MODERN METHODS
of
WATERPROOFING

By

Myron H. Lewis, C.E.

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Concrete and Other Structures

A Condensed Statement of the Principles, Rules and Precautions to be Observed in Waterproofing and Dampproofing Structures and Structural Materials

BY

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"Waterproofing—An Engineering Problem," Etc.

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PREFATORY NOTE

In the summer of 1909, The Engineering News Publishing Co. reprinted the author's paper, "Waterproofing—An Engineering Problem," read before the Municipal Engineers of the City of New York. The entire edition of this reprint having been sold, and the plates from which same was made not being available, the present reprint is substituted in response to the public demand for unbiased literature on the subject of waterproofing.

This reprint forms Chapter XXX. of the author's new book, "Popular Handbook for Cement and Concrete Users" (The Norman W. Henley Co., New York), the material for this chapter having been condensed and arranged from the author's papers read before the Municipal Engineers of the City of New York; the Philadelphia Engineers' Club; The Technical League; and from his contributions on the subject of waterproofing to the following periodicals: *Waterproofing*, New York; *Cement Age*, Chicago; *Concrete*, Detroit; *Cement World*, Chicago; *Concrete Age*, Atlanta; *Engineering News*, New York; *Waterproofing and Fireproofing*, Detroit.

For more extended discussion on the topics herein treated the reader is referred to the above papers. Criticisms, suggestions, and accounts of readers' experiences with waterproofing materials and problems are solicited.

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March, 1911.

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The Necessity for Waterproofing.—In many of the forms of construction work to which concrete is so admirably adapted, its use brings with it one inherent fault—a fault for which remedies have long been sought, but which, until recent years, have not been found in a practical form suited to all the varied needs of modern construction. This striking fault of concrete work is its great thirst for water, a fault which varies in its gravity according to the proportioning and mixing of materials and to the nature of the structure, it frequently being the cause of extremely serious difficulty. Of all the opposing forces which constructors have had to combat from time immemorial, none has exceeded in its power for evil the unwelcome intrusion of water, and building materials which in their nature favor such intrusion must suffer in value to the extent of their permeability or absorptive power.

The fact that in practice, concrete is frequently found to be porous and permeable has been one of the leading checks in its rapid development. Volumes have been written on how the ingredients might be mixed to produce a watertight concrete, but we might as well seek to solve the problem of perpetual motion as to try to mix cement, sand, and stone so as not to *absorb* water.

If we could examine a section of concrete under a powerful microscope, it would appear to us like an immense sieve through which fine particles of water flow with more or less freedom.

We have seen water rise up through concrete walls for many feet, and it will rise until the weight of the water absorbed is equal to the capillary attracting force.

As already stated in Chapter VII, if concrete is mixed rich and mixed wet, a high degree of impermeability can be secured. Mixing rich imposes greater barriers to the passage of water; mixing wet minimizes the formation of blowholes by displacing much of the extrained air, but neither mixing rich nor mixing wet destroys the "capillary positive" property of the concrete mass. Its absorptive capacity has been largely decreased, but its attraction for moisture has, however, not been eliminated; thus the water-tightness secured by rich and wet mixtures, however theoretically correct the proportions might be, is one of degree only, a degree sometimes approaching ideal but never reaching it. We cannot expect that a mixture made of cement and stone, each of which is in itself "capillary positive," or water-attracting, can become absolutely proof against the *absorption* of water by the mere act of mixing, unless, indeed, the operation had produced some phenomenal change in the very nature of the constituent materials. By care and diligence, a mixture may be produced which is sufficiently close-grained to prevent the free transmission of water, prevent it sufficiently, in fact, to be all that is required in many forms of construction work. But where water *absorption*, besides water *penetration*, is to be absolutely prevented, no degree of mixing, no richness of mixture, will altogether answer the purpose; and yet in many of the forms in which concrete enters our modern buildings, it is resistance to water *absorption* that is required. Not merely water-tightness in the ordinary sense of the word, but resistance to the ceaseless endeavors of atmospheric moisture to find its way by capillarity through porous bodies. Some counteracting influence to this tendency of ordinary concrete to take up water by capillarity, is, therefore what is required when *dampness* is to be eliminated.

It is true that concrete exposed to the free passage of water becomes after a time so clogged up by fine silt present in the water that the permeability is greatly reduced; and Hagloch states that concrete-block buildings exposed to the weather become water-tight in from three to twelve years, a fact which we must likewise ascribe to the clogging of the surface of the blocks by atmospheric dust deposited by rain, and which remains after evaporation.

Modern engineering or architectural practice should certainly not sanction a practice of waiting for the erratic and uncertain hand of time where it is essential to secure water-tightness and damp-proofness in concrete structures, and in the meantime to incur the annoying consequences that always accompany damp and leaky structures; and yet this is precisely what is being done in numberless instances by those who refuse to realize the importance of water-tightness in concrete work, or while realizing it, are willing through motives of false economy, to gamble with the future—nearly always at their loss.

The number of mistakes made by inadequate provision for waterproofing, and their costly consequences, running into thousands of dollars, should serve as object-lessons to those who have the design of concrete work in hand and the same degree of attention and study should be given the subject of water-tightness as that given to other details of construction.

The importance of the subject and the scarcity of literature concerning it has induced the author to cover the subject in greater detail than would otherwise be necessary.*

Method of Conducting the Work.—*Work Under Contract.*—Waterproofing work should be done, if possible, under contract by a specially skilled waterproofer, or by the concern making or supplying the material.

In a large proportion of cases, the actual construction is left largely to a contractor, sometimes under a more or less loose guarantee; often under no guarantee at all, and frequently without the least supervision being exercised on the part of the owner. In case of trouble after the completion of the work, the owner may consider himself fortunate if he happens to have a guarantee from a responsible contractor who values his reputation for good work as much as he does the cost of remedying the trouble. It is usually not a difficult

* Much of this chapter has already appeared under authorship of Myron H. Lewis in *Cement Era* for 1909–1910, at whose special request the material was prepared and is here rearranged with their permission.

matter for a contractor to disclaim responsibility and endeavor to shift the burden, particularly where the cause of the difficulty cannot readily be ascertained, and where several independent contractors were at work on various parts of the job at the same time. Any interference or injury to the waterproofing by any but his own men, and without his knowledge, will naturally tend to absolve the waterproofer from direct responsibility.

Any deviation from the plans and specifications forming the basis of the contract, failure to lay protecting masonry when required, necessary openings made for pipe passages through walls without the knowledge of the waterproofer, will likewise relieve the latter from his contract in case of future trouble. This division of responsibility has often been the cause of endless annoyance, delays, and expensive litigation. A competent inspector who would look after all the details of the waterproofing from the time preparation of the surfaces begin until final completion of the work, would avoid a great deal of such trouble. If a record is kept of all the work as it progresses, the responsibility for any future trouble may then be traced with some degree of certainty. Without such record, which is more often omitted than kept, establishment of direct responsibility is a difficult matter.

Work Not Under Contract.—A great deal of waterproofing and dampproofing work must of necessity be done, not by contract, but by the purchase of materials and using same according to directions. Where the work to be done is not large, and where the services of an experienced waterproofer are not available, this method must be employed, although, as a rule, it is not so advisable as having the work done by contract, owing to the unfamiliarity of the purchaser with the material and method of application.

In all waterproofing work a great deal of judgment and patience must be exercised if good results are to be obtained, and where materials are not applied by the manufacturer or by one specially familiar with same, the purchaser or owner should see that the material purchased is delivered, and that it be used in accordance with full and explicit directions furnished by the manufacturer or dealer. Conditions on different jobs of waterproofing vary so much that the trade literature accompanying materials cannot be expected to give sufficient information to cover all conditions, and consequently the purchaser in ordering material should describe to the dealer in detail the character of the waterproofing work he has in hand, and request that material and directions be sent specially adapted to that particular work. The usual vagueness and indefiniteness of such descriptions always gives rise to unnecessary delays, errors in shipments, and often in failure of the work.

Importance of Adequate Inspection.—Thorough inspection is particularly essential in the bituminous shield or membrane method, where the waterproofing is to be covered or backed up by protecting masonry or other material, and thus cannot be readily reached for repairs. In dampproofing exposed walls of buildings by application of an asphaltic coating on the interior surface of the walls, inspection should also be particularly rigid as failure means the removal of the plaster covering. Furthermore, the difficulty in tracing sources of leakage when the waterproofing is covered up makes the repair work more uncertain and costly.

On large works particularly, materials specified for waterproofing purposes should be subject to the same degree of inspection and tests as other construction materials. There is nothing easier than the substitution of poor materials for good ones by irresponsible contractors or dealers, particularly when the price is much below the standard price for like materials. So many of the coal tar and asphaltic preparations look alike, that the quality of the material delivered can be ascertained only by subjecting them to specified tests, fixed according to the character of the work in hand. Waterproofing felts and other fabrics should also be examined for defects, and powders and other materials to be introduced as a part of concrete work should be tested and compared with samples obtained, to see that the material ordered is actually delivered.

So many instances of failures due to various causes have occurred that it might be well before proceeding to the detailed consideration of various systems of waterproofing, to review briefly the important points to be considered in general to obtain permanency and efficiency.

The following general principles, if carefully followed, will result in an economical, durable, and efficient work:

GENERAL PRINCIPLES TO BE FOLLOWED IN ALL WATERPROOFING

1st. In deciding upon a system of waterproofing for any particular structure, study the individual conditions of the problem in hand. Consider the location, climate, service, nature of soil, foundation, and all other pertinent data and adopt a plan best suited for the necessities of the case. The "Tabular Outline" at the end of this chapter will materially assist in deciding on the method to employ under given conditions.

2nd. The portions of the structure to be treated must be so designed and prepared that the waterproofing may be properly applied thereon; allowing sufficient working room for securing good surfaces and providing for adequate drainage where water pressure is to be taken care of during construction.

3rd. Complete, unbroken continuity of the waterproofing stratum must be obtained, being allowed for in the design and insisted upon in the construction. Any breaks in the continuity of the work will surely be disclosed in time by leaks.

4th. The material as well as the design should be suited to the individual conditions of the work, and the delivery of the material ordered should be proved by tests and comparison with samples previously submitted.

5th. Where the designer or owner is not familiar with this class of work, alternative plans and estimates may be called for from several responsible concerns and submitted to an impartial architect or engineer qualified to pass judgment on same.

6th. Where work is to be done by the immediate purchaser of materials, complete and explicit instructions should be obtained from the dealer upon written request and in conformity with the conditions outlined by the purchaser, and these instructions should be rigidly followed.

7th. The labor employed in all waterproofing work should be intelligent and careful and wherever possible experienced. The most satisfactory way is to have materials applied by a representative of the manufacturer under a guarantee and under supervision of a competent inspector.

8th. On all large jobs a competent inspector should be present from the inception of the work to its completion, and nothing should be done, and no tampering or interference allowed without his knowledge.

MODERN METHODS OF WATERPROOFING

Numerous methods and materials are now available to keep water and dampness out of almost any structure, and under the most trying conditions, and failure to secure water-tightness at this date must be looked upon as a mistake on the part of some one; either the designer, constructor, or inspector.

All the methods may, however, be embraced in three general classes, as follows:

1. The "Membrane" or "Elastic" method; a term introduced by E. W. DeKnight. (See page 350.)

2. The "Integral" or Rigid, a term introduced by Myron H. Lewis, in 1907, while editing the *Waterproofing Magazine.* Both of these terms have since been widely accepted by leading writers on the subject. (See p. 359.)

3. Surface Coating. (See p. 366.)

These methods are defined in detail in the treatment which follows:

THE MEMBRANE METHOD OF WATERPROOFING

The term "membrane method," as employed by De Knight, refers to an elastic, continuous, bituminous, impervious sheet or membrane which completely surrounds the structure to be waterproofed. This method is adapted principally to waterproofing structures in course of erection, particularly those portions below ground, such as subways, tunnels, building-foundations, retaining-walls, arches, reservoirs, etc. It is not so well adapted to waterproofing structures already erected, or to remedy leaky conditions in same, or to damp-proofing exposed walls of superstructures. Other methods must be adopted for these conditions and these will be considered later.

Materials.—The materials employed in the membrane method of waterproofing are:

1. Coal tar pitch (applied hot).
2. Commercial asphalts (applied hot).
3. Specially prepared asphalts and compounds sold under various trade names (applied cold).
4. Asphalt mastic (applied hot).

When merely dampness is to be excluded, any of the first three

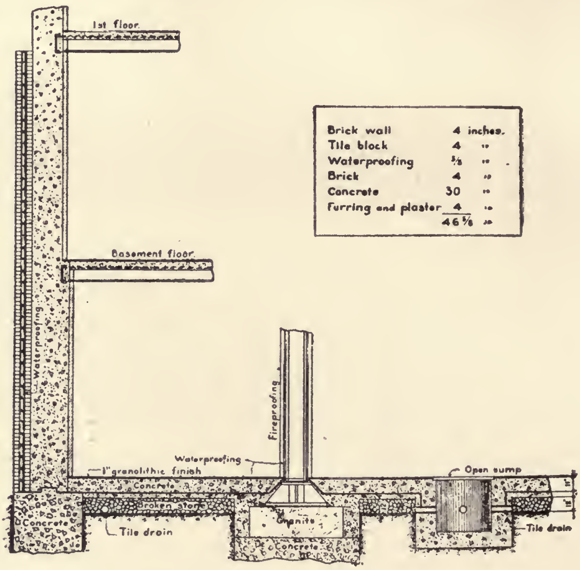

FIG. 115.—Section of Building Substructure, showing the "Membrane" Method of Waterproofing. (The Waterproofing Co.)

named materials may be employed, two or more coats being put on to insure thoroughly covering the surfaces.

When water is to be excluded, these three materials are employed as cement or binders in conjunction with either of the following fabrics:

(*a*) Tarred felt.
(*b*) Asphalted felt.
(*c*) Burlap (ordinary).
(*d*) Burlap (saturated with asphalt).
(*e*) Combinations of felt and burlap.

The cement or binder acts as the waterproofing agent, and the fabric acts as a reinforcement, in addition to its water-resisting properties (when the fabric is a saturated material).

The binding material and fabrics are applied in alternate layers, one layer of fabric coated on both sides with the binder or cement, forming one "ply." The number of ply to be used depends upon the local conditions and the head of water to be resisted. The following table gives approximately the number of ply required for various heads of water, using the material stated:

TABLE XXXVI.—Giving Number of Ply of Waterproofing Required for Varying Heads of Water.

Head of Water.	Material.			
	Coal Tar and Felt.	Commercial Asphalt and Felt.	Special Felts and Compounds.	Asphalt Mastic.
0	2	2	1	¼ in. thick
1	3	3	2	⅝ " "
2	4	4	3	⅝ " "
6	5	5	4	⅝ " "
8	6	6	5	¾ " "
10	7	7	6	¾ " "
15	8	8	7	¾ " "
20	9	9	8	¾ " "

For bridges, 4- to 7-ply, depending upon character of traffic; or a mastic about 1 inch thick; or part mastic and part felt and cement.

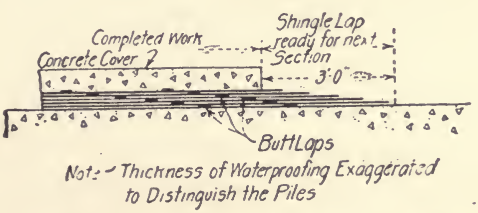

Fig. 116.—Showing Arrangement of Laps in 6-Ply Waterproofing. "Membrane Method."

The inspector should be careful to observe that the number of ply or thickness called for in the plans and specifications is actually put into place.

Quality of Material.—Both the cementing materials and the fabrics, in order to be serviceable for waterproofing operations, must be elastic and durable and retain these properties through the range of temperature to which they may possibly be subjected after being placed in the work.

In order that materials of the desired quality be obtained, certain requirements are usually outlined in the specifications, and it is incumbent on the inspector to see that these requirements are fulfilled as far as it is within his power to do so. Laboratory tests should be made on the material delivered on the work to determine whether the physical and chemical requirements are satisfied.

Typical Specifications for Bituminous Materials.—The following examples illustrate some of the requirements on important work. The New York Rapid Transit Subway has this specification:

Coal Tar Pitch.—Shall be straight run pitch which will soften at 70° F., and melt at 100° F. The distillate oils, distilled from the required grade of pitch, shall have a specific gravity of 1.105.

The requirements for coal tar pitch on the Pennsylvania-Long Island Railroad are similar:

Asphalt.—(*a*) Must be best grade of Bermudez, Alcatraz, or Lake of equal quality.

(*b*) It must be either a natural asphalt or a mixture of natural asphalts.

(*c*) Must contain in the refined state not less than 95 per cent natural bitumen soluble in rectified carbon bisulphide or in chloroform.

(*d*) Not less than two-thirds of the total bitumen shall be soluble in petroleum naphtha of 70° Baumé, or in acetone.

(*e*) The asphalt shall not lose more than 4 per cent of its weight at a temperature of 300° F., when maintained for ten hours.

(*f*) No injurious ingredients shall be present.

An excellent set of requirements for obtaining a good asphalt is found in the specifications of the Chicago and Northwestern Railroad. These are as follows:

1. The asphalt must be free from coal tar or any of its products.

2. Must not volatilize more than one-half of one per cent under a temperature of 300° F., maintained for ten hours.

3. Must not be affected by:

A 20-per-cent solution of ammonia.

A 25-per-cent solution of sulphuric acid.

A 35-per-cent solution of muriatic acid.

A saturated solution of sodium chloride.

4. Must not show any hydrolitic decomposition when subjected, for a period of ten hours, to hourly immersions in water with alternate rapid drying by warm air currents.

5. Range of temperature:

(*a*) For metallic structure exposed to direct rays of sun.

Flow point not less than 212° F.

Brittleness—Must not become brittle at 0° F., when spread on thin glass.

(*b*) For underground structure such as masonry arches, abutments, retaining walls, building foundations, etc.

Flow point, 185° F.

Brittle point, 0° F.

(*c*) Mastic made from (*a*) or (*b*) must be pliable at 0° F.

Must not perceptibly indent under load of 20 pounds per square inch when at temperature of 130° F.

6. Preparation of the asphalt.

(*a*) Care should be taken that the asphalt is not "pitched." This will take place if heated above 450° F. The inspector can tell when this point is reached by the change in color of paper from a bluish tinge to a yellowish tinge.

(*b*) The inspector can further test for the sufficiency of the cooking by putting in and withdrawing a stick of wood. The asphalt should cling to it.

(*c*) Should pitching occur, fresh material should at once be added to reduce the temperature.

(*d*) When delays occur in the work and pitching is to be prevented, the fire should be banked or drawn and fresh material added to reduce the temperature.

The weight is also a distinguishing feature between the various materials and will aid the inspector in his work. They are approximately as follows:

Coal tar, 63 pounds per cubic foot.

Coal tar pitch, 75 pounds per cubic foot.

Trinidad asphalt (natural), 80 pounds per cubic foot.

Trinidad asphalt (refined), 93 pounds per cubic foot.

A good coal tar pitch for waterproofing should weigh 70 to 80 pounds, and a good asphalt 90 to 95 pounds per cubic foot.

The relatively low melting-point will readily distinguish whether a coal tar is being substituted, when asphalt is specified, and in addition to the weight and flowing-points the characteristic odor of the tar will detect substitution.

Adulteration of the asphalts with cheaper petroleum products and substitution of domestic asphalts for the Trinidad or other foreign brand usually specified, will also make itself known in the lower flowing-point and lower flaming-point, the petroleum oils decreasing these points in accordance with the amount present.

When bituminous products are specified and delivered under trade names and are to be applied cold, the flowing-point cannot be used as a factor so readily, but such material should also be tested for brittleness under low temperature, and stability at high temperature and acid tests should be made to determine their immunity from ready attack by acid present in the ground water.

Specification for Asphaltic Felt.—The felt must be saturated and coated with asphaltic products and must conform to the following requirements:

(*a*) The weight per 100 sq. ft. shall be from 12 to 14 lbs., saturated, and from 5 to 6 lbs. unsaturated.

(*b*) The weight of the saturation and coating shall be from 1.25 to 1.75 times the weight of the unsaturated felt if coated on both sides, and from 1 to 1.5 times the weight of the unsaturated felt if coated on one side.

(*c*) The saturation shall be complete.

(*d*) The ash from the unsaturated felt shall not exceed 5 per cent by weight.

(*e*) The wool in the unsaturated felt shall not be less than 25 per cent by weight.

(*f*) Soapstone or other substances in the surface of the felt to prevent adhesion shall not exceed .5 lb. per 100 sq. ft. of felt.

(*g*) The saturating and coating materials shall remain plastic after being heated to 250 degrees Fahr. during 10 hrs. The coating not to crack when the felt is bent double at ordinary temperature.

(*h*) The felt shall be soft, pliable, and tough when received from the factory and until placed in the work.

(*i*) The quotient obtained by dividing the tensile strength in pounds of a strip 1 in. wide, cut lengthwise, by the weight in pounds of 100 sq. ft. shall not be less than 7.

(*j*) The quotient obtained by dividing the tensile strength in pounds of a strip 1 in. wide, cut crosswise, by the weight in pounds of 100 sq. ft. shall not be less than 3.5.

(*k*) The strength saturated shall be at least 25 per cent more than the strength unsaturated, taken lengthwise.

The inspector should see that all the material delivered arrives in unbroken packages and contains the proper label of the manufacturer as specified.

Application of Materials in the Membrane Method.—In the application of the materials, certain fundamental requirements must be fulfilled upon which the final success of the work will largely depend, and it is the duty of the inspector to see that such requirements are fulfilled. These requirements may be conveniently classed under three headings, thus:

1. Preparation of surface.
2. Continuity of work.
3. Protection of waterproofing.

Preparation of Surface.—It is difficult to make a bituminous sheet adhere to a surface that is either too rough, too wet, covered with dirt or foreign matter or possessing too fine a glaze due to richness of cement surface. It is, therefore, necessary to see that:

(*a*) All dirt and foreign matter are removed before waterproofing is applied.

(*b*) That an adequate drainage system is installed and maintained, and that the wall is dry when the waterproofing is applied.

(*c*) In case complete dryness cannot be secured, a layer of felt in addition to those called for in the specifications is first laid against the surface.

Some specifications require that asphalt cut with naphtha shall first be applied cold.

(*d*) The surface should be smoothed off with a trowel, if too rough.

(*e*) In case wall is of concrete, that the concrete be thoroughly set.

(*f*) In case wall is covered with a fine skin of cement, see that it is roughened up to insure sticking of material.

(*g*) Sharp projections on the masonry should be removed or they will puncture the waterproofing.

(*h*) Metal surfaces should be dry and clean, free from rust, loose scale, and dirt. If previously coated with oil, same should be removed with benzine or other suitable means. Warming may be accomplished by heated sand, which is removed as material is applied.

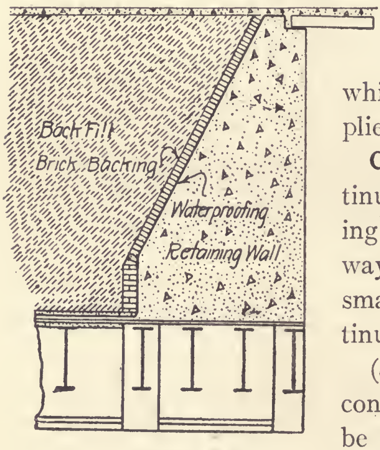

Fig. 117.—Method of Waterproofing Retaining Wall.

Continuity of Work.—Lack of continuity will be fatal to any waterproofing work, as water is sure to find its way through any breaks, however small. In order to secure proper continuity, see that:

(*a*) The waterproof sheet is applied continuously over the whole surface to be treated as shown on the plans; thus in building substructures it should be applied over all footings, walls, cellar bottoms and on the outer face of all foundation walls.

(*b*) That all joints are broken properly at least 4 inches on cross joints and 12 inches on longitudinal, and at least 12 inches lap left at corners to form good connections with adjoining sections.

(*c*) Where it is necessary to stop work, laps of at least 12 inches should be provided for joining on new work.

(*d*) Each layer of pitch, asphalt, or other cementing material must completely cover the surface on which it is spread, without cracks or blowholes or other imperfections.

(*e*) The fabric must be rolled out smoothly and pressed over the cementing material, so as to insure its sticking thoroughly and evenly over the entire surface.

(*f*) In connecting side wall with floor work, the layers of the fabric on the sides should be carried down on the outside of the ends of the floor layer and lap at least 24 inches.

(*g*) In connecting side wall and roof work, the layers of fabric of the roof should be carried on the outside of the sidewall layers with at least a 24-inch lap.

(*h*) Before new work is added to old, the inspector should be careful to see that the old surface is cleaned of all foreign matter, such as cement, mortar, or other substance which finds its way thereon. After cleaning the laps, they must be well covered with fresh cementing material before new layer of fabric is placed against it, and the new fabric should be made to stick smoothly and evenly over entire joint area.

Protection.—After the waterproofing has been put into place,

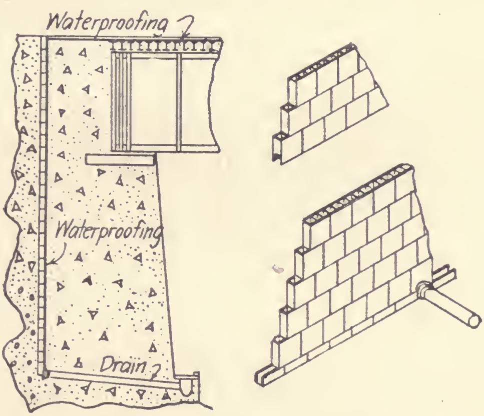

FIG. 118.—Draining and Waterproofing Tunnel Wall.

it must be properly protected against injury from any cause whatever. Such injury is liable to occur by puncturing when:

(*a*) Backfilling with earth.

(*b*) Depositing concrete against same.

(*c*) Laying brickwork or rubble against same.

Lack of protection may also cause:

(*d*) Bulging of waterproofing from wall.

(*e*) Cracking of same due to bulging.

(*f*) Running of material due to heat.

(*g*) Injury due to frost particularly when materials, brittle at low temperatures, are used.

Injury from any of the above causes may be avoided by placing against the waterproofing a protecting layer of cement mortar mixed in the proportions of 1 part cement to 2 1/2 parts sand.

This safety coat should be placed as soon as possible after the laying of the waterproofing, not exceeding 12 to 24 hours. Failure to place such protection, if called for in specifications, will be sufficient cause for relieving the waterproofer of responsibility, if under a guarantee.

When this safety coat is omitted, and backing of earth or concrete, brick or stone masonry is to be laid immediately against the waterproofing, the greatest care must be exercised that the sheet is not punctured by sharp corners of stones or bricks.

When brick work is placed against waterproofing on vertical walls, a slight space may be left for slushing in with mortar to avoid puncturing. The bricks should not be rammed up against the waterproofing sheet.

Injury to the waterproofing might also occur when the hydrostatic pressure is very large, and insufficient weight has been placed upon same to secure it against displacement by such pressure.

Protection of the waterproofing should not stop with placing the backfilling on same. Tampering with it should be absolutely forbidden. When openings or incisions in the sheet are necessary, the inspector should be notified, and he must see that such places are repaired in the most thorough manner. All pipe passages should be pocketed and connections thoroughly made. Such places should not be covered up until the work has been examined by the inspector and found properly executed.

THE INTEGRAL METHOD OF WATERPROOFING

The term "Integral" refers to those methods wherein the waterproofing material becomes an integral part of the structure treated. It includes:

I. The various methods employed in making concrete and masonry impermeable per se:

By properly grading the materials and

(*a*) The addition of special materials to the water used in tempering the cement, or

(*b*) The addition of special materials, dry, to the cement, or (*c*) The use of a cement waterproofed in the process of manufacture.

II. The application of materials thus prepared as a plaster or coating to the surfaces to be treated, such coating becoming an integral part of the structure.

The Integral method is distinguished from purely surface applications, in that the latter are applied as a paint, and while some of the materials penetrate to a considerable extent, periodic renewal is required when exposed to the elements, although, with some of the materials, renewals may not be required for many years.

Adaptability of the Integral Method.—The "Integral" method of waterproofing as above outlined, is adapted to treatment of numerous conditions. In the form of the coating, it is particularly adapted to remedying leaky conditions in substructures already erected; where excavations would be too costly and inconvenient.

Although the logical place to apply waterproof cement coatings is on surfaces exposed to the water, yet owing to the inaccessibility of the outer surfaces for examination and repairs, the coatings are applied to the inner surfaces as shown in Fig. 117. It will withstand any ordinary water pressure in this position, if the work is properly executed.

In mass concrete work, imperviousness may be secured, as already stated, by the simple expedient of carefully grading the materials, proper mixing, and the rational use of reinforcement and expansion joints to prevent the development of cracks. For many conditions, no further treatment is necessary. Where, however, capillary absorption is to be prevented, and where even dampness or slight leakage is objectionable, the introduction of special materials in the work is advisable.

In many cases, either the Membrane or Integral methods may be employed with equally good results, and the selection of type must be made by the designer, after comparing their cost.

Addition of Waterproofing Material to the Concrete.—Concrete, even when mixed according to the most rigid rules and under the most competent supervision, often falls short of its purpose in resisting water penetrations. This condition, and the inherent attraction of concrete for water, has resulted in the appearance on the market of a large number of compounds having the express purpose of obviating these objections. The compounds are of a proprietary nature, and the composition is kept secret by the makers. The designer not familiar with them should make his selection of material only after carefully investigating their merits.

These compounds may be grouped in four classes:

1. *Powders.*—Added dry to cement before mixing. These are usually of white, floury consistency, extremely fine, and are water-repellant. The water-repellant properties are imparted by the introduction of a metallic stearate, such as lime soap, which is of a fatty nature. Being so extremely fine, they have a distinct void-filling property, and their uniform distribution in the cement must give a denser mixture. In addition to the metallic stearates, they contain varying proportions of alum and hydrated lime. The latter materials are themselves extensively used to densify and waterproof concrete work.

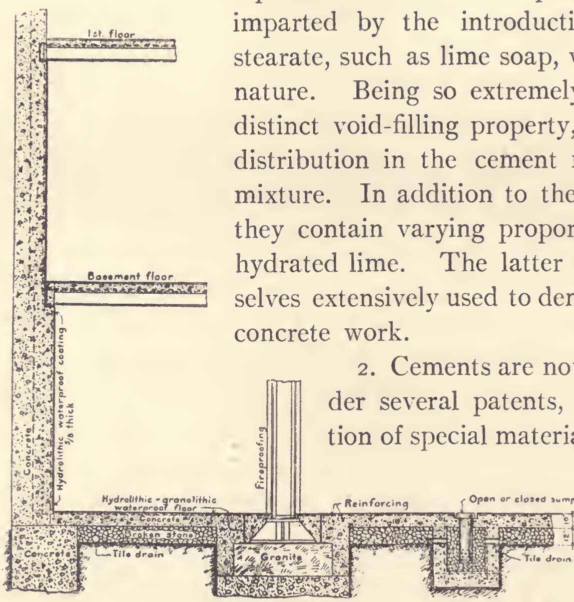

FIG. 119.—Section of Building Substructure showing the "Integral" Method of Waterproofing.

2. Cements are now manufactured under several patents, where by the addition of special materials and special treatment a water repellant cement is obtained.

3. *Liquids.* —Added to water employed in tempering the cement. These are various forms of metallic salts, such as chloride of lime and oil emulsions. Soap solutions are also employed for this purpose. In the case of the liquids, the waterproofing property is imparted by the formation of gelatinous coatings about the minute particles of the concrete. Lime soaps, suspended in the water, are also employed.

4. Combinations of liquids and powders. The most frequent form is the addition of alum dry to the cement, and the mixture of soap solution to the water employed in tempering the cement. This is usually referred to as the "Sylvester" mixture. In this case

waterproofness is imparted by the precipitation of insoluble compounds in the voids.

Where any expensive work is to be undertaken, and the employment of any of these compounds is contemplated, tests should be carried on to determine:

1. The effect on the strength of the concrete.

2. Their behavior when subjected to extreme ranges of temperature.

3. Their immunity to decomposition by various acids, etc., liable to reach the concrete.

4. The effect of admixture of the materials to steel, embedded in concrete.

These materials being usually purchased under trade names, and their composition being secret, there is little that the inspector is capable of doing in regard to them. He should, however, satisfy himself that the material specified is being used on the work, by identifying the packages, and noting that they are unbroken, and contain the proper trade-marks.

He should have the directions furnished by the manufacturer, see that they are explicitly followed, and allow variations only in case unforeseen conditions are encountered, and where special instructions to cover them are not at hand.

When the work is being done by the manufacturer or his representative under a guarantee to secure water-tightness, the inspector should give the latter free rein to follow his own methods, providing they are in conformity with the general contract. He should, however, keep a complete and reliable record of the progress of the work for future reference.

Workmanship.—As previously stated, the treatment may consist of adding waterproofing material in the body of the concrete, or in a coating or plaster applied to the surfaces to be protected.

In either case the essential requirements for good work are:

1. Homogeneity of mixture.

2. Continuity of work.

3. Soundness or freedom from cracks, etc.

When applied as a coating a further requirement is:

4. *Bond.*—A uniform and efficient bond of coating to concrete or masonry surface must be secured.

Homogeneity.—The inspector should see that the waterproofing material is uniformly distributed throughout the work. Irregular distribution will result in weak spots, which should be avoided as much as possible.

Continuity.—He must see that all portions called for on the

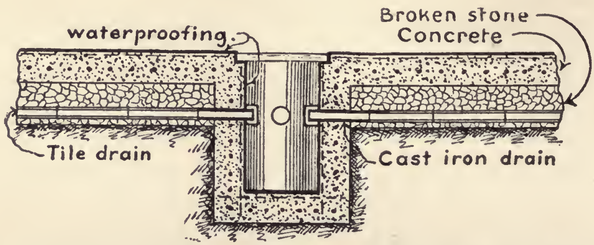

FIG. 120.—Details of Sump Employed in the Integral Method of Waterproofing. Sump may be Sealed or Open as Required.

plans receive waterproofing treatment. Any omissions will break the continuity of the work and will nullify the object which the designer had endeavored to attain.

Soundness, Freedom from Cracks, Etc.—These are essential requirements in successful waterproofing work by the Integral

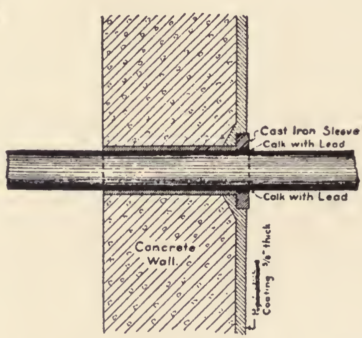

FIG. 121.—Passing Pipe Through Concrete Wall. Method of Making Water-tight Joint.

method, and they should be minimized by the use of expansion joints and reinforcements. The inspector should be particularly careful that the plans are properly carried out in this respect.

Bond.—As already stated, the bond is an important matter where the waterproofing is done by the application of a coating of specially prepared cement mortar to the concrete or masonry surface. The coating should be homogeneous, continuous, sound, and uniform. A good bond will require:

1. Correct mixture of the coating materials.
2. Proper condition of surface to receive the coating.
3. Thoroughness in application.
4. Careful connection of one day's work to preceding.

INSTRUCTIONS FOR APPLYING WATERPROOF CEMENT COATINGS

In order to carry out the above provisions the following directions are added: A powdered material is here taken as an example, although most of the directions apply equally as well whatever character of compound is to be employed. This method of procedure is followed by some of the leading contractors doing this class of work, and if intelligently carried out, a durable and watertight job will be secured.

1. **Preparation of Coating.**

(*a*) To each bag of cement add dry the waterproof compound called for in specifications in percentage directed by manufacturer. Manipulate until the appearance and color indicate that a uniform mixture has been obtained.

(*b*) Mix the cement thus waterproofed with sand in proportion of 1 cement to 2 sand. Sand to be absolutely clean and well graded from coarse to fine. Sand need not be sharp. Sand is to be moistened, waterproof cement spread over it, and the whole manipulated until a homogeneous waterproof coating mortar is obtained.

2. **Preparation of Surface.**

(*a*) The old concrete surface should be thoroughly chipped not more than two days prior to application of the coating. The chipping may be greatly facilitated by a previous application of muriatic acid or a bonding compound, the strength of the solution depending upon the age of the wall; or the use of the bonding material may be deferred until the chipping has been completed.

(*b*) In case acid or bonding powders have been employed, all unspent acid should be removed by rigid application of the hose, immediately after the acid treatment has reached a satisfactory stage.

(*c*) The dust, dirt, and loosened material must be completely removed, either by patient scrubbing with stiff brushes, water nozzle, steam jet, or other suitable means. An absolutely clean surface should be obtained, not more than twenty-four hours ahead of the application of the coating.

(*d*) All holes should be filled up, large holes with the waterproof concrete, and small holes with waterproofed mortar. Before filling the holes, the old surfaces should be drenched and slush coating applied, as described below.

(*e*) Just before the main cement coating is to be applied, the entire wall should be drenched and soaked to its full absorbing capacity.

3. Application of Coating.

(*a*) Before the wall shows marked signs of drying a slush coating should be applied quickly and uniformly with a palmetto. This slush coating should be made by a thorough mixing of waterproofed cement in water, to the consistency of cream.

(*b*) Before the slush coating has dried, the first application should be applied as a scratch coat, one-fourth to three-eighth inch thick, and pressure brought on the trowel to push the coating on, to form a uniform bearing. The scratch coating should be made by mixing one part of waterproofed cement to two parts of clean, well graded moist sand, and enough water to obtain proper consistency.

(*c*) The scratch coat should be trowelled to a fairly good surface and scratched before hardening.

(*d*) Upon the scratch coat, before its final setting, the finishing coat of sufficient thickness to obtain a total thickness of five-eighths inch should be applied. This should be pushed on hard and uniformly trowelled and floated to a true surface, free from pin holes, projections, or other defects. The composition of the finished coating shall be one part waterproofed cement to two parts sand, well graded and previously moistened.

(*e*) If not feasible to apply finishing coat until after the scratch coat has already set, the latter must be thoroughly rinsed and slush-coated before finishing coat is applied.

(*f*) The floating of the finished surface shall be done from the bottom of the wall up.

(*g*) When the work has been completed all bad and defective work shall be cut out and replaced in the same manner as above described.

(*h*) When the work has thoroughly hardened, sounding with a light hammer over the wall should be resorted to, to discover any loose or hollow portions, and same must be cut out and replaced.

(*i*) In leaving a portion of work for the day, the section being finished should be left with straight edges. When the new work is to be started the old edges are to be roughened up by chipping and roughing with the trowel and the same rinsed and slush-coated, as already described.

WATERPROOFING BY MEANS OF SURFACE COATINGS

The third or "Surface Coating" method remains to be considered. In this method, the materials are applied as a paint to the surface to be treated, and are presumed, upon completion, to form a barrier to the passage of water.

Applicability.—Owing to the comparatively low cost and ease of application, this method of waterproofing has been widely adopted and often, unfortunately, under conditions where it had no right to be employed.

It should *not* be employed to keep water out of basements or substructures of buildings, particularly when subject to water pressure; its function in building work being to *damp* proof more than to *water* proof. Its use under ground can be justified only where no permanent water is present and ground dampness merely is to be kept out. Its principal uses are:

1. To keep water and dampness out of *superstructure* of buildings.

2. To preserve building materials and structures from decay due to absorption of water and other atmospheric impurities, and avoid staining of stone and efflorescence.

3. To avoid and remedy leaky conditions in tanks, conduits, and other water-containing structures.

Materials.—A large variety of materials is on the market for waterproofing by this method, but they may be all conveniently included in five distinct classes. A large proportion of them are made on secret formulas and sold under trade names and substitution of inferior materials is often tempting, owing to the wide variations in price.

The materials employed as surface coatings may be grouped in the following classes:

1. Soap and alum mixtures applied in alternate coats, popularly known as the "Sylvester" process.

2. Paraffine and other mineral bases, applied cold (in solution), or paraffine in melted condition.

3. Specially prepared bituminous products.

4. Cement grout, with or without the addition of water repellants.

5. Miscellaneous materials of unknown composition.

All of the above, except class 3 (bituminous products), are applied to the surfaces directly exposed to the action of water. In the case of class 3, the application is made to the *inner* surface of exposed building walls, its function in this position being not only to dampproof, but to serve as an insulating film against rapid changes of temperature; and also to replace furring and lathing, as plaster may be directly applied thereon. This is particularly so in the case of brick walls. Furthermore, the material being protected from the elements, a long life is assured.

The Sylvester Process.—This process has been principally employed and is mainly adapted to coating the surfaces of tanks, conduits, and other water-carrying structures, to render them tight. It has also been employed for treating concrete roofs and walls with varying success. The process consists of alternate applications of solutions, the first, third, etc., coats of soap, and the second, fourth, etc., of alum.

Proportions.—For soap solution—3/4 lb. castile soap to 1 gallon of water. For alum solution—1 lb. alum to 8 gallons of water.

The following precautions should be observed:

1. The soap and alum should each be perfectly dissolved before using.

2. The surfaces should be clean and dry.

3. The soap solution should be applied first.

4. The soap solution should be boiling hot.

5. A flat brush should be used.

6. Care should be taken to avoid frothing.

7. The first coat to remain on 24 hours, or until it is dry and hard.

8. Temperature of air to be not less than 50° F. at time of application.

9. Alum solution to be about 60° to 70° F.

10. Alum solution, second coat to be applied thoroughly over the first coat.

11. Second coat allowed to remain 24 hours before third coat (soap solution) is put on.

12. Two or more coats of each should be employed, depending upon exposure, pressure, and other local conditions.

The Sylvester process imparts waterproofness by the formation of insoluble compounds due to chemical action between the soap and alum solutions, the compounds filling the pores.

Paraffine.—*Cold Process.*—Applicable to all classes of masonry above ground, whether old or new; adapted to protecting against decay, and preventing either leakage or absorption of water. Material is paraffine specially treated and dissolved in volatile carrier, in saturated solution. A translucent liquid leaving the surface to which it is applied the same in appearance as before. Efficient, easily applied, and inexpensive; covering capacity about 125 square feet to the gallon on first coat, and about 175 feet to gallon on second coat; two coats required. Materials best obtained from manufacturers all ready for use. Has a high penetrating capacity into masonry surfaces, and after application volatile carrier evaporates, leaving paraffine in the pores.

Precautions to be employed on the work:

1. See that the material specified is being used.

2. Obtain explicit directions from manufacturer and follow them.

3. Surface to be treated should be smooth and freed from all projections. Holes to be filled up.

4. Surface to be clean and thoroughly dry, not only on surface but all the way in.

5. Material to be applied thoroughly; well rubbed in, filling all corners, recesses, etc.

6. At least two coats to be applied.

7. In severely exposed locations three coats are advisable.

8. Fire should be kept away from the material during application.

Paraffine.—*Hot Process.*—In this process, the walls are first treated with artificial heat and when sufficiently warm, melted, hot paraffine wax is thoroughly rubbed in. This is one of the most durable of all the waterproofing methods for work exposed to the weather and for the preservation of building stones. It must necessarily be applied by those specially equipped for and experienced in the work.

Bituminous Process.—Employed for dampproofing exposed building walls of superstructures by application to the interior surface of such walls; for underground work to prevent absorption of ground dampness, and also for coating the covered faces of building stones to prevent staining and discoloration due to leaching of salts from masonry backing.

Materials must possess a high degree of elasticity and durability, and when used on walls, must have a gripping power so that plaster can be directly applied thereon.

Materials specially prepared for these purposes obtained ready for use under various trade names.

Precautions to be observed on the work:

1. See that the material specified is employed.

2. Obtain directions of manufacturers and follow them.

3. Surface to be clean and dry.

4. Two coats to be applied.

5. First coat to be allowed to set up before second is applied.

6. Work to be well rubbed in in corners and recesses and continuous throughout.

7. When plaster is to be applied directly on waterproof film, wall surface should be left rough to obtain good bond.

8. Work to be kept exposed as little time as possible after completion.

9. In applying plaster upon film see that latter is not in any way injured.

Cement Grouting Processes.—Plain cement grout has often been employed for a waterproof coating, but owing to the fact that such coatings will absorb water by capillarity and also on account of the difficulty of making such coatings adhere without peeling, they are not to be highly recommended. Several excellent prepared cement grouts are on the market which have been treated with water repellants, and, having high penetrating qualities, they assist the bonding to the masonry surfaces. They are sold under trade names and are employed to impart a flat finish in various colors to concrete surfaces, as well as to dampproof.

Miscellaneous Materials.—Numerous other materials are on the market for the purpose of waterproofing superstructures. The composition is secret and when they are employed the inspector should follow the directions of the maker. He should, however, see that in any case at least two coats of any material are applied. It is almost impossible to obtain a surface free from pinholes and other defects, on the first application.

Workmanship.—Whatever method is employed the inspector should always see that the surface is properly prepared and that the application is continuous throughout. Any omissions at corners, cornices, around windows and other points easily accessible may prove fatal to the final success of the work.

As for the preparation of surfaces, they should always be clean and free from foreign matter. Where cement coatings are employed and the waterproofing depends upon the setting of the cement, the surfaces should be *damp* or *wet*, so that the water necessary for the setting will not be absorbed by the masonry. Where the waterproofing depends upon the penetration of the material into the pores, the surface should be *dry* to increase the penetration as much as possible.

Surfaces should generally be smooth, holes filled up and projections removed. Projections are likely to be injured by scaffolding and to admit water at such points. Not only does a smooth surface make the application easier and more certain, it is also more economical in material.

In the bituminous process, however, where the material is applied on the inner surface of exposed walls and plaster is to be applied directly on the waterproof film, the surface should be rough. This is necessary in order that the plaster may properly bond to the treated surface. Joints in brickwork form excellent keys for such bonding and have been taken advantage of. A large number of brick buildings have been treated by this process.

HOW TO USE THE TABLE

The accompanying table has been prepared with a view of condensing into small space the principal features of modern water-

TABLE XXXVII.—Outline of Modern Waterproofing Processes.

METHODS AVAILABLE FOR VARIOUS STRUCTURES.

	Nature of Structure.	During Construction. (New Work.)	Remarks.	After Construction. (Old Work).	Remarks.
Buildings.	Exposed Walls	D	For Damp Proofing Only	B, C	D { Principally for Brick and Stone Walls, Not Advisable on Smooth Concrete Walls
		B, C	For Damp Proofing and Preservation of Stone.		
	Superstructural Floors	I,K,J,G,M	For Bath Rooms and Floors Liable to be Wet	G, M	
	Foundation Pits	I, J	For Resisting Dampness Only	G	For Dampness Only or Pressure Work.
	Foundation Trenches	I, J	For Resisting Dampness Only	G	
	Foundation Footings, Walls, and Floors	I, J	For Resisting Dampness Only	G	
	Walls, Reinforced	G,K,L,M	For Resisting Water Pressure	G, M	For Resisting Water Pressure.
	Walls, Not Reinforced	K,L,M	For Resisting Water Pressure	G	For Resisting Water Pressure.
	Floors, Reinforced	G,K,L,M	For Resisting Water Pressure	G	For Resisting Water Pressure
	Floors, Not Reinforced	K,L,M	For Resisting Water Pressure	G, M	For Resisting Water Pressure.
	Column Footings Heavily Loaded.	O			
	Concrete Block, etc.	G,B,C		B, C	
	Preservation of Stone	B,C	Also for Preventing Efflorescence	B, C	
Rail-roads.	Subways and Tunnels	K,L,M,G		G, H	
	Bridges	N,K,L,M		G, M	
	Culverts	E, F		G, A, B	
	Retaining Walls, Arches	E,F,K,L		G,A,B,H	
		E,F,K,L,M		G,A,B,H	
Water Supply and Sewerage.	Reservoir Banks	K,L,M		K, L, M	
	Dams	E,F,H			
	Conduits	E,F,G,		A, B	
	Tanks	G, F, B		B, A	
	Chambers	G, F, B, A		G, B, A	
	Sewers	E, F, K			
	Manholes	F, G		G, H	
1	2	3	4	5	6

TABLE XXXVII. (*Continued.*)—INDEX AND DESCRIPTION OF METHODS.

Method	Classification.	Material Employed	Manner of Application.	Position in Structure.	Thickness, Etc.	Remarks.
A	Surface Coating	Solutions of Alum and Soap (Sylvester Process)	As a Paint	On Exterior Surface.	4 to 7 Coats	Applicable to New or Old Work; Not to Underground Work.
B	Surface Coating	Paraffine in Saturated Solution.	As a Paint	On Exterior Surface.	2 to 3 Coats	" " " Also a Preservative for Building Stone
C	Surface Coating	Melted Paraffine Wax Applied Hot	As a Paint	On Exterior Surfaces (Surfaces Previously Heated)	Penetrates ¼ to ½ inch.	Also a Preservative for Building Stone
D	Surface Coating	Proprietary Bituminous Compounds, Applied Cold	As a Paint	On Interior Surface	2 Coats	Used also as a Substitute for Furring and Lathing
E	Integral or Rigid	Masonry or Concrete Correctly Proportioned				Available Only During Construction
F	Integral or Rigid	Masonry or Concrete Correctly Proportioned with Cement Water-Proofing Compound	In the Body of the Work			Available Only During Construction.
G	Integral or Rigid	Cement Mortar with Compound	As a Plaster or Stucco	On Interior Surface	1" to 2" on Floors ¼" to 3/8" on Walls	For New Work or Remedying Defective Work.
H	Integral or Rigid	Cement Mortar or Bituminous Grout	Pumped under Pressure	In Interior of Mass		Employed Principally to Fill Voids Otherwise Inaccessible
I	Membrane or Elastic	Asphalt or Coal Tar Pitch with Felt or Burlap	In Alternate Layers	On Surfaces Exposed to Water	1 to 3 Ply	Applicable Only During Construction for Subsurface Work. To Resist Dampness Increase Thickness According to Pressure.
J	Membrane or Elastic	Proprietary Bituminous Compounds, Applied Cold with Felt or Burlap	In Alternate Layers	On Surfaces Exposed to Water.	1 to 3 Ply	
K	Membrane or Elastic	Coal Tar Pitch Applied Hot with Felt	In Alternate Layers	On Surfaces Exposed to Water	2 to 10 Ply	For Water Pressure Work.
L	Membrane or Elastic	Asphalt Applied Hot with Felt or Special Fabrics	In Alternate Layers	On Surfaces Exposed to Water	2 to 8 Ply	Asphalt Not to be Used in Ground Polluted by Gas Drip, etc.
M	Membrane or Elastic	Asphalt Mastic or	As Plaster or Coating	On Surfaces Exposed to Water	¼ Inch to 1 Inch	
N	Membrane or Elastic	Asphalt Mastic Alternating with Saturated Felt Layers		On Surfaces Exposed to Water	¼" to 1" Mastic 2 to 5 Ply Felt	Useful Particularly for Bridge Waterproofing Subject to Vibration.
O		Sheet Lead or Copper		Under Column Footings		Used as Substitute for Felt When Column Loads Are Very Heavy.
7	8	9	10	11	12	13

proofing processes as applied to varying conditions, and to enable one having a waterproofing problem to solve, and not familiar with the subject, to pick out the method most suitable without having to read up the whole subject.

As previously stated, the method must be suited to the conditions of the problem if good results are to be had. In numerous cases more than one method may be employed with good results and in such cases the methods have been given in order of their desirability. Local conditions, however, may make the order of preference different.

Use of the Table.—The table is divided into 13 columns as numbered on bottom.

Columns 3 and 5 give the methods of waterproofing for the different structures listed in columns 1 and 2. These methods are listed by key letters as *A*, *B*, *C*, etc., the essential features of which are described in columns 7 to 13.

Column 3 gives the method of waterproofing that may be provided for in plans and specifications for new structures or which may be employed before the construction work has advanced too far.

Column 5 gives the methods available for the structures already erected and for remedying leaky conditions in such structures. The fact that a method is not listed in column 5 means that it is not advisable to use it for old structures.

As a practical example in using the table, suppose it is desired to dampproof the walls of a new brick building which is to be erected and also to waterproof the foundation, which is in wet ground.

To Find the Method from the Tables.—Look up columns 1 and 2 for exposed walls; methods given are *D*, *B*, and *C*, in order of desirability. Now look in column No. 7 and those following for description of the methods *D*, *B*, and *C*.

For the foundation to resist water pressure under walls, *G*, *K*, *L*, *M*, are given in order of desirability, but *G* is omitted if walls are not reinforced. The remarks point out some special features such as for *L* and *M*, "Asphalt not to be used in ground polluted by gas drip, oils, etc., that injuriously affects it. This is an important precaution."

It is not claimed that the arrangement of methods will in all cases be decisive or that some methods not listed may not be employed; but the use of the table will prevent such glaring but frequent mistakes as using a surface coating for sub-surface work or using a wash on the inside of cellar walls, to waterproof against pressure and in other ways prevent the use of wholly unfit methods.

APPROXIMATE COST OF WATERPROOFING

The following table gives approximate cost of different classes of waterproofing which may be used as a basis for comparing relative economy of the methods selected from the table:

A.—Sylvester process, 1/2 cent to 4 cents per square foot.

B, D.—Dampproofing masonry walls, 2 coats applied in place, 2 cents to 4 cents per square foot.

C.—Melted paraffine, 5 cents to 8 cents per square foot.

F.—Adds about 10 per cent to the cost of untreated mass concrete.

G.—Cement coatings with waterproofing compounds; 1 in. on floors, 1/2 in. to 3/4 in. on walls, 8 cents to 30 cents per square foot, depending upon conditions.

I.—Hot coal tar, pitch, and felt. Horizontal surfaces: first ply, $2 to $4 per square (100 sq. ft.); additional plys, $1.50 to $2.50 per square; vertical surfaces add 10 per cent to 25 per cent.

J.—Cold process, felt or burlap, same as commercial asphalt.

K.—Pressure work, 1 ply, $4 to $5 per square.

L.—Commercial asphalt and asphalt felt, add 15 per cent to 60 per cent per ply, depending upon conditions.

L.—Special asphalts and felts, add 30 per cent to 50 per cent per ply.

M.—Asphalt mastic, 1 in., 15 cents per square foot.

COMPOSITION OF SOME OF THE WATER-PROOFING COMPOUNDS IN USE.*

In the "Sylvester's process" a hot solution of soap, prepared by dissolving ¾ lb. of Castile soap in 1 gallon of water, is first brushed over and into the surface of the concrete, and allowed to dry for 24 hours. At the end of that period a second wash, consisting of 2 oz. of alum dissolved in 1 gallon of water, is applied in the same manner. The alum solution should be at a temperature of from 60° to 70° Fahr. (See also page 367.)

In "Handbook for Superintendents of Construction, etc.," the following cement wash is recommended for making a water-tight lining for cisterns: A stock solution is prepared of 1 lb. "lye," 5 lb. alum dissolved in 2 quarts of water. One pint of this solution is stirred into a pail of water containing 10 lb. of cement, and the mixture is applied to the surface of the concrete with a brush.

Another method is to apply a rendering composed as follows:

1. Portland cement 1 part, sand 1 part.
2. Portland cement 1 part, sand 2 parts, lime paste ½ part.
3. Portland cement 1 part, sand 3 parts, lime paste 1 part.
4. Portland cement 1 part, sand 5 parts, lime paste 1½ parts.

The surface of the rendering, composed according to one of the above formulas, is brushed with a solution of 1 lb. "concentrated lye," 5 lb. alum, and 2 gallons water, in the proportion of 1 pint of this solution to 5 lb. of cement.

In principle the above-named methods are alike, and all depend upon the precipitation within the surface pores of the concrete, or outer coat, of insoluble alum soap, or hydrate of alumina, or both together. The last-named example, however, combines to some extent the method of pore-filling in bulk with sand and lime paste.

In "Plastering, Plain and Decorative," Miller recommends painting the surface of the work with a hot mixture prepared by mixing

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* Compiled in part by Gadd.

20 lb. of chopped suet with 1 bushel of lime, and stirring up with boiling water.

Professor Hatt states that with a mortar composed of 1 part of cement to 2½ parts of bituminous ash, when alum and soap were mixed with the water used for gauging, the strength and hardness increased 50 per cent. and absorption decreased by the same amount. One-half of the water used for gauging was a 5-per-cent. solution of ground alum, and the other half was a 7-per-cent. solution of soap. The alum solution was used first.

Cunningham proceeds on similar lines. He uses powdered alum equal to 1 per cent. of the combined weight of sand and cement. To the water used in the mix he adds 1 per cent. of yellow soap.

Hawley employed a stock solution of 2 lb. caustic potash, 5 lb. powdered alum, and 10 quarts water. A finishing coat was made with 3 quarts of this solution in each batch of mortar containing 2 bags of cement. The mortar was made with 2 volumes of sand to 1 of cement, and the work covered to a depth of ½ in.

Marsh gives the following as a waterproof coat or rendering: 2 lb. soft soap, 12 lb. alum, 30 gallons water per cu. yd. of the mortar. Or, 2 lb. caustic potash, 5 lb. alum, 10 quarts water. Of this solution 3⅔ quarts are used for 2 bags of cement and twice its volume of sand.

It will be observed that these processes again depend upon the precipitation of aluminum soap or of hydrated oxide of aluminum, the only difference being that, in these cases, the precipitate is mixed with the mortar instead of being deposited at the surface of the hardened material.

Gaines, in a paper recently published, states that watertight concrete can be made (1) by replacing the mixing water with a dilute solution of a suitable "electrolyte" (*i.e.*, a 1-per-cent. or 2-per-cent. solution of alum); (2) by replacing 5 per cent. to 10 per cent. of the cement with dried and finely ground colloidal clay; (3) by combining methods (1) and (2). With regard to the second of these processes the action appears to be simply one of pore-filling with fine particles of clay, inasmuch as no "electrolyte" is used; and in the other cases it is probable that the same kind of action takes place by precipitation of alumina, from the "electrolytic" solution, by calcium hydroxide, whether the electrolytic theory itself be correct or not.

It may be remarked that the use of pulverized clay for this purpose is old.

"Lux," Patent No. 4606 of 1904. This material is prepared by pouring over 100 kilos of cement clinker (unground) 10 litres of boiling water containing 245 grams of stearine, 12 grams of potash (presumably caustic potash, although it is not clearly stated), and 10 grams of colophony (*i.e.*, common resin).

Gallagher's Waterproof Compound.—This material is to be added to cement in the proportion of 2 per cent. to 5 per cent. on the weight of dry cement before mixing with the sand and water. Its composition has been stated to be chiefly lime and magnesia, with about 3 per cent. of stearine or other fatty acid.

"Pharos" waterproofing compound is composed of the following:

		PER CENT.
	Free fat (tallow or stearine)	20.22
Lime soap	Combined fatty anhydrides	14.55
	Combined lime	1.57
	Lime	30.45
	Magnesia	21.15
	Hygroscopic water	3.32
	Combined water	5.77
	Silica	1.17
	Alumina and ferric oxide	1.18
	Sulphuric anhydride, etc.	.62
		100.00

Cold bituminous damp-proof paints, such as Horn's Dehydratine, Toch's R. I. W., Antihydrine, etc., for use on the interior surfaces of exposed walls or for exterior of foundations not subject to water-pressure. These are made up of specially selected asphalts dissolved in carbon bisulfide or some kindred hydrocarbon, the proportions varying according to the use to which same is to be put.

Paraffine, or other mineral substances, dissolved in gasolene with the addition of resin as a hardening agent, proportions varying according to use. This is employed for surface application to walls, etc., that are to be rendered water-tight. Trade names: Dehydratine, Waxol, Anhydrol, etc.

Medusa, Hydratite, Maumee, Whitehall, Keystone, McCormick, Toxement, etc., and similar powders in very finely divided state. These are metallic stearates or resinates, to which are added varying proportions of hydrated lime, alum, and clay. Two to five per cent. of the compound is usually added to 1 bag of cement before the addition of water

Ceresit, Lapidas, Truscon, Aquabar, Leaw's Compound, etc., are combinations of lime soaps or oil emulsions, the product being added to the water employed for tempering the cement.

Ironite, a metallic iron waterproofing compound, is one of the latest additions to the list. Its principal ingredient is a very finely divided iron, which on exposure to water oxidizes and expands, filling the voids. It probably contains, in addition to the iron, some Portland cement and sal ammoniac. Mixed with water and used as slush coat or mixed dry with cement.

A number of waterproof cement coatings are now being marketed under such trade names as Symentrex, Blanchite, Glidden's, Cabot's, Trusscon, etc. These are paints applied to concrete, the material being constructed to give an artistic waterproof surface and not to saponify when applied to same.

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