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Publisher's version / Version de l'éditeur:

Building Note (National Research Council of Canada. Division of Building Research), 1956-06-01

CANADA

BUILDING NOTE

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DIVISION OF BUILDING RESEARCH • NATIONAL RESEARCH COUNCIL • OTTAWA, CANADA

21

June 1956

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Many of the inquiries received by the Division result from problems associated with leaky basements and damp crawl spaces.

The structural details for house foundations are well known to builders, and seldom do we hear of a structural failure. Leaky basements and damp crawl spaces are common, however, and are a constant source of trouble to owners and builders.

Where a new house is involved, the owner quite naturally appeals first to the builder, who usually finds it difficult to correct the situation once the house is completed and landscaped. The proper place to damp-proof or waterproof a foundation is on the outside, and this, of course, can only be done economically during construction.

Basements and crawl spaces will be discussed here under separate headings, but problems related to surface drainage and site conditions that are common to both will be dealt with only once.

BASEMENTS

There is an increasing use being made of basements for living areas and coupled with this is the demand for dry basements. It is often said that dry basements are not designed, they just happen. It is our opinion that basements can be designed using ordinary materials that will be dry under most conditions. Care in design and workmanship to assure this is justified by the high cost of repairing wet basements.

<u>Dampness may be due to:</u>

(1) leakage;
(2) capillarity or seepage;
(3) condensation.

These may occur together but can often be identified separately. Leakage and capillarity usually occur in spring while condensation is commonly a summer condition.

<u>Leakage</u> will be apparent by the presence of free water on the inner surfaces of walls and floors. It is caused

by water finding its way through porous concrete or masonry, cracks, around service pipes, form wires, or through imperfect waterproof coatings.

Capillarity is made possible by the contact of an absorbent material such as unprotected concrete or masonry with damp earth or water. Moisture is drawn through walls and floors much the same as water is soaked up by a wick.

Capillarity is normally evidenced by damp spots. If evaporation at floor and wall surfaces is high, these surfaces may appear dry but at the same time be loading the basement air with moisture. Wicking action through basement floors is the chief cause of failure in flooring materials placed on the slab surface. Tiles and their adhesives prevent surface evaporation, and the free water formed at the adhesive often results in failure.

When damp spots are not in evidence, it is still possible to determine if moisture is passing through the slab by a simple test. Cover an area with a rubber mat for a few days and then observe the condition under the mat. If the under surface of the mat is wet, then capillarity is taking place.

The chief causes of both leakage and capillarity are inadequate drainage and faulty construction.

DRAINAGE

It may be well to mention the two basic types of drainage: (1) surface drainage; and (2) drainage below grade. Several aspects of surface drainage can be considered.

Eaves troughs and downspouts should be provided. Downspouts should be connected to underground drains where possible or discharged into leads that will carry the water away from the foundation. The least that should be done is to provide extensions directed away from the building.

Downspouts should never be connected to the footing tiles.

Backfill and topsoil at grade should be sloped away from the walls to assist run-off and prevent ponding of water near the foundation. Settlement of backfill next to the wall can result in reverse slopes and soil cracking, making it easy for water to collect around walls and footings.

Drainage Below Grade

Even though precautions regarding surface drainage are taken, some water will enter the ground, and it is not uncommon for the water-table to be above the footing line. To relieve this situation, drain tile are placed around the footings. Tile, when properly installed, are effective for other than extreme conditions such as exist in low areas near swamps, rivers, and lakes.

Tiles should be placed alongside the footings and connected to a suitable outlet. A slope toward the outlet of $\frac{1}{4}$ inch to $\frac{1}{2}$ inch in 12 feet is suggested for these tile. Joints between tiles should not exceed 3/8 inch and should be covered with tarred felt or asphalt paper to prevent the entry of soil particles. Twelve inches or more of gravel or other granular material should be placed over the tile before backfilling. Broken or cracked tile should not be used as they will cause blocking. Tile elbows are available and should be used around corners.

Outlets are sometimes difficult to provide when storm sewers are not available. Dry wells are used to drain water to the water-table where the topsoil is relatively impervious and the subsoil fairly absorptive. Dry wells should never be used in clay as ponding around footings may result. Roof drainage should not be carried to dry wells provided for the footing tile. Sometimes a house built on dry ground is troubled with a wet basement six months to a year after construction. Upon inspection, one would find that the roof leaders end in dry wells a few feet from the house.

Drain tile can often be led to open ditches on sloping lots. On level sites it may be necessary to lead the tile to a sump pit from which it can be pumped up and out to a location away from the foundation.

CONSTRUCTION

There are several factors which contribute to inferior construction.

(1) Inadequate footings can result in settlement, thus causing cracks in walls and separation at the junction of floors and walls. Cracks have occurred where the perimeter footings were adequate but no provision was made for the support of interior load-bearing walls bonded to it.

Footings should be designed for special conditions and reinforced where necessary. A special situation exists where foundations are partly on bed-rock and partly on soil. There is often movement in soil due to consolidation once building loads are placed upon it. This movement is usually uniform where the foundation is entirely on soil. Where part rock and part soil is encountered, however, there can be enough differential movement to cause cracking.

Footings should not bear on new backfill. If low areas exist in the excavation, footing depths should be increased or stepped footings used so as to be in contact with undisturbed soil.

Where footings are required, a rule of thumb design calls for the footing depth to equal the wall thickness and the width to equal twice the wall thickness. In no case should the footing be less than six inches thick, and it should project four inches beyond each side of the wall.

Footing forms should not be filled with rock to within a few inches of the top and covered with a thin shell of concrete. It is equally poor practice to use "soupy concrete". Such footings will fail under load causing cracks in walls. Clean strong rock can be used in footings and in walls if spaces are left between rocks and between forms and rock for concrete.

(2) Poorly laid blocks will crack and leak. All horizontal joints and vertical end joints should be filled with mortar. The first course should be laid in a full mortar bed. Joints should be 3/8 to $\frac{1}{2}$ inch thick and compacted after the mortar has set up a bit. Various mortar mixes are used but cement should be included in the mix for walls below grade. Suitable mixes would be:

(a) 1 : $\frac{1}{4}$: 3 - cement : lime putty : sand;

(b) 1 : 1 : 6 - cement : lime putty : sand.

(3) Walls of poor concrete improperly placed and cured can be expected to crack and leak. Today many builders use ready-mix concrete but usually the concrete is placed by the contractor and the curing is always his responsibility. Concrete 2500 p.s.i. (1: 2 : $3\frac{1}{2}$) or better is recommended for basement walls. Construction joints can be avoided by continuous placing. Good concrete properly placed and cured has a high resistance to water and is made with the same materials as poor leaky concrete.

(4) Failure to provide water-tight joints between the walls and floor often results in leakage at this point. Many of our inquiries originate from this type of failure. It is recommended that a $\frac{1}{2}$ to $\frac{3}{4}$ inch space be left between the edge of the slab and the wall to be filled with oakum and bituminous material after the floor has cured. In addition, a mortar cove should be provided on the outside at the junction of wall and footing. It is not known how much leakage at this point can be attributed to the absence, or poor installation, of footing drain tile.

(5) Damp-proofing or waterproofing should be provided on the exterior of foundation walls. When blocks are used, the wall should be plastered before bituminous coatings are applied. The plaster should be a 1 : 2½ or 1 : 3 cement : sand mix and should be surface dry to receive the bituminous coatings. A ½ inch thickness is recommended and some authorities suggest that this be done in two ¼ inch coats with the first coat scratched to receive the second.

Bituminous materials commonly used are brush-applied cutbacks and asphalt emulsions. Two or three criss-cross coats of these materials should be applied. More satisfactory results can be obtained with hot asphalt or coal-tar pitch.

Backfilling should not be done until the coatings are dry, and then care should be taken to ensure that they are not damaged.

Seepage of ground moisture through floors can be prevented by an underlay of five or six inches of gravel, crushed rock or cinders. If floor coverings or finishes are to be used on the basement floor, it is well to install a membrane between the underlay and the slab. This will prevent seepage if water rises through the underlay to the underside of the slab.

Seepage through walls is usually less severe than through floors and is prevented or reduced by the damp-proofing.

Waterproofing

Where conditions are severe, it is necessary to carry out a membrane treatment to both walls and floors.

This membrane of alternate layers of hot bituminous materials and paper or fabric should be as continuous as possible from a point above grade down the wall and should run under the floor or be placed between two lifts of concrete making up the slab.

Water pressure can be severe and where heads of 3 or 4 feet of water occur, slab reinforcement or underfloor drainage should be considered to prevent cracking and leaking.

Condensation will occur on walls and floors when humidities in basements are excessively high. The condition is usually most severe on warm, humid days in summer. Condensation is caused by moisture in the air coming in contact with the relatively cooler walls and floors which maintain temperatures close to those of the adjacent soil. Sometimes damp surfaces thought to be caused by seepage are actually due to condensation. A check test for condensation can be made by covering suspected areas with glass or sheet metal. Water on the exposed face of these materials indicates that condensation is taking place.

Condensation may be eliminated or reduced by:

(1) Ventilation, provided the air introduced is dry. Basement windows should be closed when outside humidities are high and would add to the condensation on cool inside surfaces.

(2) Heating the basement air increases its capacity to hold moisture and raises the cool surfaces above the dew-point. On warm days, the cure may be worse than the illness.

(3) Insulation will reduce condensation on walls and pipes. Vapour barriers should always be used to protect this insulation.

(4) Removing moisture from the air by mechanical or chemical means.

Mechanical dehumidifiers are available which operate on the principle of condensing moisture on cooled coils.

The chemicals commonly used are calcium chloride and silica gel. Calcium chloride is relatively inexpensive, but it must be disposed of when liquid and replenished daily. The solution is harmful to concrete and vegetation, and will corrode metal.

Silica gel is more expensive but may be dried and re-used many times.

BASEMENTLESS CONSTRUCTION WITH CRAWL SPACES

Crawl spaces are the enclosed spaces under the first floor of a building where there is no basement or occupancy. These spaces may be from one foot to several feet in height. For access purposes, a minimum height of two feet should be maintained between the underside of the joists and the ground surface.

The walls of these spaces may be concrete, masonry, wood or other materials. Regardless of details, the result is enclosed spaces which can be a constant source of moisture and trouble. This trouble is normally limited to those spaces where little or no ventilation has been provided.

Field studies have shown extensive damage occurring to buildings where improperly constructed foundations with crawl spaces were used. In one housing project of 200 units, where the crawl spaces were almost completely closed up the year round, 16 first floors had rotted enough in 4 years to require replacing. In 6 years, it was necessary to either renew or make major repairs to all units.

In other buildings, dampness from crawl spaces not only caused serious damage to floors but to other parts of the structure as well. One case was reported of a severe condensation problem in the attic of a 3-storey building constructed over a crawl space. Careful observation revealed that 32 to 45 gallons of water were evaporated in this building every 24 hours - most of which came from the soil in the crawl space.

The situations described were corrected by ventilation. There are certain recommendations for the location and size of vents. The net vent opening based on the 2 + 1/3 formula for a crawl space 24 by 40 is $5\frac{3}{4}$ square feet. If the opening is covered with an 8-mesh screen, then $1\frac{1}{4}$ times this area is required (four openings 12 inches by 22 inches or eight openings 12 inches by 11 inches).

At least four openings should be used, one near each corner; and these should be placed as high as possible in the walls.

Vents should be left open in winter, making it desirable in this climate to insulate floors, pipes and ducts. Care should be taken that the vapour barrier is on the top side or room side of the floor insulation.

In recent years it has been found practical to reduce the amount of moisture entering the crawl space by covering the ground with a vapour-resistant membrane. A layer of 55-pound rolled roofing lapped a few inches at the joints is frequently used. A more expensive treatment consists of a thin concrete slab topped with alternate layers of bituminous coatings and building papers.

It may be interesting to note that in fine-grained soils it is possible, even though the water-table be 30 inches below the surface of the ground in the crawl space, that evaporation from the earth may run as high as 19 gallons per 24 hours per 1,000 square feet. Evaporation from the same soil covered with a 55-pound roofing may be less than $\frac{1}{2}$ gallon for the same area.

As far as we know at present, membraning does not eliminate the need for ventilation; however, it seems reasonable to assume that when membranes are used, ventilation can be reduced.