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DAMPNESS IN MASONRY WALLS ABOVE GRADE*

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* Causes and remedies for dampness in basements are discussed in letter circular LC813 "Dampness in Basements and Ground Floors," obtainable from the National Bureau of Standards, Washington 25, D.C.

I. INTRODUCTION

Inquiries received at the National Bureau of Standards on the subject of damp masonry above grade1/indicate that no type of masonry is entirely free from this defect. Reports of individual instances indicate that the difficulty can often be traced to improper design or faulty construction. Dampness in masonry walls may result from: (1) the leakage of drainage water from roofs and horizontal surfaces into the walls, (2) the penetration of wind-driven rain into the walls, (3) the condensation of moisture within or on the inside faces of the walls, or (4) the capillary rise of ground water from the foundations. The following discussion is intended to supply more complete information than is feasible by correspondence.

II. DRAINAGE FROM HORIZONTAL PROJECTIONS

Structural defects that permit the drainage water from roofs and water tables 2/to flow onto or into the masonry are believed to be one of the most common causes of damp walls. The nature of the defects is well known, but in order to avoid them the designer must make provision for conveying drainage water away from the masonry and the builder must carry out the details with care.

1. Design and construction of water tables

All horizontal or sloping surfaces should be either waterproof or separated from the masonry below by a flashing of some durable material. For example, flashing may be provided under copings, cornices, pervious or jointed sills, and projecting courses of masonry. At junctions between parapet walls and roofs, the flashing which is built into the roof surfacing should be extended upward high enough to prevent overtopping by roof water

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1/ In addition to LC813, referred to on the title page, methods of waterproofing masonry walls below grade are described in the following publications:
U.S. Dept. of Agriculture, Farmers' Bulletin No. 1572, "Making cellars dry." 5¢. Copies of this and of other Government publications referred to in later footnotes may be purchased from the Superintendent of Documents, Government Printing Office, Washington 25, D.C., at the prices stated, or they may be consulted in Government depository libraries. Remittances should be made either by coupons (obtainable from the Superintendent of Documents in sets of 20 for $1.00 and good until used), or by check or money order payable to the "Superintendent of Documents," Government Printing Office, Washington 25, D.C., and sent to him with order.
"Waterproofing engineering," by Joseph Ross.
"Concrete building construction," by Crane and Nolan, both published by John Wiley and Sons, New York, N.Y.

2/ For purposes of this report a water table is defined as any ledge or offset on or above a foundation wall, formed to shed water.

and then carried horizontally through the wall to within 1 inch of the outer surface. Courses which project beyond the exposed vertical faces of walls should be provided with undercut drips, in order to shed water away from the walls.

Where flashings have not been used as suggested above, joints in copings and cornices should be filled with mortar or with a plastic calking compound. 3/ The capillary absorption of water into copings or cornices built of absorptive stone or other materials may be reduced by treatment with a suitable colorless liquid waterproofing. 4/

2. Repairs to water tables

Poorly designed or otherwise inadequate flashings on roofs, parapet walls, and around chimneys should be replaced when necessary. Cracks in the units or in the joints of horizontal surfaces should be repaired and filled with mortar. Since water that has penetrated defective flashings on the horizontal surfaces of masonry may appear on the inside faces of the walls at points far below the point of entry, it is important to check carefully the watertightness of all water tables. If this is not done, the mistake may be made of assuming that dampness in a wall is the result of penetration of the exposed vertical face by wind-driven rain.

III. WIND-DRIVEN RAIN ON VERTICAL SURFACES

The possibility that dampness may penetrate vertical walls should be taken into consideration in the original plans and specifications.

The likelihood of rain entering through exposed vertical faces of walls in sufficient amounts to cause dampness on interior surfaces depends upon wind velocity, intensity, and duration of rainfall, and the location of objects which tend to shield the wall, as well as upon its permeability. In some localities, rainfall accompanied by wind of sufficient intensities to cause the saturation of masonry walls may be expected many times during the life of a building. For example, in states bordering on the Atlantic Ocean, rains lasting over a period of three days with an average rainfall of 0.05 inch per hour are not uncommon. During such a rain, 3.6 inches would fall on a horizontal surface. For wind velocities of 10 and 20 miles per hour, the intensity of rainfall striking a vertical surface may be, respectively, twoce and three times as much as that on a horizontal surface.

3/ The calking compound should meet the requirements of Federal Specification TT-C-598, Plastic Calking, 5¢.

4/ Information on tests of colorless waterproofings for sealing the pores in stone and other masonry materials is contained in National Bureau of Standards Research Paper RP771, "Experiments on exterior waterproofing materials for masonry," 5¢.

1. Construction of watertight masonry walls

(a) Brick walls

The results of laboratory tests 5/ of masonry walls exposed under conditions simulating those produced by wind-driven rains indicate that penetration by capillarity alone is a slow process. For example, only the most rapidly absorbing bricks were wetted through from end to end within a period of 1 hour, most bricks requiring several hours and some several days. Similarly, moisture was transmitted very slowly by capillarity through mortar joints, the time required for water to penetrate solid mortar joints in an 8-inch wall generally being more than 1 day. Walls of bricks of extremely low absorption with well-filled mortar joints did not transmit moisture during an exposure of 2 weeks. Other walls of similar materials but with poorly filled joints leaked in periods ranging from 2 to 5 minutes. It is obvious, therefore, that excessive rain penetration in masonry walls results from openings in the joints rather than from capillary transmission of moisture through the masonry materials.

The tests show the importance of completely filling the vertical joints with mortar. In order to obtain a strong and water-tight bond with the masonry unit, a mortar which tends to retain its moisture when in contact with dry highly absorptive units should be used. Likewise, the mortar should not readily permit water to run from the joints when it is used with low absorptive units or with bricks that have been wetted. 6/ The mortar should be of as wet a consistency as can be conveniently handled and it should be retempered frequently if necessary. Mortar which has greatly stiffened or in which the cementing material has started to set should not be used.

It is also important to wet bricks that have a high absorption or a rapid rate of absorption because, at the time of laying, the absorptive capacity or "suction" should be low. The absorption per brick (30 square inches) should be between 6 and 20 grams (0.2 and 0.7 ounce) when the brick is partially immersed on the flat side to a depth of 1/8 inch for one minute. The brick used

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5/ Building Materials and Structures Report BMS82, "Water Permeability of walls built of masonry units," 20¢.

6/ The water retention of the mortar should conform with the requirements of the Federal Specification SS-C-181b. Suitable mortars may contain a masonry cement or portland cement mixed with either a dry lime hydrate or a slaked quicklime putty. The hydrate or quicklime should yield a plastic putty. Limes conforming to the water retentivity requirement for type S of the National Lime Association give an excellent performance in this respect. Copies of this specification may be obtained from the National Lime Association, 927 15th St., Washington 5, D.C.

in the facings of walls backed with hollow units should be wetted if necessary so that they have absorptions as near as possible to the lower limit. The head joints between the brick should be filled with mortar, and either the back of the brick facings or the face of the hollow unit backings should be parged (plastered) with at least 3/8 inch of mortar. The absorption of the brick may be near to the upper limit (20 grams) if the wall contains two or more tiers (wythes) of brick. The head joints in all-brick walls should be completely filled with mortar and the joints between the tiers should either be completely filled or parged with mortar.

Flashings should be installed at the tops of window and door frames so that water penetrating the wall above will be diverted to the outside. Flashings should also be provided at the bottoms of cavity walls so that any leakage water may be drained to the outside through weep holes.

Openings between the masonry and other materials or member, such as window frames, should be filled, preferably with a plastic calking compound.

(b) Concrete masonry walls

The shrinkage of concrete masonry units on drying from a wet condition may result in the formation of unsightly cracks in the wall which permit the entrance of water. The cracking may be prevented or greatly reduced by proper drying of the block before they are laid. Tests have indicated that high-pressure steam curing of concrete block at a temperature exceeding 340°F will reduce the volume change of the block on wetting and drying by as much as 50 percent of the change which may result if the same units are cured at normal temperatures. 7/

7/ The following articles published in the Proceedings of the American Concrete Institute, 7400 Second Blvd., Detroit 2, Mich. contain information on the steam curing and shrinkage of concrete masonry units:

"Shrinkage measurements of concrete block masonry" (Final Report), W.D.M. Allan, Proc. ACI, Vol. 28, p 177 (1932).

"Studies of high pressure steam curing of tamped hollow concrete block," C.A. Menzel, Proc. ACI Vol. 32, p 51 (1936).

"Good Practice in concrete masonry wall construction," Kenneth C. Tippy, Proc. ACI Vol. 38, p 317 (1942).

"High pressure steam curing," Committee 716, Proc. ACI, Vol. 40, p 409 (1944).

Specifications 8/ for load-bearing concrete masonry units and concrete masonry walls limit the moisture content of the units when delivered and require that the units be protected from wetting prior to laying in the walls.

It is difficult to obtain water-tight joints when laying large masonry units. Since most hollow concrete units are also highly permeable to water, walls of concrete masonry require a protective coating or facing. 9/ Excepting brick masonry, the most commonly used coatings for waterproofing concrete masonry walls are cement paints and stucco facings.

2. Waterproofing leaky walls

Waterproofing treatments of masonry walls should be preceded by a thorough examination of the entire structure to determine the causes of dampness. Cracks in the masonry produced by unequal settlement of the walls or by other causes should be filled with mortar or grout. Such cracks often pass through both the masonry units and the joints, and their size will determine whether they can be most easily filled by pointing with a mortar or by brushing in a grout. Deep cracks in bricks should either be filled with a thick grout or the wall should be coated with stucco or a sanded cement-water paint. Open spaces between the masonry and window or door frames should be calked with plastic calking.

(a) Cement-water paints

Tests 9/ have shown that two brushed-on coatings of cement-water paints will prevent excessive rain penetration of walls, provided the paint is well scrubbed into the outer (exposed) faces. Cement-water paints will readily bond to masonry surfaces which absorb water but they will not adhere well to tile or brick which have a glazed surface. When used as waterproofings on the

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8/ Federal Specification SS-C-621 Concrete Units, masonry, hollow. 5¢

ASTM specification designation C-90-44. Copies of this specification may be obtained from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa. for 25¢.

"Facts about concrete masonry," National Concrete Masonry Association, 33 West Grand Ave., Chicago 10, Ill. This publication contains suggested specifications for concrete footings and concrete masonry walls.

9/ Building Materials and Structures Report BMS95, "Cement-water paints and other waterproofings for unit masonry walls," 15¢. Similar data on the effectiveness of cement-water paints as waterproofings were previously given by R.E. Copeland and C.C. Carlson, "Tests of the resistance to rain penetration of walls built of masonry units," Proc. Am. Concrete Inst., vol. 36, p 169 (1940).

exterior of masonry walls such paints should contain a minimum of 80 percent by weight of portland cement (Type II, Federal Specification TT-P-21). 10/

Before they are painted the walls should be clean and free of loose particles of mortar, grease, and waxes. They should be well wetted and in a damp condition. It is important that the masonry absorb little if any water from the wet paint; neither should the paint be thinned by drops of water standing on the surface.

When used on a rough surface such as cinder-concrete blocks, the first coat of paint should contain fine sand passing a no.20 or 30 sieve. The amount of sand to be used depends upon the texture of the surface but it should not exceed equal proportion with the portland cement.

Either factory-made or job-prepared cement-water paints may be used. Commercial paints are finely ground and are likely to give a more uniform color where tinted paints are desired. 11/

A job-mixed paint having excellent waterproofing effectiveness may be made from either white or gray portland cement. Hydrated lime not exceeding 20 percent by weight of portland cement may be added, if desired. The opacity or hiding power of paint made from white portland cement may be increased by the addition of 3 to 5 percent by weight of either titanium dioxide or zinc sulphide. No organic material should be added to a cement-water paint with the exception of not more than 1 percent (by weight of cement) of a water repellent such as calcium or aluminum stearate. "Waterproof" portland cements have a water repellent ground into them at the mill. The water repellents reduce the capillary absorption of water by the paint coating and tend to keep it in a clean condition, but they have no important effect on the permeability of a coating subjected to wind-driven rain.

The preparation of the surface and the technique of mixing with water and applying cement-water paints are the most important factors affecting the durability and effectiveness of the coating. The paint should have the consistency of rich cream, though a slightly thinner consistency may be used for the first coating on walls of concrete units or of highly absorptive bricks. The amount of water per 10 pounds of dry powder may range from 3.25 to 4.75 quarts for commercial paints, and from 2.75 to 3.75 quarts for job-mixed paints. If the paints contain fine sand, about 2 to 3 quarts of water may be required for 10 pounds of powder.

10/Federal Specification TT-P-21, Paint; cement-water, powder, 5¢.

11/An excellent discussion of the composition and use of cement-water paints is "The Nature of Portland-Cement Paints and Proposed Recommended Practice for Their Application to Concrete Surfaces." Proc. ACI, Vol. 38, p 485 (1942). Reprints may be obtained from the American Concrete Institute, New Center Bldg., Detroit 2, Mich. for 25¢.

Cement-water paints should not be applied to frozen surfaces or when the paint may be exposed to temperatures below 40°F within 2 days after application. The paints should be stirred frequently and some aggregate should be picked up with each brush full of sanded paint. On rough-textured walls such as concrete block, cement-water paints are applied to good advantage with a scrub brush or a fender-cleaning brush. Roofing brushes may be used for painting smooth-textured brick or concrete surfaces and also for applying sanded paints to rough-textured walls. The paint should be well scrubbed into the surface and brushes with stiff fibers are recommended for this purpose; whitewash or paint brushes with soft bristles are not suitable. Extremely heavy applications are less durable than thinner coatings. Tests have shown that coatings of cement-water paints applied by a spray gun developed small pin holes through which moisture penetrated; they proved less effective than brush-applied coatings. After the paint has hardened sufficiently (usually in 10 or 12 hours), the coatings should be cured by wetting with a light spray 2 or 3 times a day for 2 days.

Cement-water paints when scrubbed into the surface with stiff brushes will seal hairline cracks in portland cement stucco facings. If the stucco is badly disintegrated a new stucco facing may be applied either over the old facing or after the old facing has been removed.12/ Coatings containing portland cement are not recommended for use over magnesite stucco facings.

Tests of brick and concrete-block walls have indicated that cement-water paints are more effective as waterproofings than emulsified resin and oil-base paints. Oil paints should not be applied to damp masonry or to masonry which may become damp by moisture entering behind the painted surface.

(b) Joint treatments

The most effective and durable methods of waterproofing brick masonry walls without changing their color or appearance are repointing or grouting of the joints. Repointing is the more effective as well as the more expensive of these methods. Since it is difficult to determine which of the joints are permeable, all of the head (vertical) and bed joints should be cut away and repointed. The old mortar should be removed to a depth of about 1/2 in. and dust from the cavity removed with water. The brick should be thoroughly wetted and nearly saturated at the time the joints are refilled with a mortar suitable for brick masonry. In order to facilitate packing of the new mortar into the joints, the mortar consistency may be slightly stiffer than that ordinarily used in laying brick. After the mortar has been applied and allowed to

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12/ Information on the application and repair of portland cement stucco facings may be obtained from the Portland Cement Association, 33 West Grand Avenue, Chicago 10, Illinois.

stiffen slightly, the surface of the joints should be tooled concave or struck with a metal tool using pressure on the tool in order to pack the mortar tightly into place.

Leaky joints that are otherwise in good structural condition may be waterproofed by grouting; joints that are loose and not structurally sound should be cut away and repointed. A grout consisting of 1 part by volume of portland cement and 1 part of sand passing a no. 30 sieve, when mixed with water to the consistency of thick cream, may be scrubbed into the joints with a small, stiff, fiber brush. The joints should be thoroughly dampened before application, and the grout should not be applied thickly but should be scrubbed into the joints. The method has the disadvantage that some cement may be deposited on the surface of rough-textured brick and be difficult to remove with a damp sponge or cloth. A template is sometimes used to cover the brick while the grout is being applied. In cleaning the brick of cement, care should be taken not to remove any grout deposited at the juncture of the brick and mortar. Grouting treatments are more effective and durable when applied to cut mortar joints, than to tooled joints.

Walls containing very highly absorptive header brick with a rapid rate of absorption may permit damaging quantities of water to enter the wall by capillary action. If walls of such brick still leak after the joints have been carefully repointed or grouted, the penetration of water through the brick by capillary action may be reduced by treating the wall with a colorless waterproofing.

(c) Colorless waterproofings

Some colorless waterproofings make the surfaces of masonry units and mortars water repellent thereby reducing the amount of water absorbed by capillarity. Colorless water repellents do not, however, seal openings larger than the pores in these materials and such openings are the major sources of leakage through the walls.

Tests (some of which are described in BMS95) have shown that colorless solutions containing sodium silicate, metallic soaps, paraffin, tung oil, and chlorinated rubber were ineffective as waterproofings for highly permeable walls built of brick or of concrete block. With one exception, water emulsions containing oils and waxes were also ineffective. A water emulsion13/ containing about 45 percent of paraffin and microcrystalline waxes

13/ Specifications for this material include the following requirements: It shall be a free flowing, stable, colloidal emulsion of petroleum waxes, without objectionable odor, which can be diluted with 5 parts of water without wax separation or stratification of wax-containing layer. The water content of the emulsion shall be less than 55 percent, and the emulsion shall contain a blend of equal parts of paraffin wax and a microcrystalline (amorphous) wax as the dispersed phase. The melting point of the solids shall be not less than 135°F. When applied to a masonry surface the emulsion shall dry to a transparent coating.

was effective when first applied, but when the treated walls were again tested after they had been stored outdoors for less than 1 year the treatment had lost much of its effectiveness in preventing leakage even though the surface of the masonry was highly water repellent.

Since cement-water paint coatings and cement-grouts (for joint treatment) require a good bond to the masonry, they should not be applied to walls that have been treated with waterproofings or oil paints, unless the wall surfaces have been carefully cleaned of waxes and oils.

IV. CONDENSATION MOISTURE

1. Causes of condensation

Atmospheric moisture condenses on or in a wall whenever its temperature is lower than the dew point of the air. The amount of moisture deposited will depend on the difference in the temperatures of the wall and of the air, the moisture content of the air and the movement of the air. 14/ The dew point depends on the moisture content of the air.

During the winter months water will condense on the inner faces of walls above grade if the temperature of the surface reaches or falls below the dew point of the air in the structure. Condensation will also occur when an increase in the amount of moisture in the air within a structure is sufficient to raise the dew point of the air above the temperature of the wall surface. This frequently occurs in kitchens, bathrooms and laundries. For a room temperature of 70°F and various relative humidities, the dew points or the maximum temperatures of the wall surface at which condensation will occur on the surface are approximately as follows:

Relative humidity of air at 70°F	Dew point
%	°F
30	37
50	50
70	60
90	67

When walls become damp during rainy weather only, it is not always apparent whether the source of moisture is condensation from the air or from rain water passing through the wall. When droplets of moisture appear on the inner face of the wall this question may be answered by a simple test. Cement a thin piece of metal in close contact with the wall so that the temperature of the metal will be the same as that of the wall surface. If no moisture collects on the metal when moisture appears on the wall surface, it may be concluded that the moisture has penetrated the masonry. If moisture collects on

14/ Building Materials and Structures Report BMS56, "A survey of humidities in residences, walls," 10¢.

the surface of the metal, condensation contributes to the moisture on the wall. It should be noted that when the wall surface is damp without visible moisture on the surface, the dampness may be caused by rain penetration or by the condensation of moisture within the wall, or both, and the test for surface condensation described above may not be applicable.

Condensation within a wall structure may occur if the temperature within any portion of the wall is lower than the dew point of the air at that point.15/ If the permeability to water vapor of the warm surface (inside of the wall) is sufficiently less than that of the cold surface (outside face of the wall), the condensation moisture will vaporize and pass to the outside. However, if the permeability of the warm side is greater than that of the cold side, the condensation moisture may accumulate 16/ until the wall becomes saturated with water. Such a condition may cause damage to the wall, its plaster, or its insulation.

2. Prevention of condensation

(a) Design and insulation of building walls

For dwellings in which the air is not humidified artificially the amount of insulation required to prevent condensation is not large. An air space, sheets of insulating material such as corkboard, rock wool, or a fibrous or mineral insulation board 1/2 inch or more in thickness should suffice. If the insulation is provided by furring, an air space of 3/4 inch will suffice, and the insulating value of a wider space would not be much greater. If the humidity of the air in a building is unusually high (as in laundries and some factories), ventilation will aid in preventing condensation by reducing humidity.

Danger of damage to insulation or plaster by the condensation of water within a wall may be reduced by the use of a vapor-resistant barrier placed on the warm side of the insulation. Thirty-five pound, smooth-surfaced asphalt roll roofing is an effective barrier particularly if the joints are lapped and cemented with mastic. Asphalt-saturated and coated sheathing papers in which the coating forms an unbroken shiny surface are also effective as are some grades of asphalt duplex papers.

15/ Building Materials and Structures Report BMS63, "Moisture condensation in building walls," 10¢.

16/ Building Materials and Structures Report BMS93, "Accumulation of moisture in walls of frame construction during winter exposure," 10¢, and Building Materials and Structures Report BMS106, "Laboratory observations of condensation in wall specimens," 10¢.

Metal-foil backed papers are excellent provided they are not used with the foil in contact with either plaster or masonry.

(b) Insulation of existing building walls

Existing masonry walls may be insulated by the addition of an air space, a layer of insulating material, or both, to either the inside or the outside face of the wall. Insulation may be provided on the outside (exposed) face of a wall by the construction of a new weatherproof coating, such as stucco, wood, or cement-asbestos siding units or shingles over the old wall. An air or furring space may be placed between the new and old wall surfaces and insulating material may also be used.

The inside face of a masonry wall may be insulated by applying sheets of insulation material over the interior face of the wall. The insulation may be furred or it may be applied directly to the wall. If it is desirable to retain a plastered interior, the old plaster may be removed and an air space (furring), insulation, or both, may be placed behind the new plaster.

As previously discussed, damage to insulation or plaster by the condensation of water inside the wall may be reduced by the use of a vapor barrier placed on the warm side of the insulation. Such a barrier may consist of two or three coats of an outside type of varnish or lead-oil paint applied to the plaster. A paint containing flake type aluminum and spar varnish is also effective for this purpose. Cement-water paints are not effective vapor barriers; since vapor barriers, if used, should be placed on the warm side of the wall, cement-water paints are preferred to oil paints on the outside faces.

V. CAPILLARY RISE OF GROUND WATER

Moisture rising from the ground is not a frequent cause of dampness in walls above grade. Where soil drainage is not adequate and the foundations of walls have not been suitably waterproofed, a sufficient amount of moisture may be drawn up by capillarity to cause dampness in the walls some distance above ground level. Measurements of capillary forces in masonry materials at this Bureau indicate that some materials can draw moisture to a height of 20 feet, but that for most types of masonry the height would not be greater than 4 or 5 feet.

Dampproofing courses used to prevent the capillary rise of moisture should be extended entirely through the wall at a height of 5 to 10 inches above the surface of the ground. These courses may consist of layers of impervious materials, such as slate or sheet copper. As an optional method, mortar containing a water repellent may be used for three or more courses of the masonry above grade. Cements in which the water repellent is incorporated are generally available, or the repellent ingredients may be purchased in the form of pastes or powders and incorporated in the mortar. These materials usually consist of salts of fatty acids, such as stearates or oleates of ammonium, sodium, or calcium. The sodium and ammonium salts are found on the market in the form of pastes, while the calcium type may be obtained as a dry powder, usually consisting of hydrated lime and calcium stearate. The amount of such admixture used should provide a fatty acid content from 0.1 to 0.2 percent of the weight of the cementing materials. The producers' specifications usually give the amount of their admixtures to use, which is ordinarily about 2 percent of the weight of the cementing materials. The pastes are added to the mixing water, but the dry powders are mixed with the sand and cement before water is added.

For stone masonry, especially of limestone and sandstone, it is considered good practice to use a granite base or at least one course of granite extending through the wall and slightly above the ground line. Such grade courses should be slightly above the ground line and should be bedded and jointed in a dampproofed mortar as described above. Information on the waterproofing of basement walls is contained in letter circular LC813.