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DAMPNESS IN MASONRY WALLS ABOVE GRADE[1]

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[1] A list of references on building materials, good construction practices and the maintenance of buildings is contained in Report BMS140, Selected Bibliography on Building Construction and Maintenance, 30 cents. This and 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.

I. INTRODUCTION

Inquiries received at the National Bureau of Standards on the subject of damp masonry above grade[2/] 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[3/] 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.

2/ Information on remedial treatments against dampness in basements and on the construction of new water resistant basements is contained in the paper, Prevention of Dampness in Basements published in the Feb. 1948 Jour. of the American Concrete Institute. Reprints, titled 44-19 may be obtained for 35 cents from the Institute whose address is 18263 W. McNichols Rd., Detroit 19, Mich. Similar information is given in U. S. Department of Agriculture, Farmers Bulletin No. 1572, Making Cellars Dry, 15 cents. Further information on this subject is contained in the books Waterproofing Engineering by Joseph Ross and Concrete Building Construction by Crane and Nolan, both published by John Wiley & Sons, New York, N. Y.

3/ 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.

1. Design and construction of water tables

All horizontal or sloping surfaces should be either waterproofed 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 and then carried horizontally through the wall to within 1 in. 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. 4/ 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.

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 amount to cause dampness in

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

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 locations, rainfall accompanied by winds of sufficient intensity 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 in. per hr are not uncommon. During such a rain, 3.6 in. would fall on a horizontal surface. For wind velocities of 10 and 20 miles per hr, the intensity of rainfall striking a vertical surface may be, respectively, twice and three times as much as that on a horizontal surface.

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 hr, 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-in. wall generally being more than 1 day. Walls of brick of extremely low absorption with well-filled mortar joints did not transmit moisture during an exposure of two weeks. Other walls of similar materials but with poorly filled joints leaked in periods ranging from 2 to 5 min. 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 watertight bond with the masonry units, a mortar which tends to retain its moisture when in contact with dry

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5/ Building Materials and Structures Report BMS82, Water permeability of walls built of masonry units, 25 cents.

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 sq in.) should be between 6 and 20 gr (0.2 and 0.7 oz) when the brick is partially immersed on the flat side to a depth of 1/8 in. for one minute. The brick used 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 in. of mortar. The absorption of the brick may be near to the upper limit (20 gr) 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 members, such as window frames, should be filled, preferably with a plastic calking compound.

6/ The water retention of the mortar should conform with the requirements of Federal Specification SS-C-181c (70 percent) and may preferably be 80 percent or more. Suitable mortars may contain a masonry cement or portland cement and either lime hydrate or a slaked quicklime putty. Lime hydrates conforming with the requirements of ASTM Standard C206-49, Type S, yield a plastic putty and should be suitable for use in a mortar of high water retentivity.

(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/

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.

7/ The following articles published in the Proc. of the American Concrete Institute, 18263 W. McNichols Rd. Detroit 19, 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, 177 (1932), ACI Jour. Nov. 1931, $1.25.

Studies of high pressure steam curing of tamped hollow concrete block, C. A. Menzel, Proc. ACI Vol. 32, 51 (1936). ACI Jour. Sept.-Oct.1935, $1.50.

Good practice in concrete masonry wall construction, Kenneth C. Tippy, Proc. ACI Vol. 38, 317 (1942). Reprint (38-22) 35 cents.

Physical properties of high-pressure steam-cured concrete block, Progress Report of ACI Comm. 716, ACI Jour. Vol. 24, 745 (April 1953), Reprint (49-53), 50 cents.

High pressure steam curing, Comm. 716, Proc. ACI, Vol. 40, 409 (1944), Reprint (40-20), 35 cents.

8/ Federal Specification SS-C-621, Concrete units, masonry, hollow, 5 cents. ASTM specification designation C90-52. Copies of this specification may be obtained from the American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., for 25 cents. Facts about concrete masonry, National Concrete Masonry Assn., 38 S. Dearborn, Chicago 3, Ill. This publication contains suggested specifications for concrete footings and concrete masonry 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] The most commonly used protective coatings for 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 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]

9/ Building Materials and Structures Report BMS95, Cement-water paints and other waterproofings for unit masonry walls, 25 cents. 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. American Concrete Institute, Vol. 36, 169 (1940).

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

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 lb

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11/ Standard ACI 616-49, Titled 46-1 discusses the use and composition of portland cement paint and may be obtained for 50 cents from the American Concrete Institute, 18263 W. McNichols Rd. Detroit 19, Mich.

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 lb of powder.

Cement-water paints should not be applied to frozen surfaces or when the paint may be exposed to temperatures below 40° F within two 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 hr), the coatings should be cured by wetting with a light spray two or three times a day for two 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 are 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.

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, Ill.

(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 ordinarly used in laying brick. After the mortar has been applied and allowed to 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 water resistant coatings

Some colorless "waterproofings" make the surfaces of masonry units and mortars water repellent thereby reducing the amount of water absorbed by capillarity. Such materials, including the silicone solutions, provide some protection against the leakage of wind-driven rain for as long as the masonry surfaces remain water repellent. However, for permeable masonry, the duration of the protective period may not exceed a few hours of exposure to wind-driven rain. Some treatments, such as the silicone water repellents, provide breather type (vapor permeable) coatings and, as such, they are preferred on the cold face of the wall to continuous films of oils, waxes, lacquers and resins which may have high vapor resistance.

None of the colorless solutions, including those containing silicone water repellents seal the comparatively large cracks and joint openings that are responsible for most leakage. Tests (some of which are described in BMS95) have shown that coatings of sodium silicates, metallic soaps, paraffin, tung oil or 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 emulsion containing about 45 percent of paraffin and microcrystalline waxes was effective when first applied, but when the treated walls were retested after they had been stored outdoors for less than year the treatment had lost much of its effectiveness in preventing leakage even though the surface of the masonry remained water repellent.

When water penetrates a coating of colorless material, some of it may be trapped in the wall. Damage to the masonry may result if this water becomes frozen or, if on evaporation, soluble salts are deposited and concentrated in the pores behind the exposed surface.

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 waterproofing or oil paints, unless the wall surfaces have been carefully cleaned to remove materials which may prevent a good bonding of the paint.

IV. CONDENSATION MOISTURE

1. Causes of condensation

Atmospheric moisture condenses on or in a wall whenever its temperature is lower than the dew point temperature of the air in contact with it. The rate of moisture deposition on a wall surface depends on the difference between the surface temperature and the dew point temperature of the air, and also on the moisture content and movement of the air 13/.

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 having an air temperature of 70° F, condensation will occur on wall surfaces cooler than the dew point temperatures listed, for various relative humidities of the air in the room.

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

When walls become damp during rainy weather only, it is not always apparent whether the moisture is due to condensation from the indoor air or due to 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

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13/ Building Materials and Structures Report BMS56, A survey of humidities in residences, 10 cents. This material may possibly be consulted in a Government depository library.

when moisture appears on the wall surface, it may be concluded that the moisture has penetrated the masonry. If moisture collects on the surface of the metal, condensation contributes to the moisture of the wall, although moisture may also be penetrating from the outside. 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.

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.[14] 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), such vapor as may enter the warm face will not condense but will pass to the outside. However, if the permeability of the warm side is greater than that of the cold side, the vapor may condense and moisture may accumulate[15] 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

Condensation on wall surfaces is not likely to occur during the winter in buildings in which the relative humidity is kept below, or not much above, levels at which condensation occurs on single-glass windows, or even on double-glass windows. A moderate amount of wall insulation such as that provided by a furring space (especially if it has a reflective surface), or by a thickness of 1/2 inch or more of commercial blanket, batt, or board-type insulation, provides an additional degree of safety or protection against condensation on wall surfaces. If the relative humidity of the air in a building is unusually high (as in laundries and some factories), special insulating applications may be desirable, or ventilation with outdoor air may be increased to prevent condensation by reducing the indoor humidity.

14/ Building Materials and Structures Report BMS63, Moisture condensation in building walls. O/P.

15/ Building Materials and Structures Report BMS93, Accumulation of moisture in walls of frame construction during winter exposure, (out of print), and Building Materials and Structures Report BMS106, Laboratory observations of condensation in wall specimens. 15 cents.

Danger of damage due to condensation of vapor within a wall may be reduced by use of an effective vapor-resistant barrier placed near the warmer surface of the wall. Among such vapor barriers are asphalt impregnated and coated or laminated vapor barrier papers, aluminum foils on paper, on plasterboard, or without a backing, and membranes of vapor-resistant plastics furnished in large sheets or rolls. Vapor barriers should be installed with all joints well sealed, and without punctures or breaks. Most insulations in blanket or batt form are furnished with a vapor barrier membrane on one side, which provides good vapor resistance when properly applied.

Aluminum foil vapor barriers 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. Moderate 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 vapor inside the wall may be reduced by the use of a vapor barrier placed on the warm side of the insulation. Suitable paint coatings applied to the plaster or other inside finish of a wall, provide vapor resistance adequate for most buildings. Such vapor barriers may consist of two or three coats of varnish or lead-oil paint applied to the inside surfaces. A paint containing flake-type aluminum and spar varnish is also effective for this purpose. Paints applied to the outside surface of masonry walls should be vapor-permeable. Cement-water paints have low resistance to vapor passage and may be preferred to oil paints or vapor-resistant coatings on the outside faces of the walls.

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.