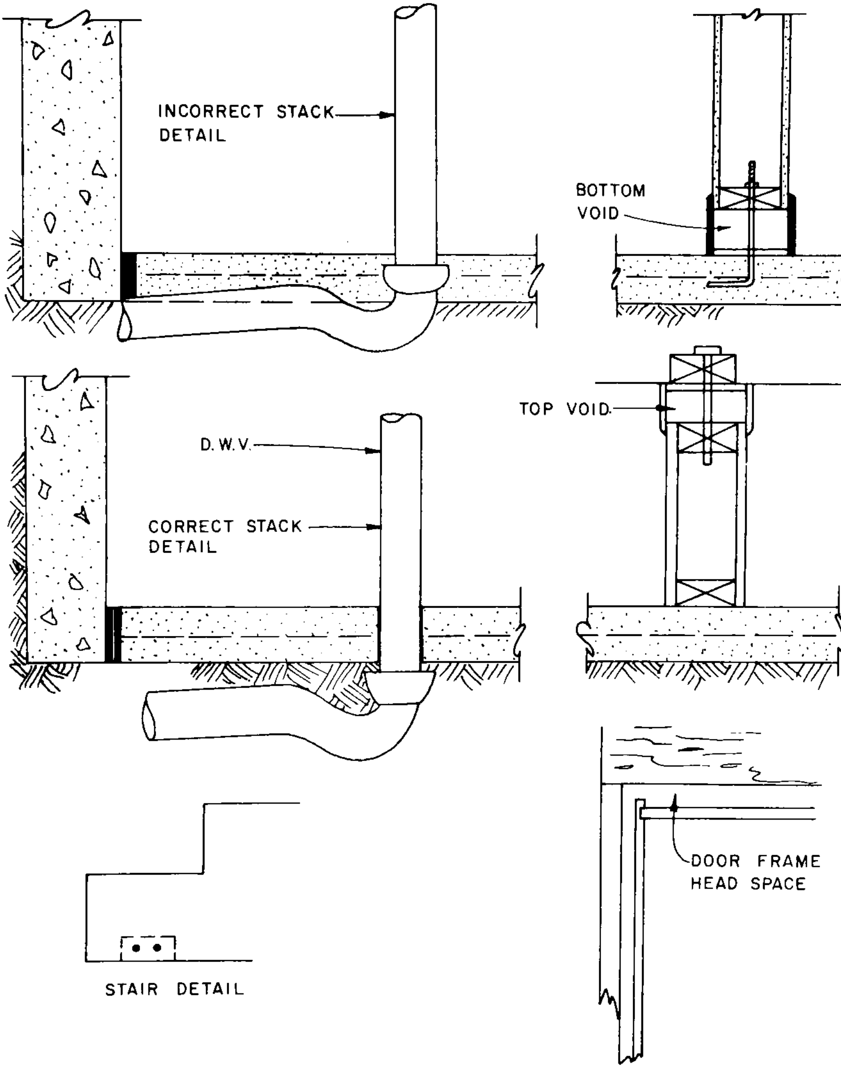

FIG. 8 INTERIOR CONSTRUCTION DETAILS

space may be covered with flexible molding attached to the wall or with standard molding attached to the floor. Water, sewer and gas lines installed through walls or floor slabs that may experience movement should be designed to absorb the movement without breaking. Flexible pipe, "U"-shaped connectors, and rubber gaskets and collars are available where utility lines enter the house through walls or floor slabs. The use of a flexible plenum between a basement furnace and the ductwork is also suggested in order to mitigate furnace damage caused by floor movement. Sewer vents should not be rigidly attached to floor slabs or unprotected walls or roof damage may occur. Homeowners or contractors should follow these precautions also when finishing the basement or garage of an existing house. Figures 8 and 9 show some of the interior construction details which have been used successfully.

Drainage. Because changes in the moisture content of expansive soils are the cause of both swelling and shrinking, drainage is extremely important in minimizing soil-related damage. Peripheral drains of clay tile, or perforated plastic pipe, imbedded in gravel envelopes, are often used around foundations to carry away excess subsurface water which could seep into the foundation level as shown in Figure 7. Compacted impervious soil backfill around the foundation walls helps to keep excessive moisture from penetrating near the foundation. Water must not be allowed to stand near foundations but must be drained into drainage swales, pumped sumps, storm sewers, or streets. Twelve inches of vertical fall in 10 feet of horizontal distance is often used as a guideline for the grade of slopes surrounding the foundation of houses. Figure 10 shows one scheme for rain and surface water control. All downspouts and splash blocks should be placed so that roof runoff will be carried at least 10 feet from the building.

Landscaping. A house with the proper foundation, interior, and drainage design may still experience soil damage if the homeowner does not properly landscape and maintain his property. The most critical aspect of landscaping is the continual maintenance of properly designed slopes. Flattening slopes, or not correcting settlement of the soil near foundations, will create ponding of rain, snowmelt and irrigation water. Asphalt, concrete, or impermeable plastic moisture barriers surrounding the foundation (Figure 10) are often used as an additional precaution. If cracks or separations develop, they must be kept filled.

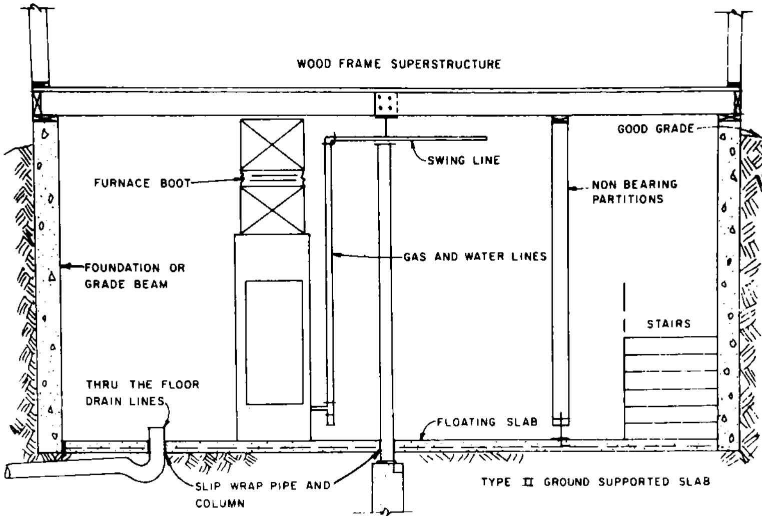

FIG. 9 INTERIOR CONSTRUCTION DETAILS

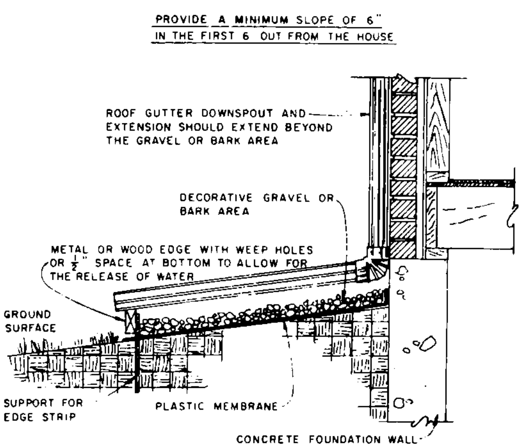

FIG. 10 SUGGESTED METHOD FOR SURFACE WATER CONTROL

To minimize soil wetting, grass, shrubs, flowers and sprinkler systems should be kept a minimum of 5 feet from the foundation. In order to control desiccation (moisture loss), all trees should be planted at least 15 feet from any building, except that large water-loving trees such as cottonwood, willow, and russian olive should be kept at least 20 feet away. Houses constructed on deep caisson (drilled pier) foundations do not usually suffer from such drying effects if founded well below changes in the moisture regime, although outside slabs may suffer.

WHERE CAN I LEARN MORE ABOUT SWELLING SOILS?

Several federal, state and local agencies can provide general information concerning swelling and shrinking soils. The U.S. Department of Housing and Urban Development and the Veterans Administration have pamphlets for home buyers. The U.S. Geological Survey has expansive soil and engineering geologic maps available for some metropolitan areas in the country, including several in the Rocky Mountain region. The Denver offices of the Colorado Geological Survey and the Colorado Division of Housing have publications concerning swelling soils, engineering geology, and building codes available to the public. Local government planning agencies and building departments may also be able to provide prospective home buyers with information concerning potential problem areas. Firms with registered professional engineers who specialize in soil and foundation engineering usually have information on troublesome areas and can be helpful when expansive soils at a site are suspected.

WHERE CAN I GET SPECIFIC INFORMATION ABOUT MY LOT OR MY HOUSE?

When shopping for an undeveloped lot in a platted subdivision, the developer should be able to furnish a copy of a subdivision report by a registered professional soils engineer. Such reports are generally required by HUD-FHA, VA, and state and local agencies, and may be found in local government planning offices if unavailable through the developer. Such reports should be utilized only to inform the buyer of potential problem areas and not for design of an individual house. During the design of the house, a registered professional engineer should be hired to inspect the homesite and design the foundation. Such an engineer may be found under "Engineers--soil" or "Engineers--foundation" in the Yellow Pages of the telephone book. It is also important that the architect designing a new house be aware of any expansive soil problems, and the type of designs needed to reduce damage risks, and that he follow the recommendations of the soils engineer.

When shopping for an existing house, the prospective buyer should look for cracks in basement and garage floors, in driveways and sidewalks, and in walls near the corners of doors and windows. Furnace plenums and utility lines in basements should be inspected for signs of movement. Some badly cracked homes have been repaired on the outside and paneled on the inside to hide the damage. If the buyer suspects that significant damage has occurred, a professional engineer or home inspection consultant should be hired to evaluate the home before a contract is signed.

WHAT LEGAL MEANS CAN I USE TO RECOVER MY REPAIR COSTS?

Homeowners whose homes have required extensive repairs due to damage from shrinking or swelling soils may seek legal aid to recover their repair costs. In Colorado, three possible legal theories of recovery have been utilized to recover such costs. The first theory -- negligence -- may be used if the homeowner-can prove that the contractor neglected to follow the recommendations of his architect and engineer. Fraudulent concealment is a second theory that might be used if the homeowner could prove that the builder, real estate agent or seller knowingly withheld information concerning damage or hazardous soil conditions, or if the builder knowingly violated building code provisions that produced the damage to the structure. The third theory of recovery is breach of either an express or implied warranty. An implied warranty, under present Colorado law, may be applied only to new homes, not to previously owned homes. This type of warranty implies that the builder has complied with local building codes, that the home was built in a workman-like manner, and that the home is suitable for habitation.

Regardless of the types of legal action that are available, the homeowner should realize that a countersuit can be filed by the builder if the homeowner was negligent in landscaping or maintaining the property. The homeowner should also realize that the statute of limitations in Colorado generally requires that suits involving actions against contractors, engineers, and architects be initiated within 2 years after a claim arises. Prior to any legal action, however, the homeowner should attempt to reconcile his problems with the builder and, if applicable, with any companies which provide warranties or insurance against structural damage.

WHAT ADDED EXPENSES CAN I EXPECT DUE TO EXPANSIVE SOILS?

When building a new home in Colorado, a homeowner should expect some additional costs for design and construction that may not be incurred in other parts of the country. A foundation investigation performed by a registered professional engineer may range in cost from $200 to $1000 with an average near $400. When compared to the common spread footing foundation design, a drilled-pier and grade-beam design may add an additional $500 to $1500 to the cost of construction. The costs of other types of foundations and other precautions, such as peripheral drains, are also in the range of several hundred to $1000 or slightly more.

Investigations of existing homes prior to their purchase may seem an unnecessary expense, but could prevent the homebuyer from purchasing a "lemon." Because, however, sellers of damaged homes may disguise damage with finished basements, paneling, patched drywall, new paint, and outside repairs, an experienced inspector should be hired if the buyer has any doubts. The rate for this type of inspection by a registered engineer or a home inspection consultant may range from $75 to $300 with an average near $150.

Repairs to soil-related damage may range in cost from hundreds to thousands of dollars, depending on the severity of the damage. In most houses built on expansive soil, such costs may involve only sufficient paint and patching compound to repair minor drywall cracks. Slightly more severe expansion may cause cracks in basement walls and floors. If these cracks open enough to require professional sealing and waterproofing, the cost may range upward from $200. If floor slabs are cracked severely enough to require replacement, the cost will undoubtedly be at least $1500. Major structural damage may require repairs costing $3000 or more, with some homes having recorded damage approaching 50 percent of the market value of the home. Although damage of this magnitude is not normal, potential homebuyers should be aware that such instances have occurred within the past 5 years.

(Costs and other data quoted in the above text are based on mid-1978 estimates.)

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