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HOUSE BASEMENTS ON PRAIRIE CLAYS

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FIGURE 1
AREAS OF SWELLING CLAY SOILS IN WESTERN CANADA

Here's how builders can economically stop floor heaving

Areas of shifting clay soils in the Canadian Prairies often cause extensive damage to basement floors and have resulted in the restricted use of basements as living space in the Western Provinces. In this article from the Division of Building Research, National Research Council, co-authors J. J. Hamilton and G. O. Handegord detail economical methods to prevent heaving of basement floors allowing builders to take advantage of the increasing trend to utilization of basement area as an integral part of a home's living space.

Differential movements of foundations on the clay soils of the Canadian Prairies often result in extensive damage to houses and restrict the use of basement space. The opinion has often been expressed that nothing can be done within economic limits and that the homeowner must learn to "live with the problem." In the light of present knowledge and because of the generally higher standards of performance demanded by homeowners, this approach can be seriously questioned.

The higher initial cost of the special foundation techniques required to cope with this problem can result in a substantially lower annual cost to the owner and can eliminate the frustration and worry of a shifting structure. Of equal importance is the additional value of basement space. One of the most definite trends in housing in recent years has been the increased utilization of basement space, either as a future extension of living space or as an integral part of the initial design.

If the builder chooses to develop the basement space as part of the total design, his costs per square foot of finished space will be substantially lower than those for equivalent main floor area. These savings may easily offset the additional costs arising out of special foundation techniques, and the builder gains greater sales appeal whether the basement is finished initially or left for future expansion. His costs for callbacks resulting from heaving floors are reduced or eliminated and his reputation is enhanced by customer satisfaction.

Nature of the Problem

In the Prairie Provinces most, if not all, soils having appreciable clay contents will shrink when dried or swell when wetted. Construction experience and agricultural soil mapping makes it possible to outline the major boundaries of the troublesome soil deposits which are shown as shaded areas in Figure 1. Certain locations within these areas may be free of the problem, but in the absence of expert investigations or long-term experience the areas outlined may be regarded as having potential soil swelling or shrinking problems.

In general, the greater the change in the moisture content of a clay soil the greater its volume change. The long-term influence of climate and vegetation on the moisture content of these soils is consequently very important. When the site is disturbed by construction activity changes in soil volume are to be expected owing to:

(a) changes in surface and subsurface drainage patterns;

(b) the sheltering of areas previously exposed to the weather, or the covering of areas of soil with impervious materials;

(c) changes in soil temperature patterns;

(d) the growth of vegetation not native to the area;

or

(e) the addition of water for lawns and shrubs.

Disturbance of the natural environment by construction is particularly evident in the shortgrass lands of west-central Saskatchewan where semi-arid conditions have prevailed for several centuries and the clay sub-soils have very low natural moisture content, even at depths ranging to 30 feet. Almost without exception, construction in these areas causes an increase in soil moisture and results in swelling of the clay under or in close proximity to new structures. This swelling sometimes reaches very large proportions and basement floor heaving of more than 2 feet has been measured.

In the more humid areas the growth of large trees or densely populated scrub trees may have dried the soil locally to great depths. When these trees are removed the amount of moisture in the soil increases and the resulting swelling may cause heaving of floor slabs and shallow foundations. Floor heaving in excess of 1 foot has occurred in areas of Winnipeg where deep-rooted trees were removed immediately prior to construction.

On the other hand, if tree growth is encouraged near shallow foundations where trees have not previously grown, settlement due to soil shrinkage may result. Damage from this cause can be observed in older residential districts of cities where large trees have grown close to buildings.

In general, the foundation problems encountered in house construction on volume-changing clays can be divided into two main categories. The first and most frequently encountered condition is heaving of the basement floor and central footings. Where only this problem occurs conventional footings can be used to support the perimeter foundation, and soil movement beneath the central footings can be isolated from the superstructure through the use of adjustable basement posts. Level basement floors can also be ensured by providing structural floor systems.

The second category includes more serious foundation problems in which both the central and perimeter footings undergo differential movements. This condition is usually most severe in clay soils having heavy tree growth. It can best be handled by deep foundations that penetrate the swelling clay to the stable soil layers beneath, combined with structural floor systems spanning these deep supports. The pile and beam construction is well suited to this purpose.

Conventional Footings

Where heaving of the interior footings is encountered in conventional construction, the movement is transferred to the house superstructure by the interior basement posts or load-bearing wall. Floor heaving, plaster cracks and racked windows and doors result. Usually, the greatest rate of heaving will be experienced within the first few years of construction, but seasonal movement of footings and basement floors may continue throughout the life of the building.

Movement of the superstructure can be controlled by the use of adjustable metal posts or jacks in the basement to support the central beam. A chalk line or stretched wire along the edge of the central beam can be used as a reference mark for adjustment. For success this method requires the continuous interest and attention of the homeowner and it does nothing to alleviate the undesirable conditions in the basement itself. The

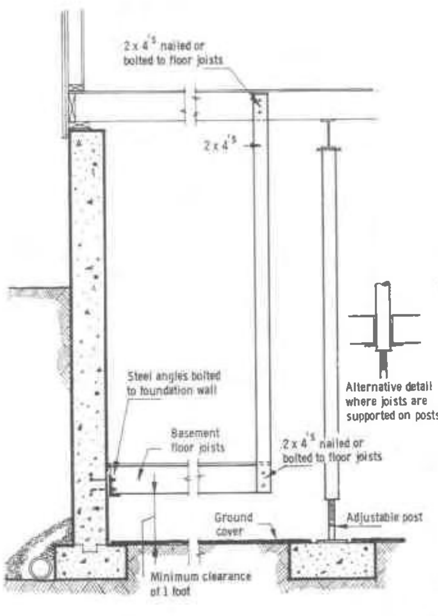

FIGURE 2
CONVENTIONAL FOUNDATION WITH SUSPENDED BASEMENT FLOOR

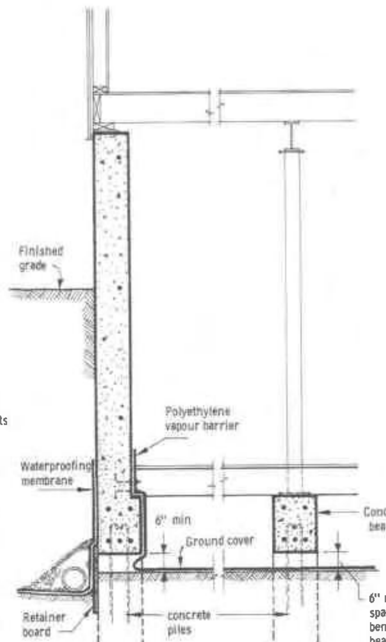

FIGURE 3
PILE AND BEAM FOUNDATION

heaving of the interior footings and concrete floor (see photo) makes utilization of the basement space difficult, if not impossible, and it may damage plumbing and heating components.

To overcome these latter problems, a suspended floor system can be used. This method can be developed with conventional footings, but it requires a deeper excavation to allow clearance between the soil and floor structure. The design of the foundation wall must make allowance for the increased depth of backfill required with this type of construction as well as the local soil conditions. Figure 2 illustrates an application of the suspended floor principle, which has been used successfully by a prominent builder in Winnipeg for the construction of houses where part of the basement space is utilized as living quarters. The wood joist floor system is hung from the joists above by the studs, which also serve as partition wall framing. Where the whole basement is to be of the suspended type either wood or steel beams may be attached to the adjustable posts to provide support for the basement floor joists. This is shown as an alternative detail in Figure 2. With these methods the posts must be installed in an inverted position so that adjustment for both basement and upper floors is provided.

Figure 2 illustrates the general principles to be followed, but the details can be modified to suit other floor systems. It is important to maintain sufficient clearance below the suspended floor to allow for air circulation as well as potential soil heave. This under-floor space can also facilitate the servicing of plumbing and provide space for running heating ducts. In any case, access must be provided to the screw-jack adjustment of the post. The soil surface must be covered with a vapor barrier to prevent excessive moisture gains to the house and drying of the soil. This membrane can be protected with a thin layer of sand or a thin concrete topping.

Pile and Beam Foundations

Pile and beam construction has proved to be a highly successful foundation for crawl space houses in volume-changing soil areas. In effect, the piles act as columns extending through the problem soil to solid bearing or to depths where soil volume changes are negligible. The load of the building is transferred to the piles by beams. An adequate space must be left beneath the beams to ensure that soil swelling will not lift them off the piles; and the piles themselves must have sufficient tensile strength to resist the uplift forces from swelling soil near the surface.

In houses with basements the conventional foundation wall reinforced at the top and bottom can be used as the perimeter beam and either reinforced concrete, wood or steel beams employed to support the centre area of the house. This approach also requires a deeper excavation than does conventional construction and a design based on local soil conditions. The method is illustrated in Figure 3. A minimum void space of 6 inches must be provided below all beams to allow for soil swelling. This can be formed by a variety of construction techniques, including supporting the beam forms on a gravel pad at the desired elevation and later removing the gravel, or using cardboard void forms under the beam. To maintain the void after backfilling retainer boards should be driven several inches into the subsoil around the perimeter of the foundation and resting against the outside of the beam.

A vapor barrier must be placed over the ground surface in the crawl space. In this instance it should continue up the inside of the foundation wall to grade level, and excess membrane should be provided to allow for any movement of the soil in relation to the wall (Figure 3).

Reinforced concrete piles 12 to 15 inches in diameter and from 15 to 25 feet in length have been used successfully in some areas, but their actual dimensions and the amount of reinforcing steel required in a particular location will depend on local conditions. All piles should be reinforced against uplift forces, which develop as swelling occurs in the soil near the surface. The additional cost of pile and beam construction is not yet well established, but initial experience suggests that for an average house it would be in the range of $300 to $500. This cost may be reduced as the method becomes more common.

Other methods that could be developed to reduce swelling soil problems include the use of roofs or partition walls designed as trusses to support clear-span main or basement floors, and open-web steel joists spanning basement walls without intermediate supports. These and the adjustable post system previously described can be satisfactory provided that no significant differential movement occurs in the soil beneath the perimeter foundation walls. The pile and beam system gives protection against such movement and permits complete utilization of basement space. In the light of present knowledge, it should provide the most reliable foundation for houses on swelling clay soils.

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