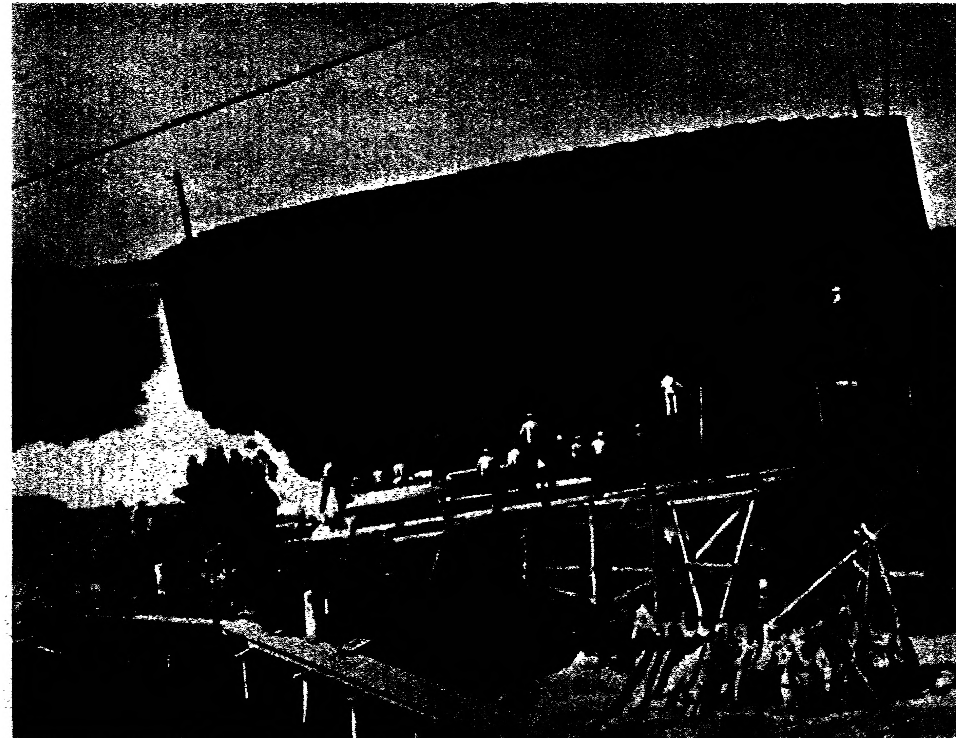
CONCRETE WATERPROOFING



Concrete Caisson to Lille Belt Bridge, Launched after Coating with a Waterproofing Bituminous Compound

(By courtesy of Inertol Co., Ltd.)

Frontispiece

CONCRETE WATERPROOFING

BY

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PREFACE

THIS book is intended as a guide to all those who are concerned with the actual construction of concrete when conditions occur which make it essential to adopt measures to render the material impervious to water.

General waterproofing principles and methods are included, together with a short outline of the nature and composition of the individual types of waterproofers. No attempt has been made to provide comprehensive details of the composition and manufacture of the different compounds, since most of the agents employed under trade names are of secret formula, many of which, however, conform generally to the basic analysis shown herein, with probably slight variations in the proportions of constituents.

The author wishes to thank the following for their generous help in preparing this book: The U.S. Bureau of Standards; the Cement Gun Co., Ltd.; Tretol, Ltd.; Inertol, Ltd.; N.A.M.M.C.; and particularly the Secretary of the N.A.M.M.C., for his generous and constructive assistance for the chapters on mastic asphalte. He also thanks the editors of the technical papers, *Civil Engineering* and *Contractors' Record*, for their kind permission to include articles recently published in their journals.

L. E. H.

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CONCRETE WATERPROOFING

CHAPTER I

NON-WATERPROOFED CONCRETE AND WATERPROOFING AGENTS

THE use of waterproofing agents has not kept pace with the use of concrete itself, except in the case of structures especially designed to withstand dampness, water pressure or generally exposed situations. Not long ago it was considered sufficient to add a little more cement to the batch to withstand any possible water or damp conditions imposed.

Concrete works completed some years ago will often show the results of exposure to the weather, the action of which is usually more severe than was then anticipated. A little extra expense incurred in dealing with the problems of waterproofing would have been fully repaid by the increased useful life and better appearance of the structure.

Generally the types of structure requiring concrete waterproofing are as follows—

1. Heavy structures that retain high heads of water pressure. These include dams, locks or graving-dock walls.
2. Lighter structures such as swimming pools and baths, reservoirs, tanks and retaining walls.
3. Structures such as pump houses, etc., which may have been buried to guard against bomb blast, or basements to commercial buildings such as stores or bank strong rooms.
4. Artificial pre-cast stone facings to exposed parts of buildings.

Generally, concrete without waterproof protection cannot be claimed to have any satisfactory waterproof qualities when exposed to rigorous water conditions. The unreliability of individual workmanship does not permit concrete to be of complete uniformity in quality. Hence, a building may have almost perfect concrete except in one or two odd places where the standard of workmanship may have been slackened. At these places, permeability is increased. As a result, the extra care taken on the whole structure is wasted.

Waterproofing precautions will have to be taken sooner or later *and extra expense incurred by the loss of time, expenditure of labour involved, and delay in utilizing the building.*

With many kinds of heavy structures, the question of water-porosity is one of stopping rather than waterproofing.

Waterproofing, density, and compressive strength of concrete are all very necessary qualities in concrete. Waterproofing has been less considered than the other two desirable properties. Yet high compressive strength is not always an indication of the relative density of the concrete. A mix, relatively rich in cement can be wasteful when used for thick mass walls. It is far cheaper and more effective to obtain waterproofed concrete by the use of a waterproofing agent rather than by using a richer mix of concrete.

Portland cement concrete has a high resistance to permeation by water when it is gauged with no more than the correct quantity of water required for its total hydration, provided that the whole of the water is taken up in the hydration of the cement, and that none is lost by evaporation during its induration. By careful and patient manipulation, under the artificial conditions observed in the laboratory, and using only Portland cement with carefully selected and graded aggregates, thoroughly cleaned, it is possible to produce specimens of substantially waterproof concrete. This type of experiment, however, whilst of value as demonstrating the nature and properties of Portland cement and concrete, does not indicate the results that can be expected under the less favourable conditions that are inseparable from all practical constructional operations. In order to obtain the workability so necessary for the flow of concrete into the required forms, and for the easy rendering of cement mortar, it is necessary to add more water than is necessary for the hydration of the cement. This surplus water forms minute pores, which, communicating with one another, become what are known as capillary canals, and are capable of conveying water throughout the mass of concrete. It is obviously impossible to waterproof concrete effectively by the addition of any finely ground, inert material, or by extra cement, in the attempt to eliminate voids, since such additions still leave it necessary to add an excess of water in the gauge mixing, and thus do not affect the predominant cause of porosity. The addition of excess water should be avoided, not only because of the expense but because mixtures over-rich in cement are liable to develop surface cracks. These minute cracks are the visible evidence of the expansion and contraction of the cement matrix. *The expansion and contraction are caused both by changes in temperature and by changes in the moisture content of the concrete.* Any specimen of concrete will expand when it is heated, or when it absorbs water, and will again contract when its temperature is lowered, or when it is dried out.

A most important fact, which has a great bearing upon the behaviour of Portland cement mixtures, is that the expansion and contraction subsequent to variations in moisture content, are on a considerably larger scale than the changes due to temperature differences. It has been established by exhaustive experimental work in the U.S.A. that when non-waterproof concrete is completely saturated, it expands as much as if its temperature had been raised by 1000° F. Experiments at the University of Michigan have also shown that the expansion of specimens of neat Portland cement which have been immersed in water was measurably progressive, although at a decreasing rate, for fifteen years. The total expansion during this period was equal to 0·162 of the initial length, of which 50 per cent of the expansion occurred during the first two months.

Alternations of expansion and contraction caused by changes in moisture are the chief cause of the deterioration and subsequent destruction of concrete structures, since the strains due to volumetric changes produced by variations in the water content are usually far greater than those produced by changes in temperature. If, by waterproofing the concrete, the absorption of water is prevented, expansion is limited to the relatively small amount caused by changes in temperature, and this is negligible.

The main essential of watertight concrete is maximum density. This is obtained by using clean, well-graded, non-porous aggregate, with sufficient sand and cement to fill the voids; using no more gauging water than is absolutely necessary to place the concrete in a plastic state; thoroughly mixing and tamping the concrete into position; and by effective curing. Too lean a mix is likely to facilitate leakage. Where construction joints occur, it is extremely difficult to prevent them leaking when there is a considerable head of water at the back of the concrete.

The grading of the aggregates is of first importance. It is necessary to arrange the proportions of different sizes of aggregate so that there are always particles small enough to fill the spaces between those of the next larger size, and so on, down to the finest grains of sand. If the coarse aggregate is deficient in fine material, sufficient sand should be added to fill all voids and leave about 10 per cent surplus. Fig. 1 shows a section through a piece of concrete in which there is no fine material to fill the spaces between the larger particles. Such a concrete would be far from waterproof. Fig. 2 indicates the result of correct grading. It is obvious that the better the grading, the better the concrete. A further precaution

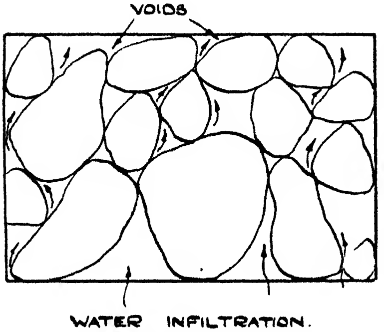


FIG. 1. POROUS CONCRETE RESULTING FROM ABSENCE OF FINE MATERIAL

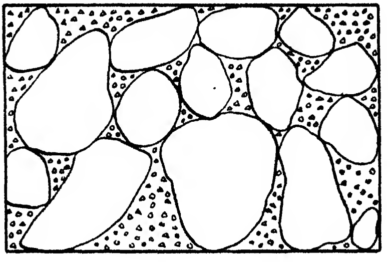


FIG. 2. INCLUSION OF FINE MATERIAL PROVIDES FILLING FOR INTERSPACES BETWEEN LARGE AGGREGATE

in the choosing of aggregates is to ensure that they are hard, strong, durable, free from injurious quantities of shale, loam, alkaline and organic matter, or thin friable laminations, and that they are inert to chemical reaction when the cement and aggregates are mixed. The size and shape of the aggregate particles as well as the relative number of particles of different dimensions are of decided importance. To obtain a good quality concrete it is apparent that an aggregate of maximum volume and mobility, or minimum mobile resistance whilst the concrete is plastic, is highly desirable.

Round aggregate will roll against each other, and their position in the group is easily changed. Angular particles slide against each other and considerably more effort is required to produce movement. Prismoidal, flat or elongated aggregate tend to jam against each other. This type of material produces extreme variation of quality and density in the concrete. A particle of spheroidal shape is more economical, in that it possesses maximum volume per unit area of surface; less voids are in consequence obtained by the use of round gravel, and it is more workable than an equivalent proportion of prismoidal or angular stone. By reducing the size of the stone used, the surface area per unit volume increases; hence for a fixed amount of stone, the cement matrix is stiffened far more by using the smaller stone than by adopting the larger stone, since the coarser particles possess less surface area. The greatest economy is obtained when the largest possible aggregate is used, since less cement is required than for a small aggregate.

To produce dense waterproof concrete, it is necessary to use sufficient cement to fill the aggregate voids with the addition of cement to separate the particles at their points of contact. Concrete well graded is not only denser and therefore waterproof but is in all ways an economical proposition. Specifications should always contain requirements regarding sieve tests for the aggregate. Allowances nevertheless are necessary for shortcomings in local aggregates and sand.

When a concrete is obtained which has a considerable compressive strength, and tensile and shear strengths are reasonably high, generally these qualities are accompanied by a compact concrete of excellent density with consequent small permeability and durability.

A great factor in the construction of reinforced concrete is that of providing adequate storage facilities. Cement should be stored in dry places and the period of storage should not be prolonged. Contamination of the aggregates with impurities should be avoided.

Segregation of the particles of the large aggregate causes variations in the strength of the mix. Restraint should therefore be employed in the dropping of aggregate on to the supply pile. Steep angle chuting of concrete together with horizontal movement are both detrimental to the final concrete. Minimum handling of the concrete is necessary. When a mixed concrete compound is dropped from a height or slid down a chute, its fall or flow should be restrained by sufficient deflectors, so that it retains its slight cohesive properties. Any movement, however slight, except vertically, involves a relative movement of its components. This tendency of coarse aggregate and matrix to cease flowing when moved horizontally or from an inclined direction should be overcome by carefully planned construction systems.

As mentioned before, the concrete should be plastic, but extreme dryness should be avoided. A general rule for water proportioning is that it should not usually exceed 5½ to 6 gal. per hundredweight of cement; this quantity includes initial dampness in the sand or stone. This, of course, is only a rough guide.

The placing of concrete should be continuous wherever possible, so as to avoid planes of cleavage. Where one day's work joins another, the face of the previous day's concrete should be well hacked, in order to expose the existing aggregate, after which the concrete should be well cleaned with water and a thin layer of grout applied before concreting is started. Complete curing is an important factor in producing water-tightness. This process prevents the body of the concrete from losing moisture which is required for the hydration of the cement. If possible all exposed faces should be kept continually damp for a few days by covering with wet hessian or other suitable material.

When waterproofing methods are reviewed for a particular purpose, site conditions should be considered in choosing the one to be adopted. The quality of the labour available is another of the problems that affect the type of waterproofing to be used. Where intelligent labour can be acquired, the use of site mixing of waterproofing powder with the concrete is a safe enough method. But when labour is very poor, and climatic and site conditions such that the mixing is exposed and subject to the elements of wind and rain, the use of powders is not satisfactory.

There are three methods of waterproofing generally in use at the present time—

1. Integral Waterproofing.
2. Internal Coatings } Surface waterproofing.
3. External Coatings }

These methods are resorted to when the structure has to be of guaranteed watertightness. Under usual atmospheric conditions, good dense concrete is impervious to water, but under conditions such that a head of water is always or recurringly present, even the most excellent concrete may fail in this respect, owing, no doubt, to some weak spot in the construction caused by a variation in the mix or by a local excess of water, leak at a construction joint, or bad punning, to mention only a few of the possible contributory causes that may result in a structure becoming pervious to water. In the case of a reservoir, for example, it is of paramount importance that no risk of leakage is taken; similarly for all other structures which hold water inside them or retain water against their outer surfaces, or which are buried in damp or water-logged ground. Any expenditure of labour, time and materials for waterproofing work that falls short of complete success is nearly always to be counted as a total loss, since when a further attempt has to be made to procure impermeability, generally the previous work has to be ignored.

A modern waterproofing compound, in addition to its waterproofing qualities, is also required to resist the attacks of acids, alkalis or organic compounds in the water which are so frequent in present-day industrial undertakings. It must fully resist humic acids and mineral impurities found in ground water, render concrete immune from the effects of gases formed in sewers or from the attacks of organic matter in the sewer itself, resist the disintegrating effects of sea water, sulphates and frost, and prevent the percolation of oil. It is essential, moreover, that the waterproofer should prevent efflorescence, sweating, or the growth of fungi. Fortunately, occasions never arise in practice when a waterproofer has to overcome all these difficulties at once.

When rendering an empty tank or a wall subject to acid fumes it is unnecessary to hasten the setting time of the cement, whereas when sealing faulty patches in a dam or reservoir from which water is pouring in large volumes and with considerable pressure, it is essential to be able fully to control the cement, so that it sets in a short period of a few seconds.

Integral Waterproofers. These consist of materials added to the cement or concrete. The addition to the cement is usually made at the works, and the waterproofer in this case is in the form of a waterproof cement. When the waterproofer is added to the concrete this is done during the mixing at the site. In this case, much depends on the skill of the person or persons at the mixer, and the diligent observance of strictly correct proportions of waterproofer to concrete. It is assumed that the admixture fills all the voids through which the water may pass.

Internal Surface Coatings. These are usually employed to stop leaks. Mortars with impervious mixtures in them, paints with waterglass or other kinds of chemicals, ferric compounds, etc., which evaporate or congeal and leave crystals in the pores of the concrete surface are some of the materials employed. These coatings are problematical in their results; generally they are successful, at other times they are not, their success depending upon the care with which they have been put on, and the nature of the leakage. The action of frost and frozen water behind the surfacing can produce a breakdown of the waterproofing. The fact that a material can waterproof concrete is no criterion of its value as an effective waterproofer, for a compound might give waterproofing qualities to concrete but at the same time not have sufficient adhesive qualities to resist an influx of water from a leak and to remain in place until it sets. A normal waterproof cement mortar does not possess the necessary qualities for this. Only by increasing the adhesive qualities and reduced contraction and by control of the setting time can this be achieved.

External Surface Coatings. These are usually bituminous or asphalte coatings with or without strengthening membranous layers inside the layers of the surfacing. It is essential that the concrete should be quite dry, and this method is consequently not adopted for the stopping of leaks. Often this method is used to counteract dampness, only one or two coats being employed. This is known as "damp-proofing." It is not sufficient to keep out a large head of water, unless three coatings are applied.

CHAPTER II

GENERAL PROPERTIES AND COMPOSITION OF WATERPROOFING COMPOUNDS

A. INTEGRAL WATERPROOFERS

INTEGRAL waterproofers may contain calcium chloride, soaps, hydrated lime, etc., in composition as shown in the following list, which gives an approximate analysis of some of these compounds—

Group No. 1: Calcium Chloride Liquid

16 to 40 per cent calcium chloride;
60 to 70 per cent water in inverse proportion to calcium chloride;
Small amount (in the order of 1 per cent) of resinous material or calcium hydroxide.

The liquid may be light yellow with a small quantity of flocculent precipitate, or a clear solution. Sometimes the agent is dyed a dark colour such as blue or purple. The solution is frequently turbid.

Group No. 2: Calcium Oxychloride Paste

This is usually mixed with the cement before water is added.

Group No. 3: Calcium Chloride with Miscellaneous Materials

57 to 75 per cent water.

May contain calcium chloride, silica and calcium stearate. The stearate may be present as fatty acids. Other compositions contain aluminium chloride, silica, calcium chloride or colloidal silica.

The waterproofer may be in the form of a white semi-liquid, turbid liquid, yellow paste or a dyed liquid.

Group No. 4: Soaps

80 to 90 per cent water;
10 to 20 per cent fatty acids as stearate.

This group may contain up to 5 per cent of fatty acids as oleate. The waterproofer may be in the form of a thick white paste or semi-liquid, a thick cream, or a coloured or yellow turbid liquid.

Group No. 5: Hydrated Lime with Soap

Contains from 5 to 10 per cent of fatty acids as stearate or oleate. The remaining materials consist of hydrated lime and calcium stearate, with sometimes a small amount of iron oxide.

This waterproofer is in the form of a powder which is usually white, but may be pink if iron oxide is present.

Group No. 6: Fine-grained Material Used as Fillers

These consist of finely divided powders of the following: diatomaceous earth, silica, hydrated lime, dolomitic lime, silica soapstone or bentonite. The powder may contain one or more of these constituents as powders.

Group No. 7: Miscellaneous Materials

May contain barium sulphate, calcium or magnesium silicate, petroleum jelly, cellulose, wax, alum or coal tar with benzene. These may be in the form of pastes, powder or a thick black liquid.

Group No. 8: Various

Portland cement containing calcium stearate, calcium sulphate, butyl stearate.

Heavy oils which contain mineral oil and 10 to 15 per cent of stearic acid.

Thick brown liquids containing sodium silicate and an organic glue-like material.

Summary. Extensive tests made by the Bureau of Standards, U.S.A., have shown that the addition of calcium chloride to concrete does not materially decrease the permeability of the concrete.

When such materials as soap, silica and aluminium chloride are added with calcium chloride, the concrete is not reduced in absorptive powers. Calcium chloride and soap together decrease the permeability, but do not increase the compressive strength of the concrete. Soap and lime added in an appreciable percentage to the concrete are definitely harmful, as they lower the strength, at the same time reducing the absorption.

Hydrated lime and soap together and incorporated in concrete give an increase in the permeability of the concrete, which is not so high as the addition of soaps alone.

Soap and lime added together lower the strength and reduce the absorption.

Finely divided compound fillers generally reduce the permeability and increase the compressive strength.

Such materials as wax, cellulose, compounds containing uncombined fatty acids, fluosilicate, vaseline, napthalene, or coal tar do not improve the waterproofing qualities of concrete. They lower the compressive stress but reduce the absorption. Heavy mineral oils reduce the permeability, absorption and strength.

It should be noted, however, that individual waterproofings in a group may vary considerably in their properties.

B. SURFACE WATERPROOFERS

These do not include asphalte (with or without membranes). Surface waterproof compounds may be asphalte emulsions, bituminous solutions, iron compounds, cement and transparent coatings, paints and varnishes. The compounds vary in composition. Typical compositions of surface mixtures are as follows—

Group No. 1: Asphalte Emulsions

Clay asphalte emulsion is frequently used for a first coat, with a clay asphalte emulsion with asbestos for the second coat; 20 to 25 per cent of water is added to the first coat. The second coat is applied by trowel to $\frac{1}{16}$ in. after the first coat is dry. The directions may vary slightly. In some cases, a small quantity of calcium chloride and/or alcohol is included. The most efficient of this group is the clay asphalte emulsion, first coat with the second coat of clay asphalte emulsion containing asbestos. Coatings containing asbestos are among the most efficient in this group. One mixture which is quite efficient employs a third topping coat of one part Portland cement to two parts of cement, completed to a trowelled finish.

Group No. 2: Bituminous Solutions

The composition of bituminous solutions always contains asphalte in petroleum spirit (percentage of non-volatile spirit from 50 to 75). Some coatings contain asbestos in a proportion which may be small or large (5 to 45 per cent). One particular solution has the following composition—

Asphalte .	50 per cent
Asbestos .	45 ,, ,,
Petroleum spirit	5 ,, ,,
	100 ,, ,,

This latter mixture is applied in one coat only, from ⅛ in. to ¼ in. thick. All bituminous solutions containing asbestos require only *one coat by trowel. Asphalte-petroleum spirit solutions, on the other hand, require two coats, at from one to four days apart.* The asphalte-asbestos-petroleum spirit mixture is very impervious to water.

Group No. 3: Iron Sal-ammoniac Compounds

These compounds contain finely ground iron and sal-ammoniac. The surface to be waterproofed is usually well saturated with water prior to coating, for a period of from twelve to twenty-four hours. Sometimes the waterproof specification requires that the surface be first coated with a solution of magnesium chloride. Sometimes it is required that the coating should be applied with equal parts of Portland cement. The finished waterproofer is often ⅛ in. thick. Some require four coats to be applied, as follows—

(*a*) The first coat is applied as a thick paste.

(*b*) The surface is dried for twenty-four hours during which it is wetted four times.

(*c*) The second coat is applied as a thick paste.

(*d*) The third coat is applied with one-fifth part of waterproofer, three-fourths part sand, and one part Portland cement as a plaster.

(*e*) Drying period of twenty-four hours during which the surface is wetted several times.

(*f*) The fourth coat consists of one part cement, three-fourths sand, mixed with water to a sloppy consistency and applied with a brush.

(*g*) The drying period of twenty-four hours is necessary, together with several wettings during this period.

Group No. 4: Cement Coatings

These liquids are incorporated with a cement mix and then applied to the surface of the concrete. The mixing of the cement and the coating is undertaken at the site. The coatings contain from 60 to 70 per cent of water, with 10 to 30 per cent of calcium chloride, aluminium chloride, and a small proportion of organic matter or a glue-like material with sodium silicate.

A typical composition is as follows, for a light yellow liquid—

Water . . .	73 per cent
Calcium chloride .	26 ,, ,,
Resinous material .	1 ,, ,,

In this case, three coats are applied of the following mix of the above preparation—

1 gal. of waterproofer.
2 gal. of water.
½ bag of Portland cement.

Other types of waterproofer may be clear acidic amber-coloured liquid, or a thick brown liquid of gluish odour, to take but one or two examples. Some of these coatings are applied to a full thickness of ¼ in., if sand is included in the mix; these coatings are more efficient since the mortar thus provided helps to withstand the water better.

Group No. 5: Transparent Coatings

These are liquids or oils and may consist of butyl stearate, butyl oleate, glycol, ammonia, alcohol and paraffin or a solution of sodium silicate or boiled linseed oil. The colouring varies, being usually of a yellow shade, and may be viscous, clear or turbid.

Butyl stearate and butyl oleate, which are applied in three coats brushed on at twenty-four hours apart are quite effective as waterproofers.

Boiled linseed oil when used in three coats, the first two at twenty-four hours apart, and the third three days later, gives excellent results.

China wood oil in mineral spirits is even better and is as good as any transparent coating. This is applied in two coats twenty-four hours apart.

Solutions of paraffin, waxes, mineral spirits and oil are not usually very efficient and break down after a very short period. Sodium silicate is not very effective and breaks down after some little time.

Group No. 6: Paints and Varnishes

These may consist of a grey gelatinous paste, paint, varnish or oily liquid.

The waterproofer in the form of a thick grey gelatinous paste may contain varnish and asbestos and is applied with a trowel.

White lead paint, zinc oxide oil paint, white lead and zinc oxide oil paint, or white barium sulphate paint eventually break down under constant water pressure or damp conditions. Of this group, a plain varnish with 50 to 60 per cent volatile liquid is the most efficient.

Summary. Asphalte emulsions and bituminous solutions are among the most efficient coatings.

Linseed oil, China wood oil and varnish are among the most efficient transparent coatings.

Paints are effective for a period of some months, but eventually break down.

Concrete can easily be made that will withstand heads of water of as much as 25 lb. per sq. in. However, in the placing of even the best concrete, segregation can and does occur at certain places. Moreover, these points are not always easily identified, and local repairs not always possible. Such places are frequently too lean in mortar or glutinous cement, and will permit the passage of water. In such cases, waterproofing is necessary. Integral waterproofers in some cases do help the concrete to minimize segregation and produce placing, acting in the manner of a lubricant. Some waterproofers render concrete waterproof against a sprinkling of rain or even periodic rains, but do not withstand concentrated water pressure or prolonged dampness.

Sealing-up of slightly leaky seams appears to be quite an effective means of obtaining water tightness. This can be achieved fully as effectively without a waterproofing agent.

When the choice of a waterproofing agent has to be made it must be borne in mind that an integral waterproofer is of no use against settlement cracks. Bituminous coatings are better for this purpose. Simple materials, such as stearates and oleates, are as effective as any and can be purchased far more cheaply than the products sold under fancy trade names. Calcium chloride is also fairly effective. This also can be purchased as such, though often it is camouflaged under a trade name and a very effective dye.

Water emulsions of asphalte are generally efficient. It appears that asbestos is a superior mineral extender to clay. Asphalte applied in paints is also effective.

Coatings consisting of iron oxide, sal-ammoniac, cement, etc., are not very effective even over a short period. These coatings contain very fine pores which cause sufficient capillarity to produce distinct water absorption. Paint coatings are very similar.

Transparent coatings are excellent waterproofers, and among these are linseed oil, and China wood (tung) oil, which are readily obtainable.

The above list does not include an example of every type of waterproofer on the market, but gives a fair range of the general composition of waterproofers now available.

Tests made by the Bureau of Standards, U.S.A., were not exhaustive. The results were obtained under laboratory conditions on samples subjected to immersion in water for a period of over a year. The results do not, of course, prove what can happen under normal atmospheric and water conditions, but serve as a useful guide in the choice of a suitable waterproofer for any specific purpose.

Integral waterproofers where used are always included in the concrete mix, either at the site or in the cement under the guise of "waterproof cement." Surface waterproofers contain both internal and external types applied by brush or trowel and do not include asphalte (with or without membrane reinforcing).

Internal waterproofers are frequently renderings, which are usually iron compounds, cement coatings, transparent coatings, and paints and varnishes.

External coatings may consist of the same compounds as used for internal coatings, but very frequent use is made of asphalte emulsions or bituminous solutions.

CHAPTER III

TESTING OF WATERPROOF COMPOUNDS

WATERPROOFING compounds vary very considerably in their ability to resist permeability. Tests by the Bureau of Standards, U.S.A., in 1936, which were comparatively thorough compared with any tests undertaken elsewhere, showed this variation. These tests proved that proprietary compounds were not the only effective waterproofers that could be used.

Ordinary chemicals such as butyl stearate and butyl oleate are equally effective as integral waterproofers and as surface waterproofers.

Boiled linseed oil and China wood oil are very effective—in fact better than most proprietary transparent surface coatings on the market at present.

Neither calcium chloride nor sodium silicate is effective in itself.

Bituminous compounds are very reliable and are probably the best surface coatings apart from molten asphalte (with or without membranes).

Tables I and II are abridged results for absorption tests taken from the Bureau of Standards' Report in 1936. These tables are self-explanatory. The samples used were 3 in. by 6 in. cylinders of 1 : 3 : 6 concrete for the integral waterproofing tests, and 1 : 2 : 4 for the surface tests. The reason for choosing 1 : 3 : 6 for the integral tests was to produce a concrete which was not too dense. Immersion was in water throughout. Integral waterproofers, since they are included in the mix, have some effect on the compressive strength of the concrete. Some waterproofers raise the compressive stress; compounds of soaps lower this stress—in some cases very considerably—and for this reason, are to be avoided. Waterproofed cement raises the compressive stress. Fig. 5 is a diagram showing the breaking compressive stress for periods up to one year.

Absorption was shown by these tests to be considerably reduced by prolonging the curing. The first series of tests was commenced after nineteen days' curing, the second series after one year's curing. Tables I and II illustrate the advantage of delaying the time of subjection to dampness or water of any concrete surface in order to complete the curing effect as much as possible.

From these tests, it appears that concrete of a very moderately strong mix 1 : 3 : 6 will absorb water up to 5 or 6 per cent of its weight. These tests were under laboratory conditions, and naturally do not give a complete indication as to what absorption will occur

TABLE 1

ABSORPTION TESTS ON INTEGRALLY WATERPROOFED CONCRETE (ABSORPTION AS PERCENTAGE OF WEIGHT)

Description	Constituents	After 19 Days' Curing				After 1 Year's Curing			
		1 hr.	4 hr.	24 hr.	48 hr.	1 hr.	4 hr.	24 hr.	48 hr.
Non-waterproofed	1 : 3 : 6 concrete	2·7	4·8	5·3	5·4	0·9	1·5	3·1	3·9
Liquid	Calcium chloride	2·0	4·2	5·3	5·4	1·1	1·9	4·0	4·5
Powder	Calcium oxychloride and sodium stearate	2·2	4·1	5·4	5·5	0·8	1·3	2·8	3·6
White paste	Calcium chloride	2·1	4·3	5·3	5·4	0·6	1·2	2·3	3·0
White semi-liquid	Sodium stearate	1·9	3·5	4·8	5·0	0·8	1·3	2·5	3·1
Cream-coloured liquid	Aluminium oleate and oil	1·3	2·4	3·8	4·1	0·7	1·2	2·1	2·6
White powder	Hydrated lime and calcium stearate	2·1	4·0	5·0	5·1	0·8	1·3	2·8	3·4
Fine powder	Diatomaceous silica	2·5	4·3	5·3	5·4	0·9	1·6	3·2	4·1
Thick black liquid	Coal tar and benzene with calcium stearate	2·4	4·8	5·4	5·6	0·8	1·4	3·4	4·2
Cement	Portland cement	1·4	2·4	4·1	4·4	0·7	1·1	2·0	2·5
Cement	Portland cement with calcium sulphate	1·6	3·2	4·9	5·1	0·9	1·3	2·4	2·9
Liquid	Butyl stearate	0·7	1·1	2·2	2·8	0·5	0·6	1·0	1·2

with such concrete placed under normal site conditions. It must also be borne in mind that one year is not a very long period in the life of a structure. Much deterioration is possible later. This is the case with external surface coatings which are subjected to atmospheric conditions, which are variable, whatever part of the world the structure is built in.

Unprotected concrete of the normal workmanship used to-day will eventually deteriorate if subjected to the elements. Frost is a great erosive force. The use of internal waterproofers cannot greatly help the wearing qualities of the concrete made with such waterproofing agents, but when surface waterproofers are applied on exposed faces some protection is available to the concrete. The

TABLE II

ABSORPTION TESTS ON SURFACE WATERPROOFED CONCRETE (ABSORPTION AS PERCENTAGE OF WEIGHT)

Description	Constituents	1 Hour	24 Hours	3 Months	1 Year
Non-waterproofed concrete	. . . . .	2·9	4·4	5·1	5·2
Asphalte Emulsions					
Emulsions	Clay asphalte	0·0	0·5	3·6	3·9
Emulsions	Clay with asbestos	0·0	0·1	2·3	2·9
Bituminous Solutions					
Solution	45 per cent asbestos, 50 per cent asphalte, 5 per cent petroleum spirit	0·0	0·1	0·4	0·6
Solution	74 per cent non-volatile asphalte in petroleum spirit	0·0	0·0	0·8	1·2
Finely Divided Fillers					
Powder	Finely-ground iron and sal-ammoniac	1·5	3·8	4·6	4·9
Powder	Finely-ground iron and sal-ammoniac	0·7	3·5	4·6	4·8
Cement Coatings					
Liquid	Calcium chloride and resinous material	2·0	4·3	5·1	5·3
Transparent Coatings					
Liquid	Butyl stearate	0·4	1·0	3·1	3·3
Liquid	Butyl oleate	0·4	0·9	3·2	3·4
Oil	Boiled linseed oil	0·0	0·2	2·0	3·8
Oil	China wood oil in mineral spirits	0·1	0·2	2·3	2·8
Liquid	Sodium silicate solution	1·5	4·1	5·0	5·1
Yellow oil	Paraffin wax in mineral oil	1·7	4·5	5·1	5·2
Paints and Varnishes					
Varnish	(60 per cent volatile)	0·0	0·3	2·5	3·5
Paint	Zinc oxide oil paint	0·0	0·1	4·3	4·9
Paint	White lead and zinc oil paint	0·0	0·1	2·6	5·1
Paint	White barium sulphate paint	0·0	0·0	4·2	4·4

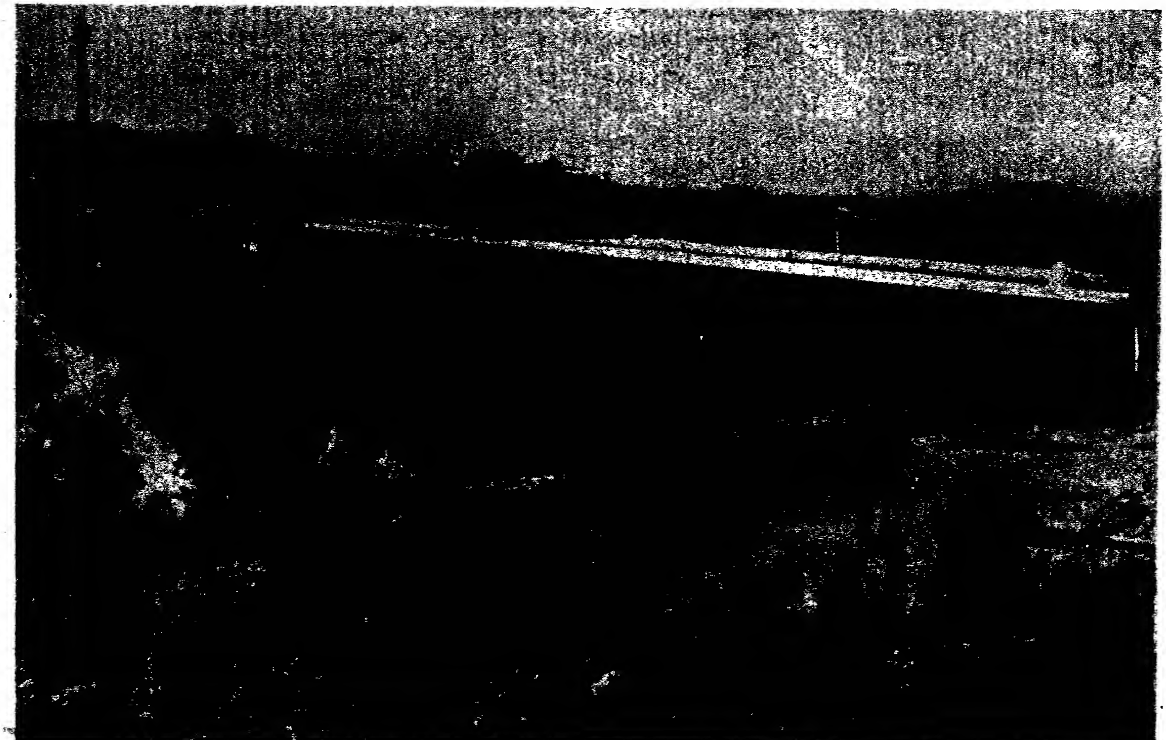


FIG. 3. SURFACE WATERPROOFING OF A DAM BY MEANS OF A BITUMINOUS COMPOUND

(*By courtesy of Inertol Co., Ltd.*)

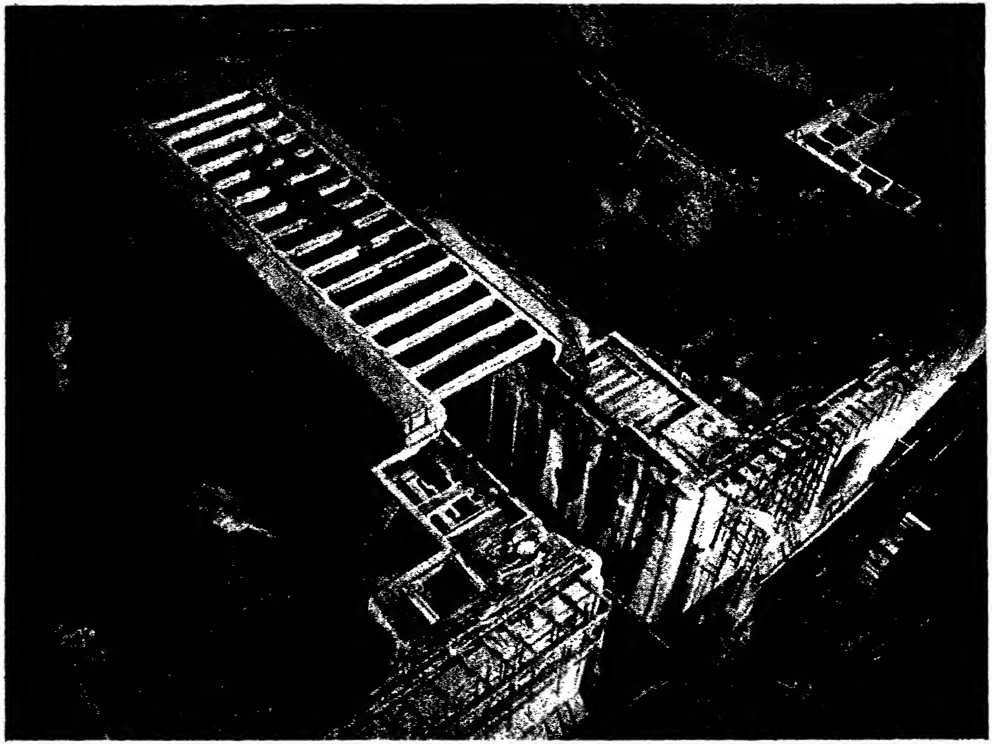


FIG 4. YMUIDEN LOCK, NORTH SEA CANAL, HOLLAND, RENDERED IMPERVIOUS TO WATER BY BITUMINOUS WATERPROOFING

(By courtesy of Inertol Co., Ltd.)

measure of this is dependent on the type of waterproofing used. Asphaltic emulsions, and especially bituminous compounds, offer much better resistance than transparent coatings or paints or varnishes.

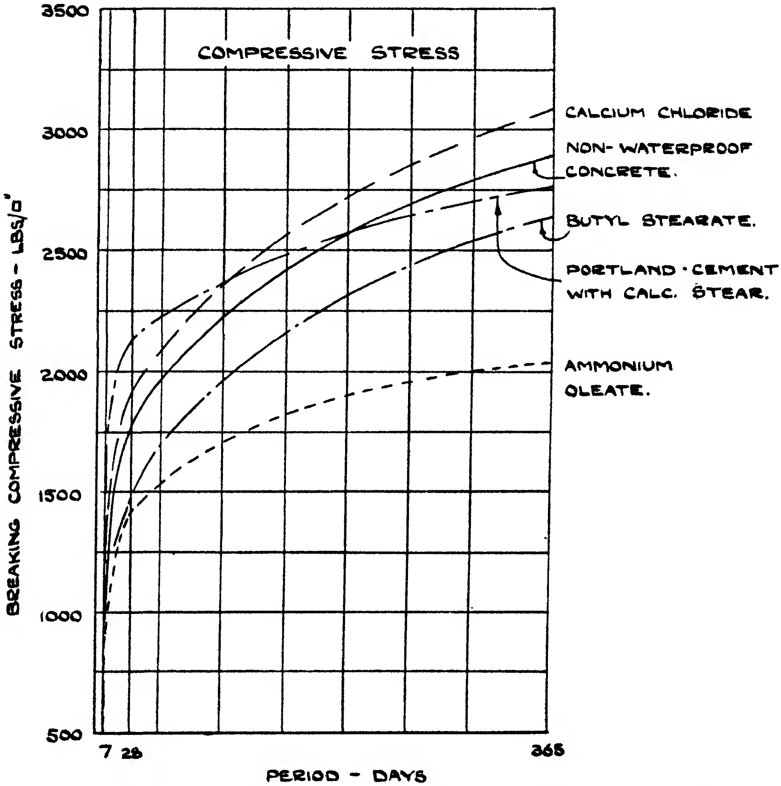


FIG. 5. COMPRESSIVE STRENGTH OF CONCRETE WATERPROOFED WITH DIFFERENT AGENTS

Tests made in Germany in 1925 on two concrete cubes of length 20 cm. along their edges (one cube being coated with two applications of a well-known bituminous compound, the other being untreated) showed some proof of this. The cubes were composed of one part of cement to eight parts of sand. After four days' curing, one of the cubes was coated as described above, the coats being twenty-four hours apart. Twelve days after casting, the two cubes were placed in a refrigerator. One day afterwards the cubes were thawed under water, then allowed to remain in the normal atmosphere for half an hour. Another day was then taken up by the cubes in the refrigerator. This was repeated twenty times in succession. The thawing process took one hour. At the conclusion of this test, no damage was noticeable to the bituminous-compound coated cube. The untreated cube, on the other hand, showed distinct evidence of spreading crumbling.

Integrally waterproofed concrete does not resist chemicals to the same extent as surfaces waterproofed by coatings. This applies to sewer construction, sewage tanks, industrial chemical plants, or structures subjected to marsh or peaty moorland water. Surface waterproofing by bituminous compounds appears to be a reliable agent for preventing deterioration of such structures, which may be subjected to the action of acids, alkalis, brine, sugar solution or sea water.

Tests made in Germany in 1913 by a special commission of German State engineers showed that normal concrete blocks after immersion in water—with constituents such as humic acid, corresponding to marsh water—were found to be slightly dissolved after ten months. Bituminous coatings available were tried to determine the suitability of this type of waterproofer in such circumstances: no deterioration was found to have occurred.

The disastrous effects of sugar solutions on concrete of normal manufacture is well known in industry. Dr. Nitzsche in 1926 made exhaustive experiments on concrete cubes, some of which were non-waterproofed and the others surface-waterproofed with a bituminous compound. The blocks were of porous mortar of a mixture of 1 : 4½. The solution was 20 per cent sugar in water. After twenty-eight days immersion, the loss of compression stress was found to be as follows—

Unprotected blocks 62 per cent.
Blocks protected with a bituminous solution 8 per cent.

In many cases the provision of a surface waterproofer helps in the curing of concrete. This quality is absent in integral waterproofing. Tests made at Stuttgart over a period of four years from 1919 to 1923 have given proof of this quality. In this case, the waterproofing agent was a bituminous solution. Thirty-six cubes of 1 : 3 mortar were tested. The tests were made at intervals of twenty-eight days, three months, one year and three years. The beneficial effects of conserving the water content of the concrete were even noticed after one month. Even after three years the treated concrete was from 5 to 15 per cent stronger than the untreated concrete.

The value of tests as made by the manufacturers is purely local and the tests do not give a true indication of the general behaviour of waterproofers. Usually manufacturers' tests are for periods of immersion or subjection to water pressure of only a comparatively short time, whereas the general life of any waterproofed structure is frequently decades. It is no use testing a waterproofing material for one week, two weeks, or even one year, if the probable reason for the test is that the waterproofing agent is required to have extended life of several years. Many waterproofers are impermeable over a period of several weeks, but some break down all at once.

Where 100 per cent watertightness is vitally necessary, as in reservoirs, dams, etc., the use of an integral as well as a surface waterproofer is required. Tests do not prove that proprietary articles are superior to chemical compounds, which can be purchased far more cheaply than the former. Offset against this advantage is the accumulative experience of specialist firms, most of which have very competent chemists. The technical service and experience of these firms are of material advantage when difficult problems of waterproofing occur.

CHAPTER IV

INTEGRAL WATERPROOFING

THERE are three forms of integral cement waterproofers available, viz.—

Pastes of various specific gravity and colour.

Powders of different specific gravity and colour.

Fluids of widely differing viscosity and specific gravity and colour.

The essential difference between these three types is that of mixing. Usually powders and pastes require considerably more effort to mix than do fluids. Pastes are normally very dense, and since they have to be worked by hand into the condition of a thick cream, free from lumps before adding the final amount of water, it is only possible to mix a very small proportion at a time. All lumps must disappear, otherwise trouble is bound to ensue. Should the labourer fail to mix the paste free from lumps, the lumps, having a mainly dry core, cause considerable trouble, especially in rendering, because they invariably initiate cracks and crazing. If the paste is used with a percentage of lumps, then that percentage of the paste is useless. After the final amount of the water has been added to the paste, since the latter is invariably heavier than water, immediately it is left standing in a tank or barrel on the site it begins to sink to the bottom and forms a thick sediment which produces a dilution in the liquid towards the top of the container. Thus with pastes, it is very necessary that the solution be stirred extremely well before each mixing in the cement, otherwise the final compound will not obtain the benefit of the waterproofing qualities of the paste. Most of the pastes are dense and of a glutinous nature, and are delivered in barrels or metal containers.

Powders are often mixed neat with the cement, and never with the gauging water before the fine and coarse aggregates are added. When so mixed with the cement they are known as admixtures. Sometimes this term is used for all integral waterproofers. Some powders are added at the works with the cement. This has the advantage that correct proportions of powder are obtained, which is not always possible under the variable conditions in which site operations are undertaken.

Where powders are mixed at the site, the general procedure is roughly as follows: The cement to be used is first spread over a flat surface to a depth of 1 in. or so. The waterproofing powder has then to be sprinkled evenly on top of the cement in the required proportion. The cement and powder are then well mixed and are afterwards screened two or three times before adding sand or ballast. Since powders are usually light, it is necessary to protect the mixing operation from the atmosphere. Unless extreme care is taken over this process, the waterproofing effect of the powder on the resulting concrete will be haphazard and unreliable. It is assumed that the powder particles swell and harden after coming into contact with the lime contents of the cement. The swelling particles fill the voids in the mix as it sets and dries out. This idea is not always realized in practical construction, mainly owing to the site conditions of mixing.

With waterproofed cements this has more likelihood of realization. These are far better than admixtures, for the proportions are strictly controlled and the cement itself is actually improved in performance, since by its use an increase in strength in the concrete is obtained over the use of ordinary Portland. Normally, the cement is manufactured as ordinary Portland cement up to the stage of grinding. At this point, another material is now substituted for a percentage of the raw gypsum which is often added at the final grinding. This is a processed gypsum which helps to increase the hydration of the aluminates and silicates present in the cement.

The advantage of having a waterproofing medium present in the cement is considerable. The worry and responsibility of supervising and providing adequate supervision for site admixing is abolished, and the correct proportion of waterproofer goes into the concrete evenly.

The waterproofed cement is more able to withstand the corrosive actions of acids, alkalis, sewer gases and soluble harmful salts often present in industrial waters.

With the use of a liquid waterproofer the filling of the voids is more completely realized than by using powders or pastes. The action of a liquid waterproofer is distributed throughout the mix, setting up a chemical reaction on the particles of the cement by filling all the voids, and at the same time adding to the binding properties of the cement itself. When the solution comes into contact with the cement matrix the cement starts to crystallize and thicken. This process continues until it has completely set and all trace of coloration has disappeared. A particle of cement can be considered as having a latent life which can only be actuated by the addition of water, which causes a chemical reaction. The result of this activation is that the cement binds itself firmly to the particles of sand and ballast with which it is in contact. The usual period of this activation is from twelve to eighteen hours at a temperature of 60° F. to 65° F., and if the water is retained during the complete period of activation, then total and perfect setting of the cement is obtained. But in practice the water always is sucked

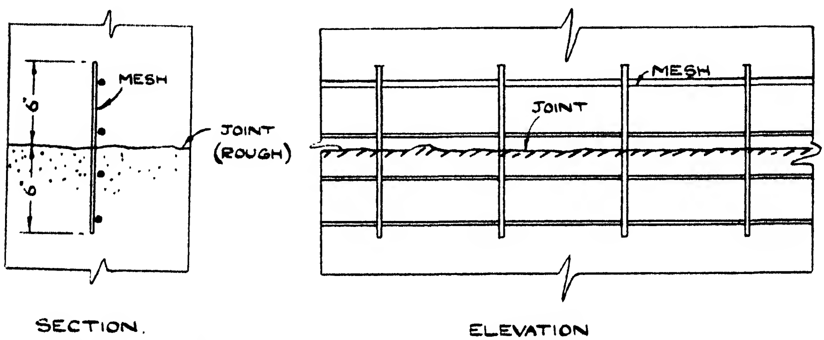


Fig. 6. Precaution at End of Day's Concreting for Waterproof Concrete

away from the cement almost as soon as the cement has been brought to life and started to activate, with a resultant loss in the binding properties of the cement matrix. A great number of unstable particles are left, which help to start cracking and crazing and eventual deterioration and disintegration of the structure. The use of a liquid waterproofer tends to thicken and to produce a fatty matrix whilst helping to retain the gauging water, since the matrix is now too thick in consistency to be affected by suction. All the bad aspects of too short an activation period are eliminated.

The placing of waterproofed concrete should always be carried on continuously, so as to avoid the weakness of day work joints. If the concrete cannot be completed in the course of the day, it is necessary to leave the edge as rough as possible and on the resumption of work to water the edge adequately and then brush it over with a thick creamy mixture of neat waterproofed cement. It is essential to follow on quickly with waterproofed concrete before the grout dries. If the concrete does not contain reinforcement it is necessary to embed a strip of Expanded Metal or other reinforcement across the joint, so that half of the strip will protrude and form a bond when it is covered by the abutting layer of concrete (Fig. 6). The new concrete should be well tamped round the mesh reinforcement.

BASEMENTS

When the walls of a tank or basement in flooded ground are of concrete, especial care should be taken with the joints between the

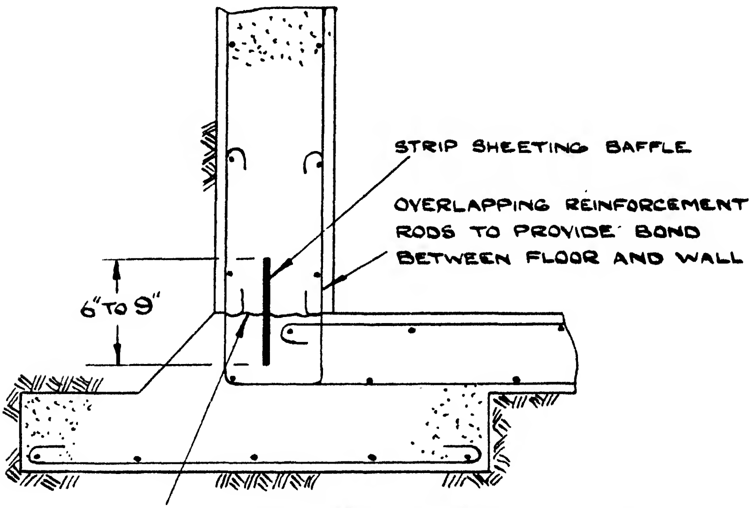


FIG. 7. CONSTRUCTION JOINT AT BASE OF WALL TO REINFORCED CONCRETE TANK

bottom of each wall and the top surface of the concrete floor. The surface of the floor concrete, where it occurs under the walls should be left as rough as possible, and a rough groove formed for the toe of the chamfer or cove of the interior angle between the wall and the floor (Figs. 7 and 8). Before the concrete sets, 6 in. to 9 in. wide strips of galvanized corrugated iron, sheet tin or other sheeting are forced edgeways into it midway in the thickness of the wall, leaving half their width protruding. These form a tongue or "baffle." The surface of the joint should in all cases be well grouted before the wall concrete is poured, and its thickness should not be less than ⅜ in.

Waterproofing a basement floor is often a difficult problem. Sometimes springs run through or near the site. In these cases, the course of the springs must be controlled into a main pipe drainage or series of pipes and thence into the normal drainage system, or else a sump must be constructed from which the water is pumped out.

When a structure is built in or on waterlogged ground, the waterproofed work is subjected to a hydrostatic pressure that may produce considerable damage to the floor, although internal renderings may not show signs of damage. When floors are subjected to such conditions, the upward hydrostatic pressure is always

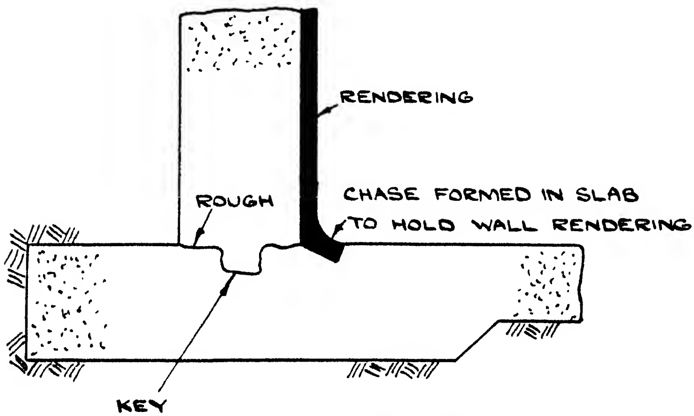


Fig. 8. Construction Joint at Base of Mass Concrete Wall

proportional to the head of water above the soffit of the waterproofed concrete. It is usual to design rafts of this nature to resist fully such fluid pressure, which may be very large. When the water pressure is small, the hydrostatic thrust is counterbalanced by the floor load. A nominal amount of mild steel reinforcement is required, if only to provide against cracking caused by slight subsidence or other detrimental effects.

When the pressure of water exceeds one foot, it is economical to employ a thickness of concrete suitably reinforced to withstand the upward water pressure. In this case, the floor is designed as a raft, the whole of the reinforcement being in the top of the slab, except for rods turned down at the perimetral supports for shear and reverse bending moments.

A further point is that, especially in basement construction, the latter must not be subjected to water pressure until the concrete is hard enough to develop a considerable strength. The provision of a sump, either externally or inside, is necessary to drain off the water. If the latter can be carried to the external drainage there is no need for pumping. Continuous pumping from the sump is necessary during the construction of the raft and walls, and frequently during the construction of the roof as well owing to the buoyancy imparted by the water pressure exerted on the structure. For ordinary Portland cement not less than seven days should be allowed before the basement is subjected to water pressure.

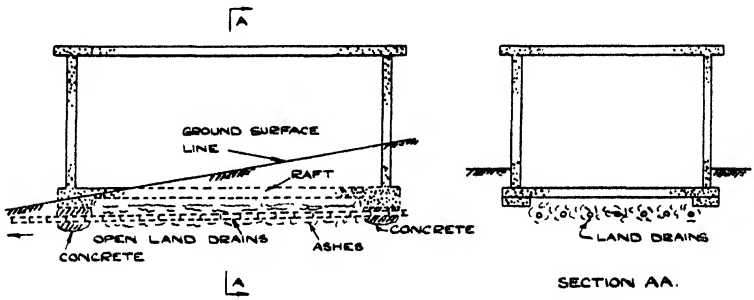


Fig. 9. Drainage to Subsoil by Land Drains

Where the basement has a natural run-off, such as sidelong sloping ground or is adjacent to a river, etc., it may not be necessary to form a sump. Land drains can be incorporated in the subsoil beneath the foundation of the basement (Fig. 9). Difficulties of access, obstruction by other buildings, or site conditions sometimes, however, render it impossible to provide a sump on the outside of a basement. It is then essential to form the sump in the floor of the basement itself. The sump can consist of a small concrete catchpit or stoneware gully. A very economical and effective sump is a sound perforated cylinder, say 18 in. deep by 12 in. diameter. This is placed in a hole dug beneath the floor level and is surrounded by hardcore, bricks, etc. The access flow should be obtained by 3 in. or 4 in. diameter land drains or open-jointed spigot-and-socket stoneware pipes, or alternatively 3-in. diameter porous concrete pipes; all of these should have a surround of 6 in. minimum of hard core. The cylinder should be provided with a board or steel cover. Precautions should be taken to keep out detritus, silt, etc., from the pump.

Fig. 10 shows the general details of the sump drainage lay-out. A double-flanged cast-iron tube should be provided, of sufficient

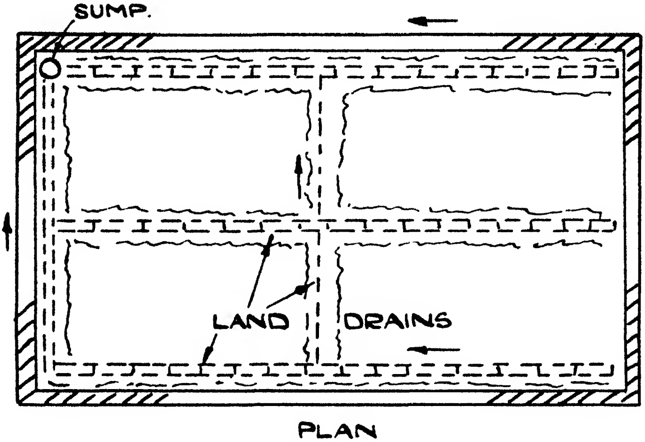


FIG. 10. ARRANGEMENT OF DRAINAGE TO SUMP IN RESTRICTED AREA

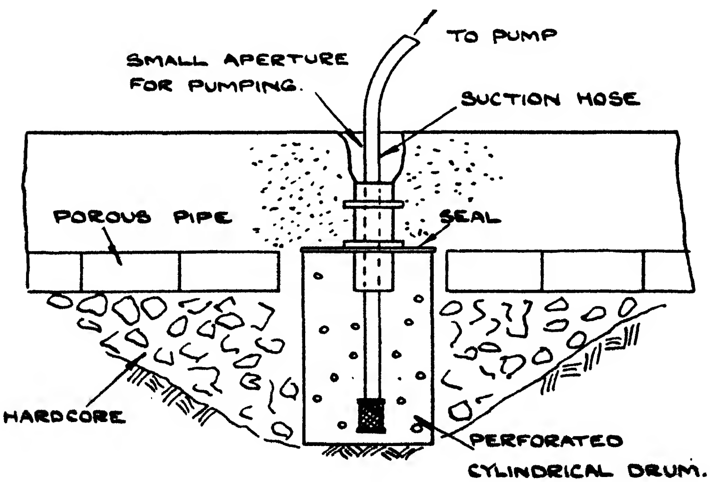


FIG. 11. TYPICAL SUMP AND SUCTION PIPE TO PUMP

diameter to allow free passage of the suction pipe and filter. The flanges, when the tube is encased in concrete, provide a watertight joint (Fig. 11).

Fig. 12 shows the finished raft with the suction pipe removed and the top of the tube sealed by a cap or stopper: a cap is more convenient for re-opening for inspection. The hole above the stopper should be sealed off with a rich plug of waterproofed grout and topped with waterproofed cement. A floor rendering all over is not necessary.

If the subsoil in which the basement lies is permeable the water can freely percolate through it, and the water will drain from the surrounding ground into the sump. If the building is constructed on rock or impervious subsoil, the water has to be drained from the

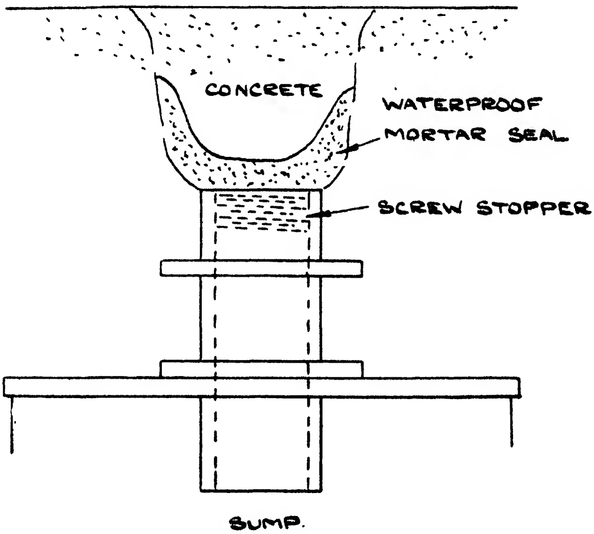


FIG. 12. SEALING PROCESS TO TOP OF SUMP

excavation through weep-holes in each of the outer walls. The water is then carried to the sump by means of hardcore or channels placed beneath the floor-slab.

For new construction, the method of waterproofing is determined largely by the design shape and the future use of the building, and by the severity of hydrostatic conditions imposed. The various methods may be roughly classified in the following manner—

1. Tank construction involving monolithic use of reinforced concrete for walls and floor and frequently roof as well, due precautions being taken with joints at wall, floor and roof. This is only practicable in new work, but is the most economical for such cases and is the best defence against excessive hydrostatic conditions

imposed on marine or inland water sites. Fig. 13 shows a typical construction adjacent to a very porous quay wall.

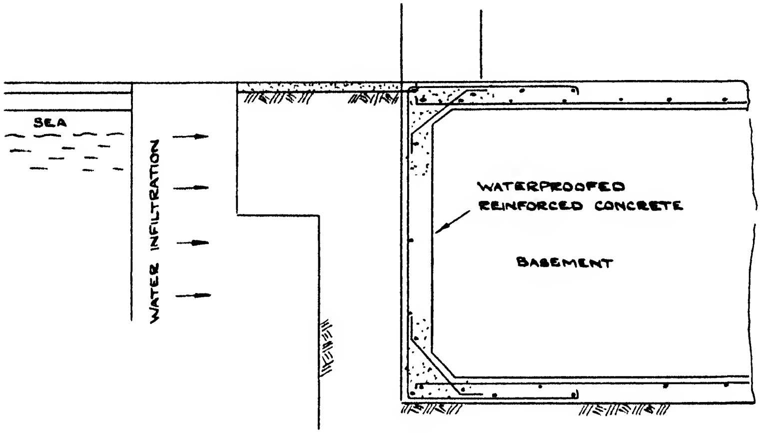


FIG. 13. TYPICAL WATERPROOFED REINFORCED CONCRETE BASEMENT

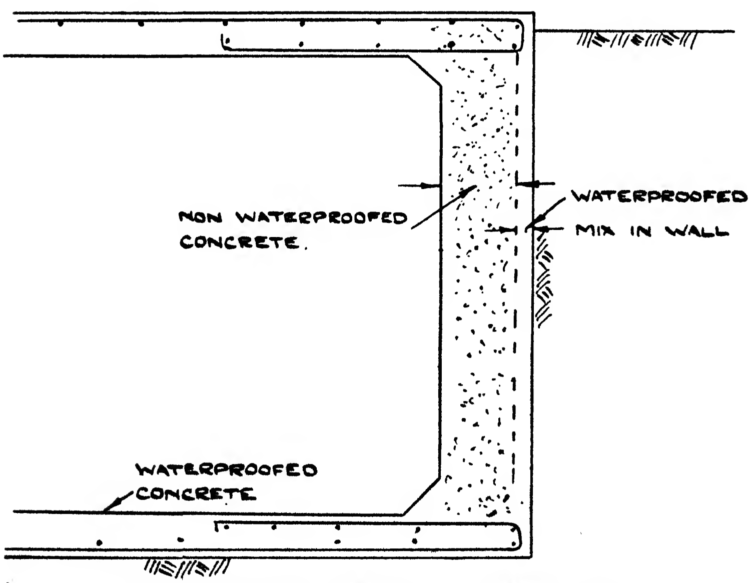


FIG. 14. WATERPROOF BASEMENT WITH MASS WALLS

2. Reinforced waterproofed concrete floors, with mass concrete walls, but, for economy of the more expensive waterproofing cement,

with provision of a dual mix, the waterproofed facing being 3 in. or so wide on the external face.

This construction is generally suitable for deep heads of water and especially for marine work. For shrinkage reasons, the walls should be undertaken in short lengths with adequate keying. It may be necessary to use a vertical metal baffle at each joint (Fig. 14).

3. Monolithic mass concrete construction with floor in mass concrete in addition. This method is very suitable when good rock is the foundation and as a result a slab of reasonable thickness can

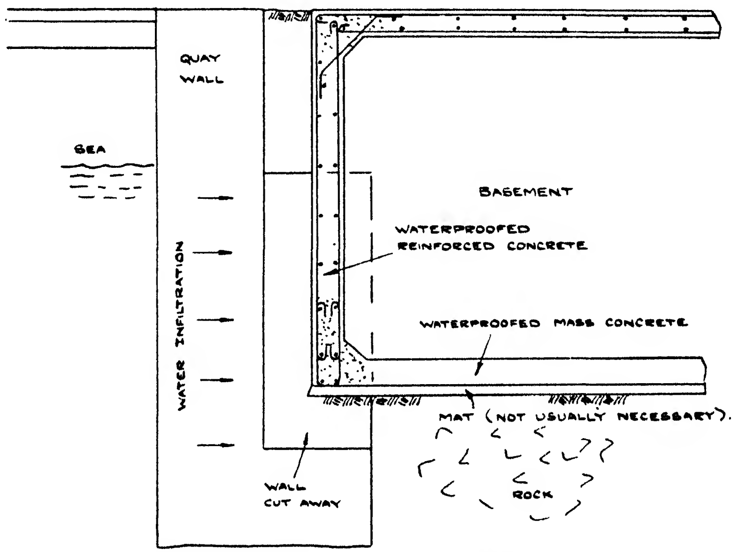


FIG. 15. TYPICAL BASEMENT ON ROCK WITH MASS CONCRETE WALL

be used. The floor should preferably be waterproofed throughout its full depth, but when the rock bed is fairly level the lower 4 in. should suffice for waterproofed concrete. The walls should be externally faced (Fig. 15).

4. Composite structure of mass or reinforced concrete floor together with brick or stone walls (the roof, of course, being in reinforced concrete). This method is not very suitable for large heads of water and should be used for damp conditions only (Fig. 16). In restricted sites, it is not possible to put on an external cement waterproofed rendering. The rendering in this case has to be internal. It is necessary to waterproof all walls, whether of

concrete brick or masonry, if below ground level, unless extremely dry conditions occur and there is a permanent prospect of no water collecting at the site.

When new waterproofed concrete is laid on an existing floor surface it is essential to provide sub-surface drainage to the floor. To achieve this it is necessary to hack chases in the top of the old

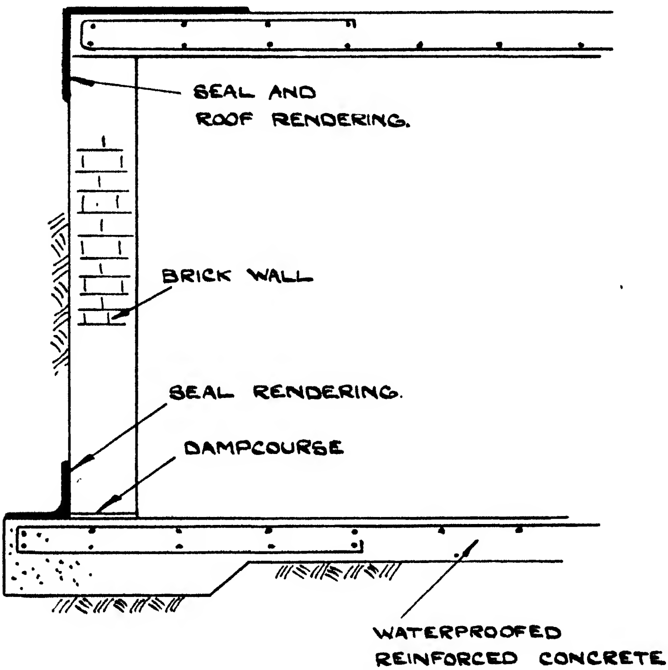


FIG. 16. COMPOSITE BASEMENT SUITABLE FOR DAMPNESS ONLY

concrete. The chases should not be less than 4 in. deep with a cross chase leading into the sump. Porous concrete pipes or agricultural drains surrounded with stone of ½ in. to 1½ in. grading are necessary. When no sump is provided internally, the chases should extend through the basement walls and connect with drainage channels and pipes leading to the external sump (Fig. 17).

In existing basement waterproofing it is highly essential to ensure continuity of construction. The preliminary step is to clear the room of all plant and to disconnect all piping. On replacing these items precautions must be taken not to crack the floor and wall surface by dead load or radiant heat. Asbestos sheeting around boilers is a wise precaution against heat and timber, or concrete pads should be provided to withstand the dead load. Under no circumstances should the new work be pierced. Brickwork forms a

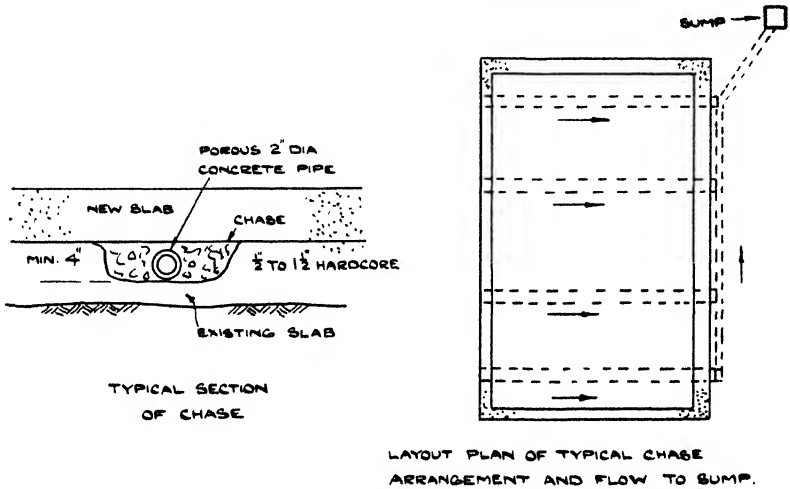


Fig. 17. Drainage to New Slab Superimposed on Existing Concrete by Means of Chases

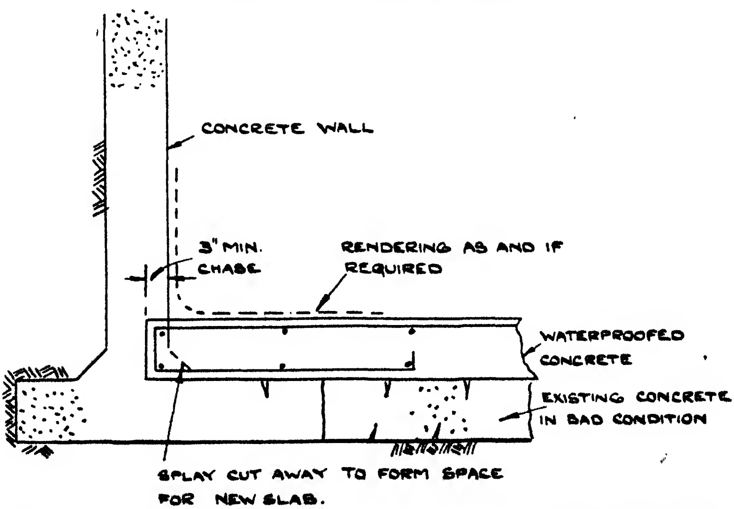


Fig. 18. Typical Superimposed Reinforced Concrete Raft Designed for Water Pressure

very good key to a cement rendering, but plain stonework does not. All sharp corners should be chamfered for rendering, whilst internal angles are coved.

All old concrete surfaces should be well hacked or chipped and swilled with clean water before new concrete is placed. Vertical chases all round the existing brick or concrete walls are necessary in order to provide an adequate seal and are frequently a means of ensuring a reaction against hydrostatic pressure (Fig. 18).

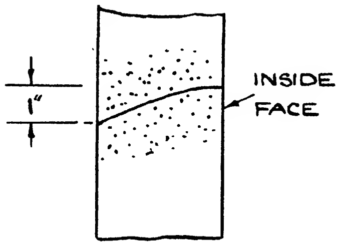
ROOFS

The waterproofing of roofs with integral waterproofers follows very closely that of floor construction. New roofs can be provided with waterproofed cement included or a waterproofing admixture to the mix. Old roofs can also be waterproofed by the addition of a top rendering (see Chapter V).

Roofs waterproofed by an admixture to the concrete mix, or by waterproofed cement, are constructed in the usual way. Where the roof is thick, as for air-raid precautions, only the upper portion of the roof need be waterproofed. To ensure complete uniformity of adhesion between the bottom layer of non-waterproofed concrete and the top layer of waterproofed concrete, the latter should be laid within two or three hours after the laying of the bottom concrete. Construction joints cannot always be avoided and these lead to trouble unless great precautions are undertaken. This gives the surface waterproofer an advantage over the integral waterproofer, since with the adoption of the former the number of joints do not matter. Top screeds are also good, but are not so positive or yielding as surface waterproofers such as membranes or bituminous compounds.

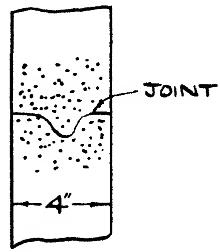
WALLS

Since walls are the portion of a building which is mostly exposed to driving rain and creeping dampness from the foundation, it is necessary to procure the maximum impermeability possible with the available materials and labour. Whether waterproofing cement or an admixture is used or not, it is vitally necessary to provide efficient joints. The importance of this point cannot be too strongly emphasized. The troubles ensuring from poor horizontal wall joints will occur after a considerable period. Weathering at each joint should be provided. One method is shown in Fig. 19. The rain has to drive up-hill to gain access into the structure. Fig. 20 shows another method of making a horizontal joint. The Vee shown can be easily made by hand. This is suitable for thin walls. An alternative is to place precast blocks in the top of the new concrete,



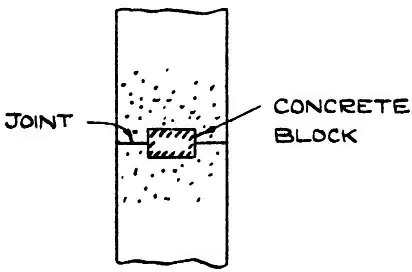
SECTION OF WALL.

Fig. 19. Weathering at Horizontal Joint in Wall



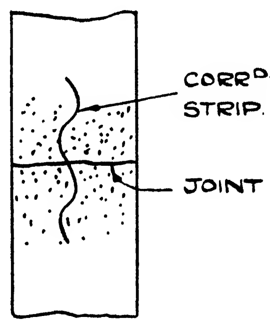
SECTION OF WALL.

Fig. 20. Vee Joint in Narrow Wall



SECTION OF WALL

Fig. 21. Placing of Concrete Blocks at Joint



SECTION OF WALL

Fig. 22. Concrete Wall with Corrugated Wrought-iron Strip at Joint

half the blocks projecting above the concrete (Fig. 21). These are, however, easily forgotten, and require extra hand operations. Corrugated wrought iron strips or strip sheeting can be used for walls as well as for the top of foundations.

All laitance and dirt must be cleaned off before new construction commences. Wire brushing, water under pressure from a hose pipe or other means should be employed to clean the old joint, and due care is necessary to ensure that the ensuing lift of shuttering should be tight to avoid loss of water and cement and thus consequent stoniness, if not bulging.

The number of construction joints should be kept to the bare minimum, since these are future weak places in the structure and may give trouble unless carefully constructed. Thick walls for economical reasons need not be constructed for their full width in waterproofed concrete. Fig. 23 is an illustration of the method of using only a facing of waterproofed concrete from 3 in. to 4 in. thick. Walls of thickness greater than 11 in. or 12 in. can be economically provided with an inside shutter. This is usually placed on the inside face of the reinforcement and withdrawn as concreting progresses, in order to obtain mixing of the adjoining concrete before the initial set occurs and to form a waterproof key. The removal of the shutter immediately after tamping or vibration has ceased, permits the waterproofed and non-waterproofed concretes to coalesce freely and form a homogeneous wall. The non-waterproofed concrete need not be of the same strength as the waterproofed portion, if the wall is not reinforced and has to withstand substantial load. Only such strength as is necessary for flexural or direct load reasons is necessary. It is advisable to use a very well-graded mix for the facing concrete to ensure maximum impermeability.

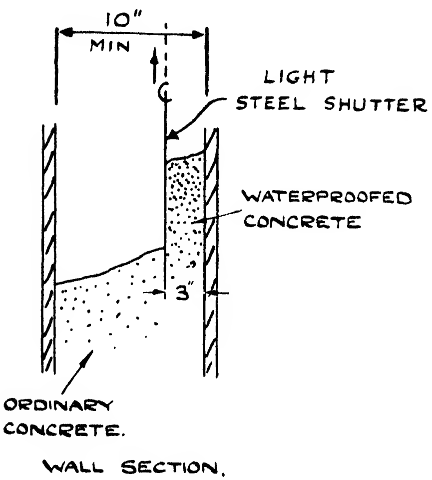


FIG. 23. USE OF A MOVABLE SHUTTER TO PROVIDE A WATERPROOF WALL FACE

Such facings to retaining walls and wing walls of bridges would greatly enhance their appearance, besides increasing the waterproofing capabilities of the members. A facing of waterproofed concrete is considerably brighter and has a better appearance—resembling stonework far more than unwaterproofed cement does. Fig. 24 denotes a derivation from the method of waterproofing thick walls. This illustration shows the method applied to a wing wall of a bridge with the coping waterproofed in addition to the front face. It frequently happens that disintegration of wing and retaining walls occurs at the top coating. This portion of the wall is subjected to greater atmospheric variation than any other part of the wall. Once the coping is in a bad condition of deterioration,

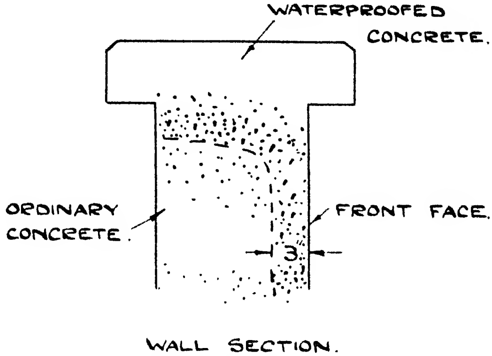


FIG. 24. WATERPROOFING OF WALL COPING

weather conditions can easily attack the top of the wall and complete disintegration may follow as a result.

RAFTS

These are always necessary for subsurface structures or for structures at ground level. The design is dependent on the structure and the bearing pressure and hydrostatic head of water. Rafts of plain concrete are thick and uneconomical. For new work the raft can be monolithic with the walls or independent of the latter which may consist of brick or masonry. The raft is designed and constructed to resist ground and hydrostatic pressure which tend to produce bursting of the floor. Reinforcement is necessarily mainly in the top of the raft and if the basement is a monolithic structure relief of the top raft tension is obtained from the rigidity of the walls. It is advantageous to form a splay between the footing and raft to provide gradual variation in stress from the footing to the raft. (Fig. 25.) It will be essential to provide a rendering to both the top of the raft and the external surface of the brickwork.

For cases of brickwork walls on existing floors which are not considered structurally adequate, or where the site contains water of variable pressure it is sometimes necessary to provide an extra slab on top of the existing floor. The former should be designed to withstand fully all possible hydrostatic pressure, which will be imposed on the new slab owing to percolation or water issuing from cracks in the old slab.

It is generally sufficient to provide 3 in. or 4 in. of wall bearing to the new slab.

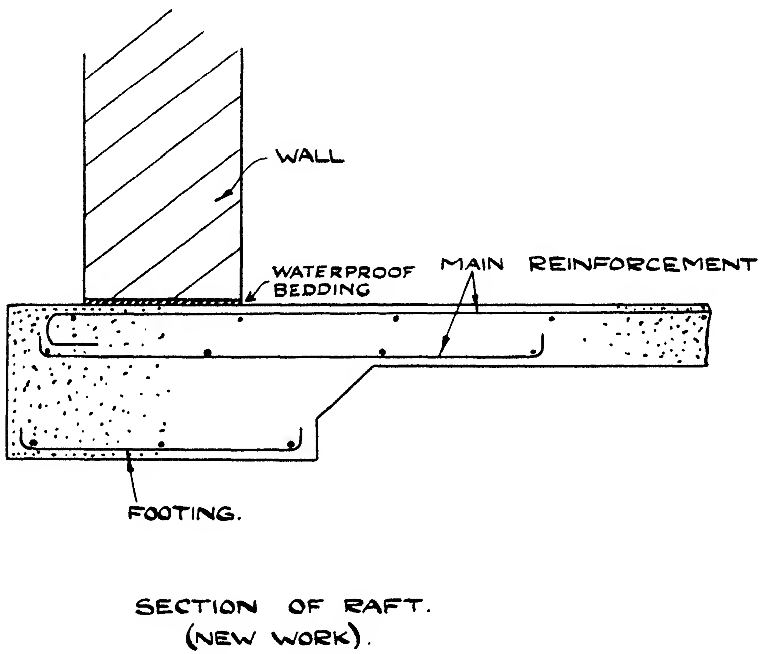


Fig. 25. Typical Raft Designed for Water Pressure

Figs. 26, 27 and 28 give thicknesses of raft and reinforcement required for different water pressures. In such cases, it is preferable to anchor the slab all round by cutting the chase in the complete perimeter of the bearing walls. This also facilitates the obtaining of impermeability. The stresses used are 18,000 and 750 for mild steel in tension and concrete in compression respectively. Since bearing is developed all round the slab the reinforcement is considered as spanning in two directions. This is a more economical design than one-way reinforcement. The slab is assumed to be simply supported on all sides. Thus, all the reinforcement is placed in the top of the slab. To waterproof completely the basement in this case, it is necessary to lay a rendering, before the slab is

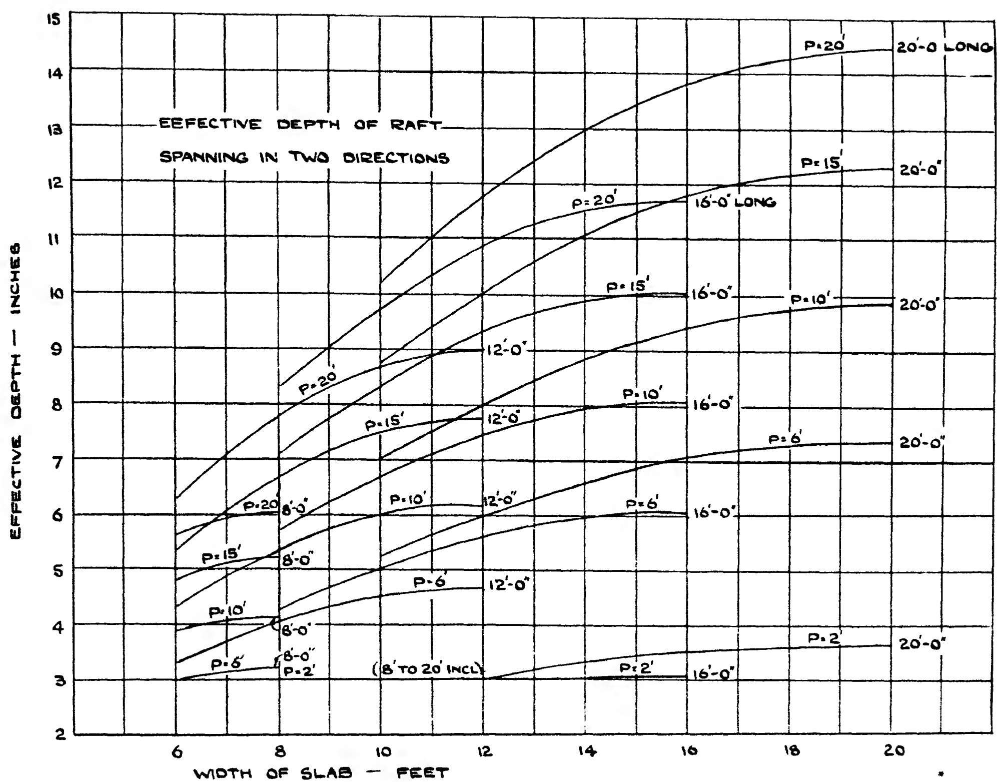


FIG. 26. REQUIRED THICKNESS OF REINFORCED CONCRETE RAFTS SPANNING IN BOTH DIRECTIONS

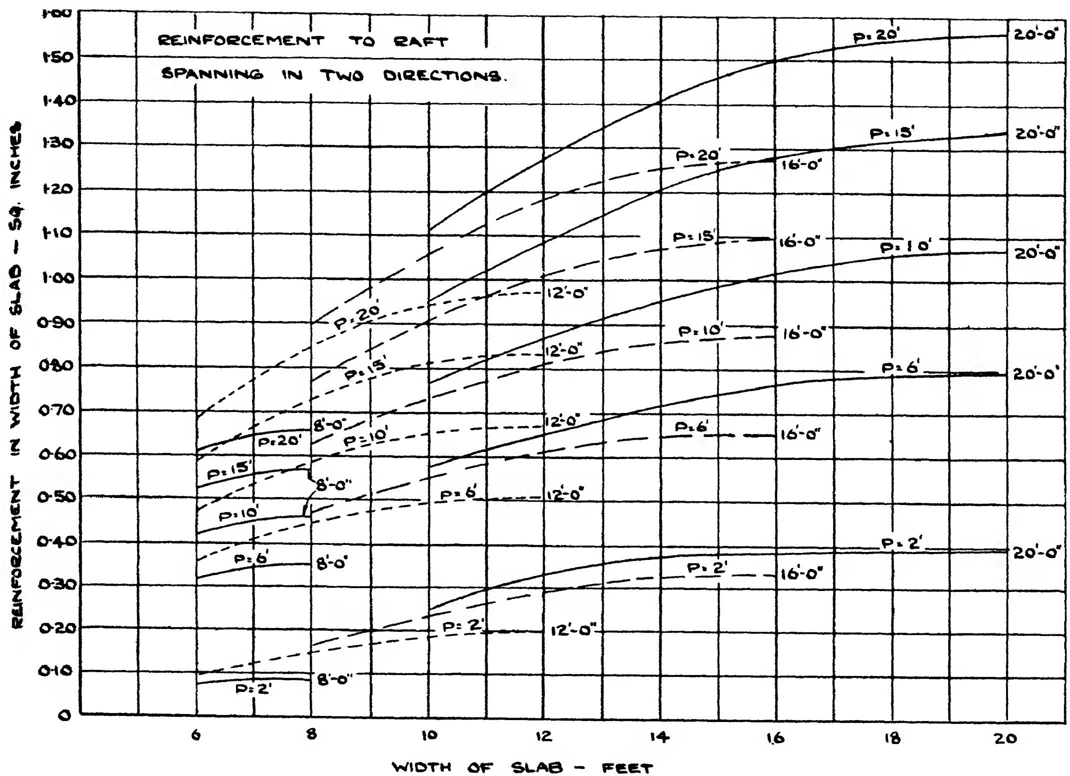


Fig. 27. Steel Reinforcement Required in Width of Rafts

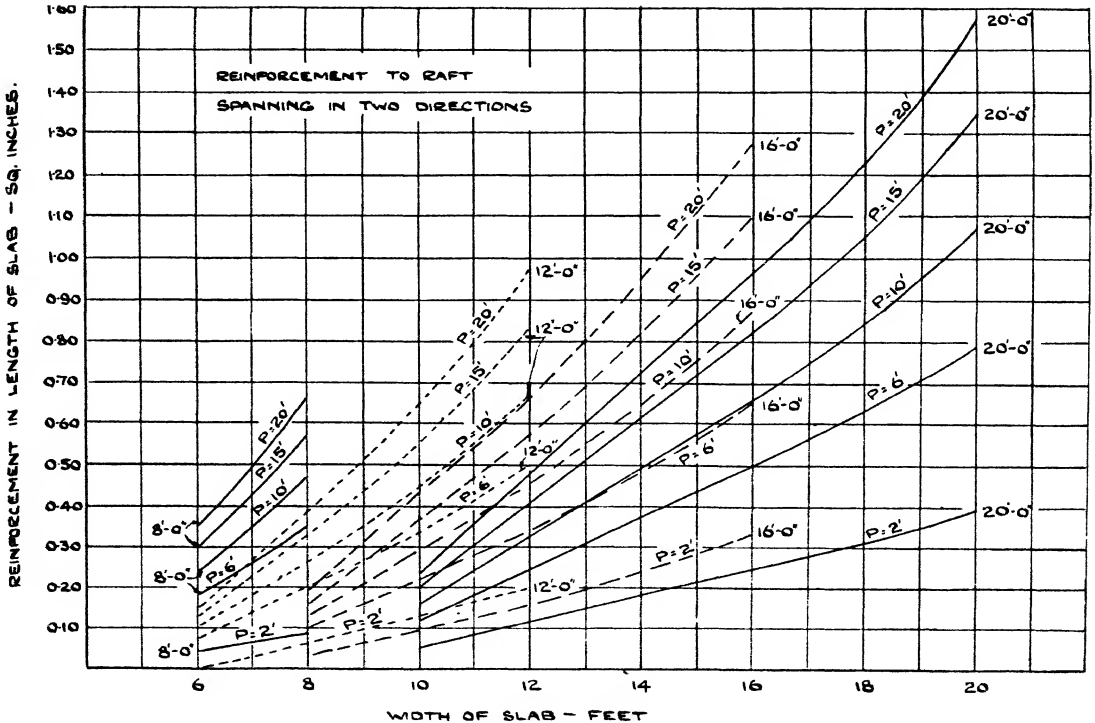


FIG. 28. STEEL REINFORCEMENT REQUIRED IN LENGTH OF RAFTS

EXAMPLE

Slab effective length = 16 ft. Slab effective width = 13 ft. Water pressure P = ft. head. Result—Effective slab thickness = 5·8 in. (Make slab 7 in. thick). Reinforcement—In length of slab = 0·41 sq. in. In width of slab = 0·63 sq. in. (per ft. width of slab in each case).

completely set. This is detailed in Chapter V, where renderings are dealt with (Fig. 18).

FACINGS

Modern reinforced concrete construction has not improved in appearance. Precautions with regard to finishing which were taken fifteen to twenty years ago have not been applied as rigidly as they ought. Keen competition has ruled out these very necessary aids to more durable finish, and the need for economy in view of slump trade conditions has not improved this state. Modern methods are often very slap-dash.

The use of a richer facing mix is an expedient that fully justifies the extra cost (Fig. 24). The facing mix should be of the plasticity of putty. After the movable shutter is raised, the coarser mix works forward, but does not smother the facing mix. Another excellent finishing is to take back the heavy aggregate from the mould face, thus allowing the matrix to work to the front. Vertical joints show a good appearance if cut at the surface at the correct distance and slight bush hammering of the face produced. By this means, the shutter board marks are completely deleted.

MIXINGS

These amounts of admixtures vary, but the following is a very good mean of the requirements for different types of work—

For surfaces not subject to heavy water pressure, 4 lb. per cwt. cement.
Mass walls requiring damp proofing, 2 lb. per cwt. cement.
For thin walls holding back high heads of water, 6 lb. per cwt. cement.

Costs range considerably. An admixture may cost from one shilling to two shillings per pound. The additional cost of water-proof cement may be from eight to ten shillings per cubic yard for a 1 : 2 : 3 mix. Similarly a 1 : 3 rendering ½ in. thick may cost from two to three shillings per square yard.

WATER-STOPPING

This is generally one of two types: (*a*) from a single crack or outlet hole, (*b*) from several points in a surface.

Type (*a*) is the simplest to deal with. Fig. 29 shows a vertical section of a wall subjected to water pressure, through which water has started to percolate through a crack. Since this appears at only one point in the wall, the main outlet is naturally the crack itself. The crack is enlarged to approximately 1 in. to 1½ in. diameter, and from 2 in. to 2½ in. deep. An inward taper is provided on the hole (Fig. 30). Large diameter holes may require two or more sealing operations. Neat cement and a fast-setting admixture should be used, just stiff enough to roll into a cigar-shaped plug. This is

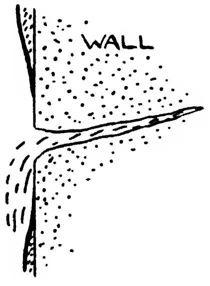


FIG. 29. POINT OF INFILTRATION

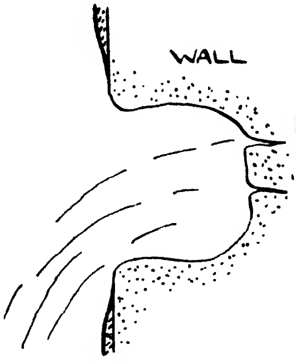


FIG. 30. HOLE CUT IN FACE OF CONCRETE

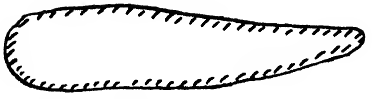


FIG. 31. SHAPE OF WATERPROOFING PLUGS

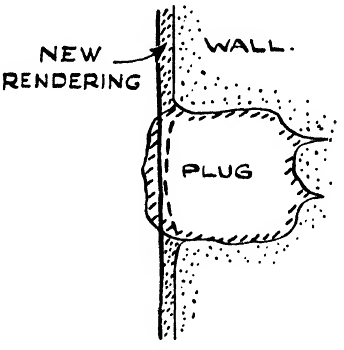


FIG. 32. WALL PLUGGED

thrust into the hole and well rammed into position, and held there until it has set quite hard. The plug is pointed off over the initial rendering (if any) (Figs. 31 and 32).

Where several leaks are encountered, it is necessary to provide an initial rendering in the area of the leakage, the aim being to drive the water into a central area where holes should be cut to concentrate the infiltration. These final few holes should be dealt with as described above.

CHAPTER V

WATERPROOF RENDERINGS

It frequently occurs that integral waterproofing cannot be applied because of site requirements or because it is preferred to adopt other measures. These may be either internal or external, depending on circumstances. Renderings on new construction can be external, but for work which has been constructed previously waterproofing repairs by rendering are usually undertaken as internal work. Renderings may be applied to both walls and floors.

WALLS

Wall renderings should be thin and consist of coats of from ¼ in. to ⅜ in. A greater thickness of coating is impracticable owing to the plasticity of the material which would slump down the wall before setting could occur. An uneven surface would ensue which would be not only unpleasing to the eye but detrimental for structural reasons.

Owing to the spreading of moisture caused by dampness or any vertical or horizontal surface, it is necessary to extend the limit of the rendering 2 ft. at least in each direction beyond the boundary of the dampness.

An inside rendering is frequently invalidated if there exists a cumulative head of water which can penetrate the external structural wall. The first consideration in basement waterproofing is to convey the surrounding water away by sump or other means to relieve the pressure on the walls. When the construction is a new one the placing of the rendering on the external face helps the coating to withstand the applied hydrostatic pressure without failing. It may occur that the floor drainage to the sump is not capable of withdrawing the water from the immediate site, in which case the best solution is to introduce an improvement in the drainage. Whilst being undesirable except as a last resort, it may be necessary to provide weep-holes in the wall for existing basements. The diameter and number of these holes depend on the quantity of water to be collected. Such holes can be drilled by a Rawlplug tool if small, or by a pneumatic drill for larger diameter. The pipes may conveniently be normal tubing of wrought iron, long enough to extend not less than 1 in. proud of the wall face. Large diameters are difficult to plug afterwards, hence it is advisable to restrict the diameter to about $\frac{5}{8}$ in. (Fig. 33). A quick-setting rendering is required for this purpose. When local bursts of water occur, a mixture of cement and sodium silicate of a stiff mix should be provided. If hot water is used the mixture will set in just over sixty seconds. A rendering can be applied over the bursts (see Figs. 29–32 inclusive).

Mass concrete walls of considerable thickness are preferably not waterproofed throughout. A rendering coat is far more economical, and probably more effective since the admixture does not react on the aggregate and frequently the mix used for mass walls is insufficient to produce waterproof conditions even with a good admixture. Moreover, when large lumps of stone are included in the aggregate, cavities are formed in the concrete which cannot be filled by means of the waterproofer. A 1-in. to $1\frac{1}{2}$-in. thick rendering in the proportion of one part of cement to three parts sand to which gauging water is added, with the correct proportion of admixture, will sustain the wall against permeability. It is well established that mass concrete sets in layers: it is of granular form—like timber—the grains not being visible to the naked eye. These layers are known as "soft seams," and are caused by gravitational segregation of the water, this taking with it in its downward path all loose particles of cement. These loose particles form the soft seams. Admixtures help to stop this occurrence. They thicken up the cement matrix, and, as mentioned in Chapter I, the resulting matrix is thicker and of greater consistency. The gauge water is not lost by evaporation and crystallization of the matrix develops as a result.

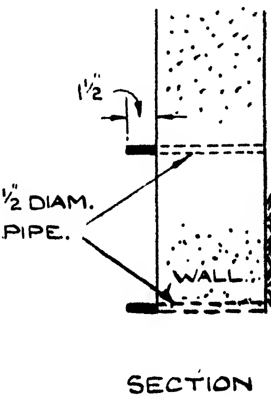


FIG. 33. METHOD OF LOCALIZING SEEPAGE BEHIND WATERLOGGED WALL

The initial procedure in rendering basement walls is to turn the water-table off the surrounding ground. This can be done by the well-point method if the soil is pervious, or if clay or other impermeable soil, it may be advantageous to use electrolytic means. Following this, the internal dry cement surfaces of the walls are dried and cleaned. The joints of the rendering must not be made at the angles. The angles should be splayed slightly as shown in Fig. 34. When a joint is made, this is produced at the wall face at 1 ft. from the angle. The joints in the second coat are preferably placed on the wall on the other side of the basement to that on which the first joint is made. The third joint is kept as far as possible away from the other joints (Fig. 34 shows a suitable staggering of joints). A thick grout of neat waterproof cement and

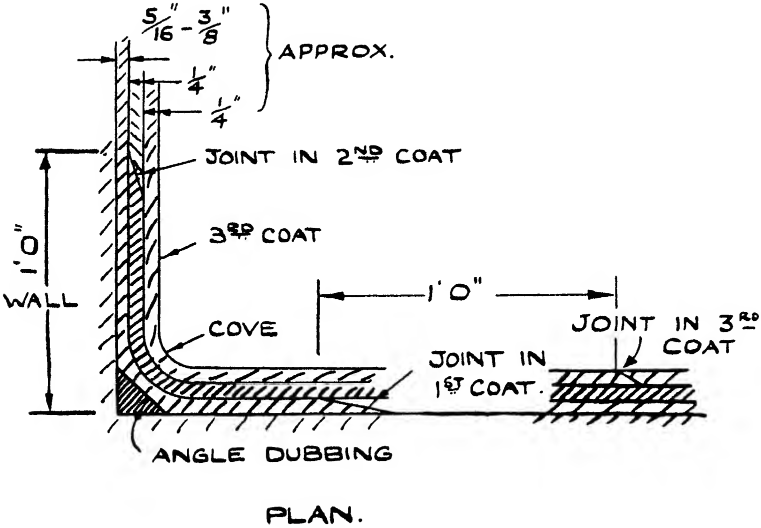


FIG. 34. TYPICAL METHOD OF RENDERING WALLS TO A BASEMENT

water should be applied immediately before the next section of a coat is started at a joint. The work is facilitated as in all inside face treatment by providing coves at all internal angles. Fig. 35 is a detail of a splay joint to a coating.

It is very essential to provide a good key to the ensuing coat. This can be obtained by abrasion of the undercoat.

Existing basements have usually to be internally waterproofed, and the floor and walls of the basement are then treated to a rendering which should not be thinner than ¾ in. thick nor, economically, any thicker than 1 in. Figs. 36 and 37 show renderings as applied to internal and external surfaces of basements respectively.

When the walls are porous it is necessary to slake these with clean water in addition to roughening the surface, whilst all dirt, distemper, varnish or paint should be scraped off the surface before roughening.

The surface should be roughened all over to provide the best possible key. The first coat of the rendering should be applied on a preliminary cement wash whilst the latter is still wet.

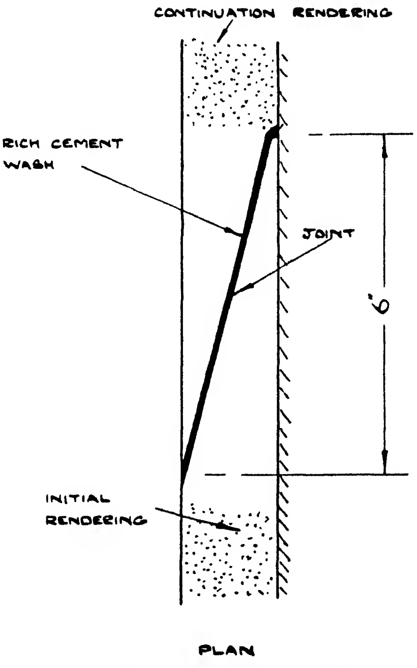


FIG. 35. TYPICAL DAYWORK JOINT IN WALL RENDERING

Stonework or brickwork is treated in a similar manner, the surface being roughened where it has worn smooth, and well watered.

FLOORS

Sometimes the point of infiltration is at the junction of a floor and wall. A chase is cut into the concrete at this point, and lined with quick-setting cement or neat Portland cement and silicate of

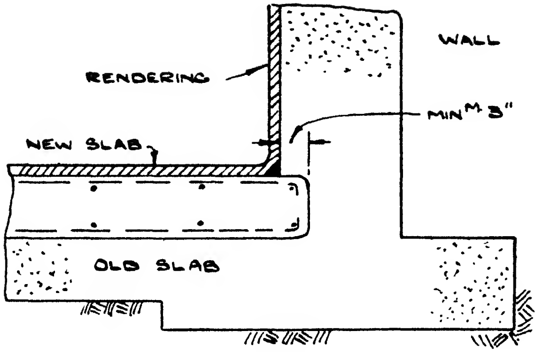


Fig. 36. Provision of New Raft to Existing Basement

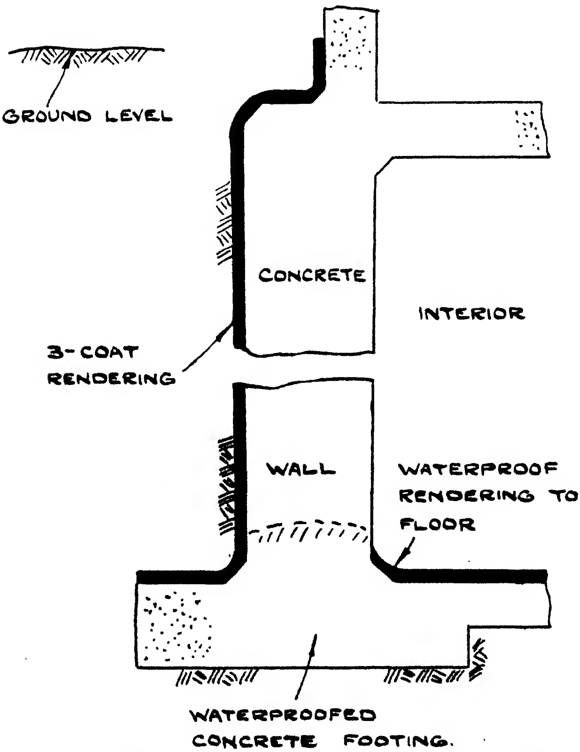


Fig. 37. A Method of Waterproofing a New Concrete Basement, Using External Rendering to Walls

soda to seal off the water. The chase is then filled with waterproofed mortar and finished to a cove surface. Thereupon the renderings are completed (Fig. 38). A normal concrete floor surface should be well brushed and cleaned before a thick wash of neat waterproofed cement is added. Whilst the wash is still wet, the waterproofed cement rendering should be laid over the whole floor in one operation without any joints. Flaunching to the floor

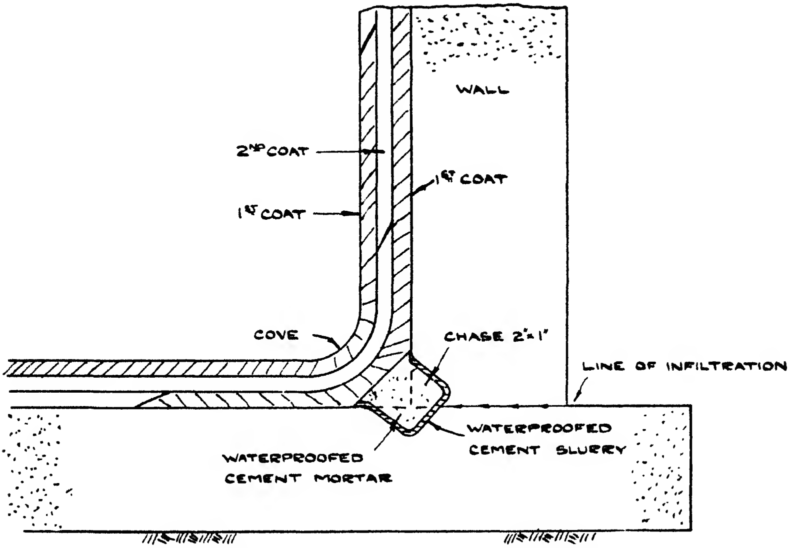


FIG. 38. WATERPROOFING AT ANGLE OF FLOOR AND WALL AGAINST INFILTRATION AT BASE OF WALL RENDERING

rendering is necessary where the latter meets the wall rendering. Fig. 39 shows advantage being taken of a corner splay. Before the application of the wall rendering, the surface of the channel should be coated with a good strong grout of waterproofed cement.

It is extremely necessary to ensure that no new work is laden with the hydrostatic conditions prevailing at the time, until the floor is strong enough to bear this load. To ensure this condition, the floor can be flooded inside the basement.

Floors for kitchens and sculleries are normally 3 in. to 4 in. thick. It is economical to provide only a top course of waterproofed concrete if the floor is large enough, otherwise the floor should be waterproofed throughout. One inch in thickness is laid directly on it. This topping may be a three to one mixture of graded sand-cement with the addition of an admixture (Fig. 40). If the full depth of the floor is waterproofed, the concrete should preferably have a $\frac{5}{8}$ in. to $\frac{3}{4}$ in. aggregate graded down to $\frac{1}{4}$ in., and the proportions should be 4 : 2 : 1 with the addition of an admixture. When floors have to withstand hard surface wear and where waterproof qualities are valuable, a 1-in. thick minimum waterproofed granolithic topping is provided instead of the 1-in. thick waterproofed mortar topping of Fig. 40. In this case the thickness of the bottom layer of concrete is reduced to 3 in. thickness (Fig. 41). The granolithic mix should be a 3 : $1\frac{1}{2}$: 1 mix, the granolithic aggregate not exceeding $\frac{3}{8}$ in.

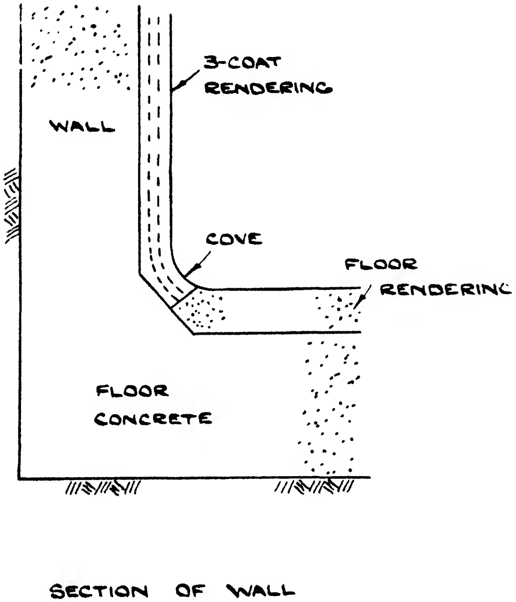


FIG. 39. DETAILS OF WALL-AND-FLOOR JOINT TO RENDERING

Defective dampcourses are a frequent source of trouble. However, it is exceptionally expensive to repair dampcourses in existing buildings, especially if the latter are buried.

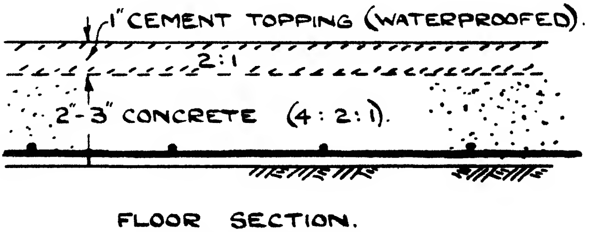


FIG. 40. TYPICAL WATERPROOFED KITCHEN FLOOR

An outside rendering has the advantage that it retains the whole thickness of the wall in a dry condition. But it is utterly a waste of time to apply an external rendering to a building that has a defective damp-course. In such cases it is essential to apply an internal rendering.

GENERAL

It is advantageous and usual to restrict the spreading of dampness and water percolation. The unwanted ingress of water in any form to public buildings of any kind, private houses or industrial concerns, is prejudicial for sanitary and health reasons. People cannot exist for any great period in damp surroundings without gaining from this insalutary environment some form of disease, whether rheumatism or some other more virulent complaint. Dampness is in itself a precursor of dirt and filth, since dust tends to cling to moist areas.

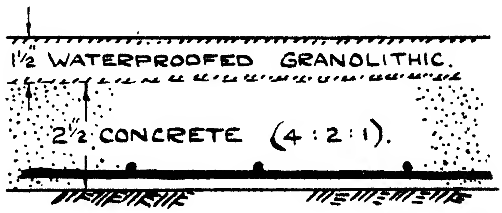


FIG. 41. HARD-WEARING DUSTPROOF KITCHEN FLOOR

It is difficult to understand why elaborate precautions are undertaken with the architectural features and general construction of buildings, yet frequently—and especially so with small buildings—no precautions are taken to keep out damp or water. It is expected that the contractor will produce a good enough concrete to obtain a damp-proof building, generally without being required to do so in the specification. It is not uncommon for repairs to cost considerable sums of money, not only in the repair itself but in the inconvenience caused.

CHAPTER VI

SPECIFICATION FOR WATERPROOFED CONCRETE

GENERAL CONCRETE SPECIFICATIONS

ALL normal precautions should be taken as with all concrete work. The following recommendations are a good guide to the correct proportioning of the waterproofed concrete.

Clean washed gravel, shingle, river ballast, granite chippings, broken flint limestone and whinstone are typically good examples of aggregate. Flakey aggregate containing mica or felspar and those containing ferrous material should be rejected.

Porous aggregates are entirely unsuitable for waterproofing work. In this class are included coke, brick, clinker, sandstone, etc. Broken bricks are entirely unfitted for this type of work for the same reason.

Aggregates should be clean and carefully graded from $\frac{1}{4}$ in. up to a maximum size which is decided by the thickness of the concrete in accordance with the following table—

For a thickness of	1 in.	use $\frac{1}{4}$ in.	down to	$\frac{1}{8}$ in.
do.	$1\frac{1}{2}$ in.	use $\frac{3}{8}$ in.	do.	$\frac{1}{8}$ in.
do.	2 in.	use $\frac{3}{8}$ in.	do.	$\frac{1}{8}$ in.
do.	3 in.	use $\frac{1}{2}$ in.	do.	$\frac{1}{4}$ in.
do.	4 in.	use $\frac{5}{8}$ in.	do.	$\frac{1}{4}$ in.
do.	5 in.	use $\frac{5}{8}$ in.	do.	$\frac{1}{4}$ in.
do.	6 in. to 9 in.	use $\frac{3}{4}$ in.	do.	$\frac{1}{4}$ in.
do.	9 in. to 12 in.	use $\frac{3}{4}$ in.	do.	$\frac{1}{4}$ in. (for external facing only)

The sand used in the formation of waterproofed renderings is of great importance. It should be clean, coarse-grained and well-graded, and should pass through a $\frac{1}{4}$ in. sieve; the minimum size retention should be fixed by adopting a 50×50 mesh sieve. A cement rendering should be well-balanced: a rendering consisting entirely of fine grains should not be allowed and if at all possible material from fine grains up to $\frac{1}{8}$ in. should be used. It may be necessary to use a fine and coarse sand together, mixed in correct proportion, since too fine a sand requires more cement owing to the excess voids. Fine sand renderings are usually not waterproof for this reason.

The sand should never be used in a dirty condition, should be free from organic or other soil impurities, and should not contain any trace of salts or iron. A brownish or bright red is usually an indication of the presence of iron impurity. Sea sand should only be tolerated if it is free from salt, not otherwise.

Mixes of 1 : 2 : 4; 1 : 1⅔ : 3⅓; 1 : 1½ : 3 and 1 : 1 : 2 are normal impervious mixes, but it is not wise to use a proportioning containing less cement per gauging than the first.

The water quantity should be strictly controlled, whilst the cement should not be less than that prescribed. Machine mixing of the main quantities is vitally necessary to obtain a controlled mix, and if an admixture is added, this should be placed in the main mixing in its original condition.

GROUT

For grout mixing, hand proportioning and mixing is inevitable. The integral waterproofer should be added to the cement. Thorough spreading of the former is necessary. Water should not be sluiced on to the mix but should first be sprinkled, then increased in quantity until the mix is just plastic when worked.

The final form of the grout as used for daywork joints or construction joints should be that of a liquid that will run into all interstices and reinforcement, thus providing a film of uniform and homogeneous thickness.

BASEMENTS

New slabs to be subjected to hydrostatic pressure if rendered on top have a mix of 1 : 1⅔ : 3⅓; or 1 : 2 : 3; or even 1 : 2 : 4 if the pressure head is to be very small. Slabs without a top rendering should be of a slightly stronger mix depending on the extent of the water pressure.

When a rendering is used, this should be applied within the initial set of the rendering mix and before the concrete is hard. 1 : 2 mix with Portland cement and coarse washed sand is very suitable. To this should be added the admixture. The coatings should be ¼ in. to ⅜ in. thick. A weaker rendering mix may be used, but the saving is small compared with the increased impermeability guaranteed by a 1 : 2 mix.

For new work, it is frequent to render the external surface of the walls to the basement. This rendering should be three-coat work not less than 1 in. thick. A 1 : 2 mix is suitable for this type of protection.

FIG. 42. WATERPROOF RESERVOIR COATED WITH A BITUMINOUS COMPOUND
(By courtesy of Inertol Co., Ltd.)

In all rendering work the foundation coat should be $\frac{3}{8}$ in. thick, and as in normal plaster work the surface should be worked to provide adhesion for the subsequent coat by lining the surface at $\frac{1}{2}$ in. to $\frac{5}{8}$ in. intervals, each line being from $\frac{1}{8}$ in. to $\frac{3}{16}$ in. deep.

Usually two days are allowed before a second coat is applied. If a third coat is to be applied, the second coat should be lined as for the first coat and after hardening for two days the third coat should be completed. Lining may be diagonal, waved or rectangular. When a waterproofed cement is adopted, the proportions of the rendering may be reduced in strength to 1 : 3. Generally for all internal tank or basement walls, the rendering may be $\frac{3}{4}$ in. thick. Where external rendering is applied, since this is subject to climatic conditions, a thickness of 1 in. is essential.

For floor renderings, a thickness of 1 in. minimum is usual practice and is generally necessary, especially where wear and tear is excessive.

When condensation has to be overcome a skimming of absorptive plaster is necessary.

Internal linings to reservoirs, swimming pools, tanks, etc., should always have a three-coat waterproofed rendering. When a granolithic facing is used for the floors of these and other structures, the proportions should be as follows—

2–1$\frac{3}{4}$ parts by volume of washed granite chippings ($\frac{1}{4}$ in. down);
1–$\frac{3}{4}$ parts by volume of washed sand;
1 part by volume of waterproofed cement.

UNDERWATER CONCRETE

Underwater concrete has certain characteristics of which the following are a few—

Concrete which is dropped by means of a tremie tube into deep water should have a continuous feed to provide a uniform flow of material.

It is desirable to produce increased plasticity in submarine concrete, and chemical constituents such as powdered silica and extra cement are used. The maximum quantity of silica to be used should not exceed 3 lb. to 4 lb. per cwt. of cement. The mix should never contain less that 6 cwt. of cement per cubic yard of concrete. For watertightness a waterproof cement is necessary, or a good integral waterproofer mixed with the batch.

For cool water below 55° F., it is an advantage to utilize a rapid-hardening cement. Alternatively an accelerator such as calcium chloride or silicate of soda can be added to the mix, which should be of a ready plasticity when mixed; it should never be dry. The bottom of the tremie should be submerged in the concrete during the whole process.

The aggregate should be carefully graded in order to reduce the number of voids to the very minimum. An aggregate of large size stone (1½ in.) down to ⅛ in. produces a concrete mass of excellent plasticity and strength.

Alternative methods to the tremie are the use of a drop-bottom bucket and jute bags. Drop-bottom buckets should be of the type that cannot be emptied until they rest on the concrete. The bucket should be completely filled and lowered and raised slowly.

Jute bags, when employed, should be half full of dry concrete. These are packed closely together, and form a solid mass, as the bags prevent the small ingredients of the concrete from being washed away.

EXTERNAL PAINTING

This consists generally of the application of liquids such as bituminous compounds (the composition of which is discussed in Chapter II).

The precautions to be observed are that the concrete should be dry and clean. Wet concrete will not form a suitable base, and it is necessary to dry the surface before any application of the compound is proceeded with. The method of drying-out in cases such as water tanks is to use braziers. In the case of sewers it may be preferable to dry the walls by an initial application of cloths followed up by heating of the walls by blow-lamps. In such a case, the painting should be undertaken immediately after the drying of the green concrete, which can be painted with very good results when the concrete is damp in the hardening process. The paint for this example should be chosen very carefully; a solution or emulsion is necessary that reacts favourably on the hardening of the concrete by protecting the latter against drying out, thus keeping it damp. This latter condition also prevents the rising of hair cracks. Another advantage is the good adhesion derived owing to the mixing water of the green concrete being gradually absorbed during the hardening process and because the coating is soaked to some extent into the pores of the concrete.

There are paints available which fulfil the above conditions and are very suitable for waterbearing structures such as reservoirs, tanks, and sewers, etc.

The glossy surface of most bituminous compounds is a great asset in sewer or channel construction, as the coefficient of friction between the water and the concrete is considerably reduced. The introduction of such waterproofers thereby reduces the pressure head of water lost which may be considerable in a length of line of several miles. Paints should resist the action of moist heat up to a reasonably high temperature of 160° F. to 190° F. and be practically insoluble in fat oils. A good paint will also withstand dry heat up to 350° F. to 400° F. provided the temperature rises gradually.

Paints are usually applied in two or three coats, the area of surface covered being dependent on the waterproofer. When the black colour is objectionable, the last coat of a bituminous paint can be sprinkled with dry sand, and after the surface has dried, a thin skim of cement mortar will completely mask the original colour. Otherwise certain colours can be obtained.

PROTECTION OF CONCRETE IN SEWAGE TREATMENT PLANTS

Sewage plants submit concrete to very rigorous conditions. The very aggressive salts and gases dissolved in sewage water attack even the best concrete. This is found to be especially the case when the concrete is new. It is therefore vitally necessary to provide an interposing medium between the concrete and the effluent. During the first few years of its life new concrete should be protected by a suitable coating, which will not only prevent grease and sewage from penetrating into the concrete, but will facilitate the cleansing of sludge from the concrete. This is especially important in all tanks used in the primary treatment of sewage.

It is beneficial that the coating should penetrate into the pores of the concrete and become a portion of the structure. The most suitable compound is not a penetrating liquid but one that penetrates only slightly into the pores, whilst the external position of the material provides an unbroken impermeable film. For very successful results, a three-coat application of a refined coal-tar paint should be utilized. The coats should consist of a penetrative primer and two finishing coats. When there is no abrasion, the primer can be omitted.

Above water, concrete is impaired by condensation, fumes and sewage spray. This severely taxes the whole of the exposed portion of the concrete with the great probability that the concrete will become rough and porous. Small cracks will lead to spalling. For these surfaces a black colour is not wanted. Only recently has this problem been solved, since oil paints are soon destroyed. New synthetic enamels should be used. These give satisfaction when applied properly. Many of the colours available are not suitable for sewage work : solid shades such as white, light green, red or aluminium are to be preferred. According to Dr. A. F. Pistor, of the Inertol Co. Inc., New York City, a simple test can be applied to prove the value of a coating—

Two coats of the clear base paint should be applied to three glass plates with twenty-four hours' drying time between coats. Seven days after the second coat has been applied, the coating on the first panel should be exposed to a 40 per cent sulphuric acid solution, the coating on the second panel to a 10 per cent hydrochloric acid solution, whilst the third panel should be subjected to a 5 per cent sodium hydroxide solution. The test should be made by placing a few drops of the corrosive liquid upon the painted surface of the glass plate. If no peeling, blistering, or other sign of deterioration has occurred at the conclusion of ten days, it may be considered that the tested coating is satisfactory for its purpose.

When painting new concrete, it is essential to have a dry and dust-free surface. Smooth surfaces should be etched before the paint application. Old concrete is thoroughly hosed down and wire-brushed. A solution of 1½ oz. of trisodium phosphate and 1½ oz. of soap chippings in a gallon of warm water will provide a suitable mixture that will remove all grease and render the concrete perfectly clean.

After the concrete surface has dried, the protective coating should be applied by brush or spray. When work is conducted in a closed tank, it is necessary to provide a means of drying the surface. Braziers will usually fulfil this requirement.

These precautions also apply to the application of coatings to all other types of concrete structures.

CHAPTER VII

GENERAL PROPERTIES OF MASTIC ASPHALTE

THE first examples of the use of mastic asphalte in this country were laid in 1837, the industry therefore being over a century old. Asphalte has become a very commonplace substance, and most townspeople quite unconsciously encounter different forms of mastic asphalte nearly every day. We have among other examples, mastic asphalte footpaths, roads, railway station platforms and booking halls, roofs of every description, yards, and foundations protected from subsoil water.

The sight of a cylindrical-shaped mixer containing a black viscous material with a pungent smell is quite familiar to most people who have to pass building sites. Very rarely does the casual observer note when and how this mastic is applied, nor does he know how the "cakes" with which the mixer is charged are made, or from where the raw materials come.

The asphalte contractor does not usually stay continuously on a contract during the complete course of its construction. He is usually present for waterproofing the foundations. Thereafter he generally leaves the site until the roofs require waterproofing. The use of mastic waterproofing has steadily increased owing to its well-recognized waterproofing qualities.

When it is remembered that ordinary bricks will absorb up to 20 per cent of their own weight in water, it is realized that unless all basements are protected by a sound method of waterproofing the construction of an underground (with water imposed) structure will be a gamble with the dice heavily loaded against dryness.

Mastic asphalte is generally the term used for the application of this material to buildings, although in appropriate form it can be used for road surfacing. Asphalte is a physical mixture of mineral aggregate and bitumen. In the U.S.A. "asphalt" is frequently used synonymously with "bitumen." "Asphalt" is spelt with or without a terminal "e," thus causing some confusion, not only to the layman but to the general building community too. The British Standards Institution has now standardized the spelling without a final "e." Another mistake which is frequently made is to associate bitumen or asphalte with coal-tar products; bitumen is allied to petroleum and has no direct connection with any distillate of coal. It follows that the use of the term asphalte to describe surfacings such as tar macadam is not correct.

There are three broad types of asphalte for building purposes, each depending on the nature of the raw materials used, and the purpose for which the asphalte is intended (see Table III). Two broad types of minerals are used in asphalte manufacture; one of these has bitumen present in association with the mineral, the second has not. Under the first heading comes the natural asphalte rock, and in the second an example is certain types of aggregates of a siliceous type which are employed when acid-resisting mastics are necessary.

The main rock asphalte deposits available to Great Britain are found in France, Switzerland and Sicily. The asphalte lake in Trinidad also provides a useful source of supply, and contains over 50 per cent of bitumen in association with very finely divided mineral matter.

Since hardening of the asphalte on cooling does not chemically change the original nature of the material, there is no risk of a loss of waterproofing ability from this cause.

The plasticity and ductile properties of asphalte are sufficient for it to conform to any normal movement of the structure. More rigid coatings may crack.

Owing to its inherent coefficient of friction, asphalte forms an ideal surface for foot traffic.

Asphalte has very little heat insulation value, but this can be considerably improved by placing a good insulating medium underneath it. Cork is a very efficient means of providing heat insulation.

Electrical insulation properties of asphalte are considerable, but where static electricity is undesirable, as in explosives magazines, it is necessary to use a special gritless conductive form of flooring.

Asphalte does damp sound, and this is a necessary property for such buildings as flats, hospitals, public buildings, etc.

ORIGIN AND COMPOSITION

The raw asphalte rock is a limestone, which has been permeated with bitumen by nature. The empty shell chambers of small organic organisms are filled by the bituminous infiltration. A good quality asphalte rock should have a fine grain and its particles should be intimately associated with bitumen. The bitumen content of good quality rocks varies from 6 per cent to 10 per cent, and the impregnation is of such a nature that the bitumen is able to combine freely with the added ingredients during the manufacturing processes. The initial operation in the manufacture of the mastic is to crush the coarse rock, and grind it to a fine powder. It is then mixed with an asphaltic cement in proportions varying with the character of the work for which it is required. Usually the rock is

FIG. 43. TYPICAL SCENE OF OPERATIONS IN GAINING ASPHALTE AT TRINIDAD LAKE, B.W.I.

imported from Europe, where it is mined. Lake asphalte contains a high proportion of bitumen associated with finely divided mineral matter, and in conjunction with an asphaltic flux comprises the "asphaltic cement." The main process of manufacture is that of intimate incorporation combined with the influence of heat.

The original method of use when the material was first introduced into this country, a century ago, was to add to the bituminous limestone enough bitumen to produce a mastic substance. A fixed proportion of fine grit was also added. This gave excellent results, and formed the basis from which the industry has grown. Improvements have since been made and the technical knowledge considerably advanced. Informed opinion is that, especially for roofing purposes, the presence of natural asphalte is necessary for the product to be enduring over a long period.

During the war progress has been made in the utilization of mastics in which certain selected grades of coal tar pitch have been substituted for bitumen, particularly for flooring purposes, and certain emergency British Standard Specifications have been drawn up.

Good quality asphalte has the material advantage that it is an ideal means of protecting porous materials. Brickwork or concrete

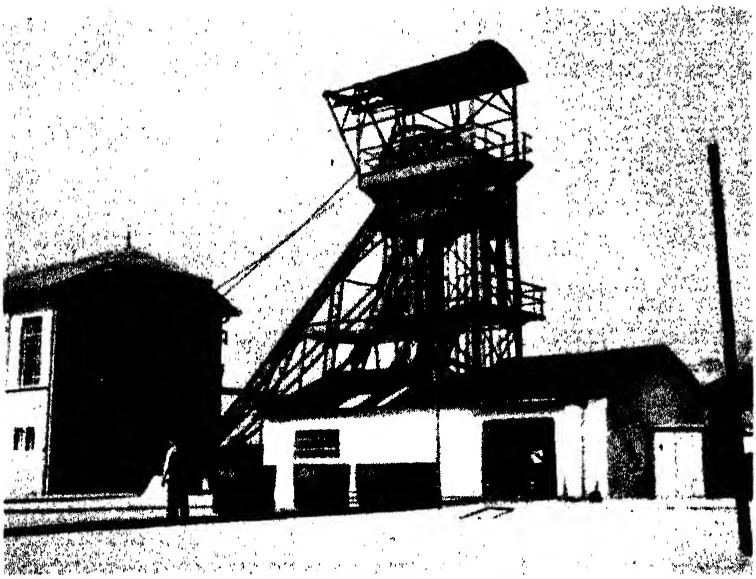


FIG. 44. DERRICK AND POWER-HOUSE AT THE MINE OF ST. JEAN DE MARUEJOLS, GARD, FRANCE

is generally porous or develops porosity in due course. Subsidence or other causes may develop cracks which are paths of ingress for any rainwater or damp that comes along. When jointed protective material is used, each joint is a source of weakness. Mastic asphalte if properly applied has no definable joints and is entirely monolithic. It has the property of welding together; if applied in two or more coats, the joints are made to overlap, and are staggered so that no two joints coincide. Asphalte is of a highly plastic nature and, in shrinking after hot application, does not crack. It takes but a short space of time to cool and hence to harden, and is a chemically inert material to the normal atmospheric conditions. Its plastic nature is of very great use in waterproofing materials which are lacking in rigidity or are liable to the formation of fissures due to settlement, such as may occur in coal-mining districts. Integral or rendering waterproofers, on the other hand, do not help to withstand cracking of the building material. The best results are derived when the asphalte is separated from the building material by an isolating medium. The use of a layer of sheathing felt which is not fixed to the foundation allows the structure to move or crack to some extent without damaging the asphalte. Such underlays are in

TABLE III

TYPES OF ASPHALTE

1.	Natural asphalte	+	Lake asphalte : asphaltic flux mixed with asphaltic cement	=	natural asphalte rock mastic with natural asphaltic cement.
	$(M + B)$		$(M + B) + F$		$(M + B)$
2.	Graded aggregate	+	Lake asphalte : asphaltic flux	=	mastic asphalte with natural asphaltic cement.
	M		$(M + B) + F$		$(M + B)$
3.	Graded aggregate	+	bitumen obtained from crude asphaltic oil	=	mastic asphalte with asphaltic bitumen cement.
	M		B		$(M + B)$

M = mineral matter
B = bitumen
F = asphaltic flux

general use at the present time. The use of underlays obviates water blisters which under damp conditions occur on the concrete when hot asphalte is laid on a non-dry surface.

MANUFACTURE

The rock is first crushed; thereafter the manufacture is one of mixing only, and is independent of chemical reactions. When all the ingredients have been completely mixed, the rock asphalte and asphaltic cement form a homogeneous cement. The siliceous grit is frequently obtained from beach deposits and should be carefully graded at the place of manufacture. Conversion of the raw materials into mastic asphalte, although essentially simple in character, is in fact a highly skilled operation, and calls for expert supervision and the use of considerable laboratory control under qualified chemists.

The addition of Trinidad Lake asphalte is considered a desirable ingredient for the best quality asphaltes, since this material has an influence in stabilizing the mixture.

Generally it can be said that asphalte is a natural or mechanical mixture of asphaltic bitumen with mineral matter. Sometimes, as an alternative, bitumen derived from crude asphaltic oil is combined with specially graded aggregate such as limestone. The result is a plastic, voidless mass, which can be laid when hot in a fluid state. Usually, for building work, the aggregate is smaller than for road surfacing, whilst the properties and proportions of the components differ.

APPLICATION OF ASPHALTE

The applications of asphalte for waterproofing or other surfacing purposes is a highly skilled trade, and the use of asphalte is extremely varied. The following gives some indication of the scope of asphalte in its application to building or road surfacing—

1. **Damp-proofing.** Asphalte is applied horizontally and vertically as damp-courses, joined by connecting asphalte fillets.

2. **Waterproofing.** By external and internal application in three coats to buildings subjected to water pressure with the protection of a skin wall of concrete or brickwork. This is known as "Tanking."

3. **Roofing.** Roofing of concrete, timber, etc., on all kinds of buildings. Frequently this work incorporates details such as skirtings, gutters, gulleys, fascias, cornices and balconies.

4. **Linings.** Three-coat internal lining to water-bearing structures such as reservoirs, swimming-pools and baths, water-towers, culverts, water-tanks.

Tanks containing hot water and other liquids including corrosive acids, etc., at normal temperature. Special acid-resisting grades are needed in such cases. Low temperature storage.

5. **Flooring.** Industrial buildings, especially where a dust-free surface is necessary.

For certain purposes must be acid-resisting and resist high temperatures.

Also used as an underlay to other floor finishes. Can be coloured.

6. **Yard Protection.** Frequently used in areas, courtyards, dock wharves platforms, terraces, etc.

7. **Other Applications.** Various, including road surfacings, jointing of concrete and metal pipes, electrical insulation, air-raid shelters, and in buildings for the manufacture of explosives.

The technical precautions required to produce good asphalte are utterly wasted if the handling and heating of the material at the site are carelessly undertaken. If the blocks are allowed to become dirty, e.g. caked with clay or earth, the resultant asphalte is deteriorated, whilst overheating of the mass will produce charring. This burnt material will find its way into the product as laid and impair the impermeability of the coating. Overheating also produces a

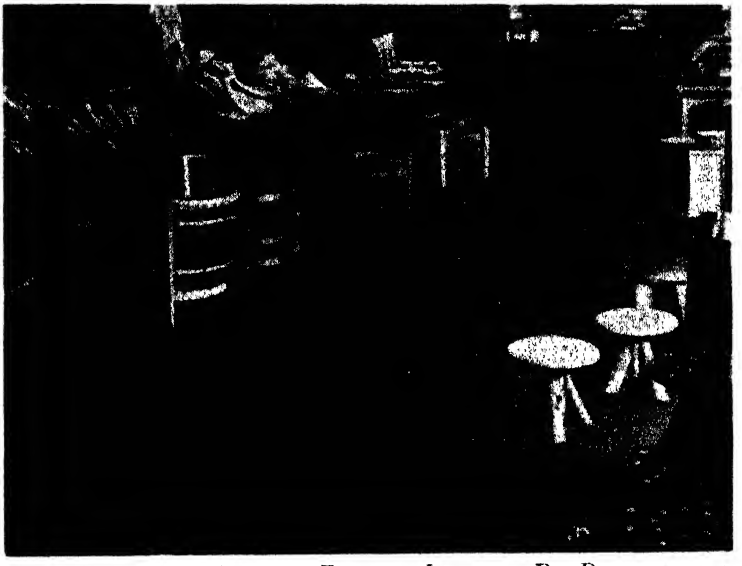


FIG. 45. COLOURED ASPHALTE FLOORING LAID IN A BIG DEPARTMENTAL STORE IN LONDON

deterioration in the quality of the material. It is highly important to bring the asphalte to the right temperature whilst it is being constantly stirred to provide equal consistency, otherwise the heavier particles will fall to the bottom of the mixer. The experience of the spreader and potman derived over a period of several years' apprenticeship is the best guide to satisfactory work. It is also an advantage where possible to use mechanically agitated mixers.

It is essential that to ensure good waterproofing qualities considerable attention should be paid to the design of the structure. Asphalte should be laid on an adequate foundation, whilst extreme care should be taken with the finishing details, such as provision for skirtings, tuck-ins, etc.

Unsatisfactory construction is a great handicap to successful waterproofing. Wherever possible, surfaces should be finished to a screed, whilst all dampness should be dried out.

Asphalte is used extensively for the flooring of factories, dairies, breweries, etc., whilst for special purposes, such as the floors of explosive houses and magazines, a special form of gritless asphalte is adopted to overcome the risk of friction underfoot causing a spark. Cold Storage depots use asphalte in the refrigeration rooms.

When heavy wear is anticipated, such as pavings generally, and for traffic on private road surfaces, a coarser form of asphalte is adopted. This occurs in such locations as railway loading yards, or dairies, where heavy milk churns have to be moved about. To overcome the difficulty of providing an asphalte surface that will not mark or deform under heavy concentrated loads, it may be desirable to increase the thickness, to reinforce the asphalte by placing a steel mesh in position before asphalting is commenced, and also sometimes to increase the percentage of added coarse aggregate.

One of the main advantages of asphalte flooring is that it can be placed to a uniformly level surface even if the top of the under-surface is far from level. This is specially suitable for old, worn floors whether of concrete or not.

Asphalte can now be obtained in different colours, such as red, green, brown or grey, the colour being a permanent and even feature of the asphalte. This has applications in many types of public buildings, cafés, cinemas, etc. Not only is coloured asphalte permanently attractive, but it loses none of its durability because of the colouring treatment. By mixing coloured marble chippings with the asphalte during manufacture an excellently durable floor is obtained, which, when the surface is ground, provides an exceptionally attractive finish, especially if coloured.

Asphalte is not always used as a finishing surface. It may be used as a damp-proof underlay. On top of the coat of asphalte (which may be ½ in. to ¾ in. thick) is laid the final surface. This may be blocks, rubber, or linoleum.

CHAPTER VIII

THE APPLICATION OF MASTIC WATERPROOFERS

GENERAL

ASPHALTE in its variety of uses has a range embracing roof covering, tanking, damp-proofing, flooring, damp-coursing and linings.

As a roof covering, asphalte has the great advantage that it accommodates itself to a wide range of temperatures by its property of plastic flow. Flat roof construction is exceptionally common,

FIG. 46. ILLUSTRATION OF COVERING OF CURVED ROOF SURFACE WITH MASTIC ASPHALTE

inasmuch as the flat surface provides an extra floor which can be used for recreational purposes, and the heat insulation of the flat roofs is considerably simpler than that of pitched roofs. Uncovered concrete roofs are not generally waterproof and are liable to cracking, because of either temperature variation or subsidence with or without lateral movement of the building itself, whilst asphalte is a suitable surface for foot traffic.

As asphalte has the property of clinging securely to vertical or steeply sloped surfaces, it can be employed on sloping and vertical sections of roofs such as mansard roofs. These are a frequent occurrence in cities where local regulations impose limits of height and shape to the upper stories. Pitched roofs are easily waterproofed by means of asphalte, whilst the valleys and gutters are efficiently treated in a monolithic covering. The very nature of asphalte and

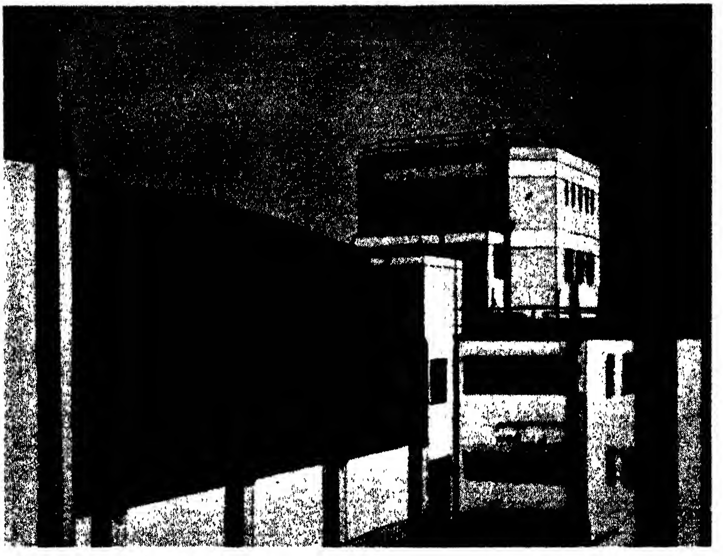


FIG. 47. ILLUSTRATION OF VERTICAL AND VERY STEEPLY SLOPING ROOF WORK IN MASTIC ASPHALTE

its plasticity make it suitable for unusual shapes such as domes or any other type of curved roof surface.

Where projections occur in any type of roof these are very easily treated by asphalting, which can be taken round the projections with internal angle fillets allowing continuous incorporation of local asphalting over the projections as the latter occur. Dressing of ventilation pipes, lantern lights, louvres, etc., can be completed round to form a waterproof protection above rainwater level.

Asphalte has a wide application in basement work, where water pressure is often encountered. Generally it is preferable to adopt a skin wall on which to lay the vertical asphalte layers. Where water pressure exists, careful measures have to be taken to ensure that the surface to be waterproofed is kept dry, whilst it is very essential that the asphalte is relieved of point loads and supported against hydraulic pressure by the laying of what is known as a loading slab.

Other uses of asphalte, such as damp-coursing of walls and parapets, are very necessary in brick structures. Damp-proofing should be undertaken only when water pressure or soil pressure is absent.

Vertical damp-proofing is normally executed to a minimum thickness of $\frac{3}{4}$ in., whilst horizontal damp-proofing in three coats is laid to a thickness of not less than $1\frac{1}{8}$ in. Where there is any doubt at all about the general surroundings or conditions imposed on a structure, it should be given three coats of asphalte. If this is not done, the cost of making good the depredations of damp on a wet site will usually be far more exorbitant than the cost of an extra coat of asphalte. To obtain the best results with asphalte it is necessary to produce a satisfactory surface; the skill of the building contractor varies considerably on different jobs, mainly because of different levels of labour standards and variations in supervising qualities and technique.

TANKING

This is the term used to denote complete waterproofing work which is buried underground or is subjected to natural hydraulic pressure. The object is completely to surround with asphalte the structure waterproofed, so that no ingress or infiltration of water to the inside of the building is possible. When measures of waterproofing are under consideration for a building whose foundation will be subjected to a head of water, it should be borne in mind that pressures of fairly large magnitude are often built up even in ground that is not exceptionally wet. Local conditions such as the height above the foundation of surrounding ground, the distance from site of any watercourse, and the porosity or permeability of the subsoil affect the waterproofing measures required.

Hydraulic pressure is an exacting taskmaster on foundation pressure. Not only must the basement walls, floor and roof be designed to withstand the imposed water pressure, but complete security from water ingress can only be achieved by taking special precautions with the waterproofing. Further, if the pressure is not relieved or reduced on the waterproofing by interposing a wall between the subsoil and the structure, and unless the relieving wall is itself impervious to water, it follows that when the asphalte is applied to a wall the waterproofing material also receives the full water head against the building.

Tanking, and in fact all sub-surface vertical waterproofing, is more advantageously undertaken if a skin wall is built before the asphalte is executed. The methods of waterproofing to a typical

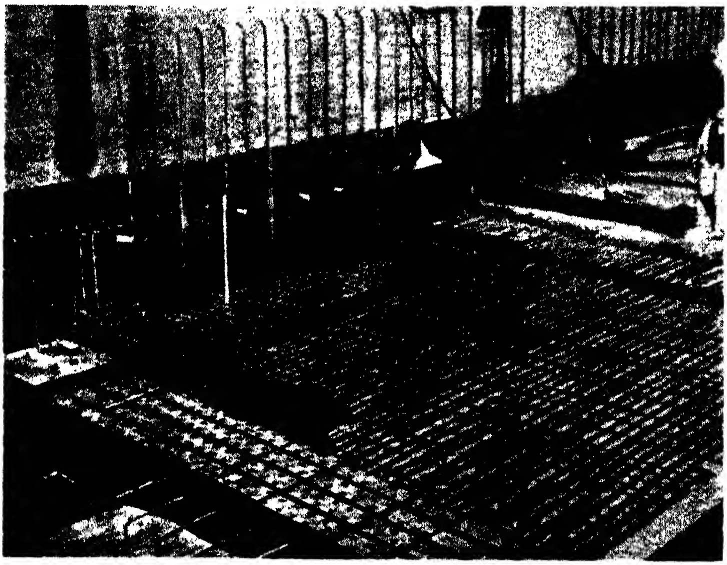


FIG. 48. THREE-COAT ASPHALTE TANKING IN BASEMENT

rectangular basement differ according to the methods used in the general building construction. One method is to build the structural wall first and the asphalte on the outside afterwards. The disadvantage of this method is that the asphalte is exposed to the excavation side and the removal of shutters may cause accidental damage to the asphalte layers, unless they are protected. Where the basements adjoin a main thoroughfare, this method is impossible (Fig. 49).

The use of a skin wall on the inside of the structural wall, as shown in Fig. 50, is adequate when low water pressures are encountered. Water pressures behind the asphalte enforce pressure on to the inner skin wall. It is advisable to put light reinforcement on the inside face of the latter, but even this precaution is not sufficient to allow the use of this method under exacting water conditions. The most economical procedure is to erect a skin wall all round on the outside, before the structural wall is started. The asphalte should be laid up the skin wall, after which the inner basement wall is completed. This is the only recognized means of waterproofing in restricted street sites. Fig. 51 shows this method of waterproofing.

At least two feet must be provided in working space for asphalting. For exceptionally deep excavations, more working space is required.

When the outer skin wall is of brickwork, and the joints cemented so that a plain face is prepared for the asphalte layers, it is not possible to ensure that no air spaces are left between the asphalte and the inner wall brickwork. For brick skin walls the foregoing method is quite suitable, but when the main wall is of brickwork this method is not to be recommended because of the previously mentioned reason. In all cases, the spaces of brickwork joints should be completely filled, wherever possible. To ensure successful treatment of brick structural walls with an outer skin wall, it is necessary to ensure that the inner wall is well grouted so that no voids occur (Fig. 52).

The floors to waterproofed basements are rendered impervious to water by similar measures. As the water pressure is upward it is usual to lay a lean concrete mat before the asphalting is undertaken, the asphalte tanking being covered, as executed, by the application of the structural slab (Fig. 53). This is general for considerable water pressure and when the direction of the water thrust is upwards. When only light water pressure is anticipated—such that the reverse bending moments caused by the hydraulic head do not exceed the structural bending moments caused by the dead and live loads of the basement on the floor slab—a light loading slab can be laid on top of the asphalte which in turn is laid on top of the main slab (Fig. 54).

In such a process considerable care must be used to provide a reasonably level surface for the asphalte. Further, all dirt must be cleaned off the top of the concrete before applying the mastic coatings. The concrete surface must in all cases be bone dry, otherwise "blows" will occur.

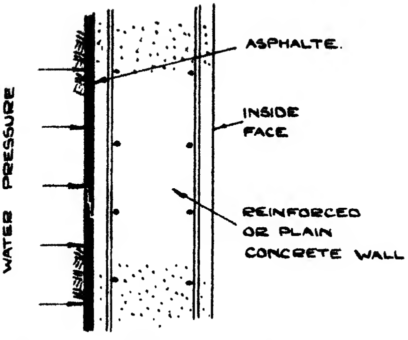


Fig. 49. Asphalte Laid Directly on to External Face of Concrete Wall

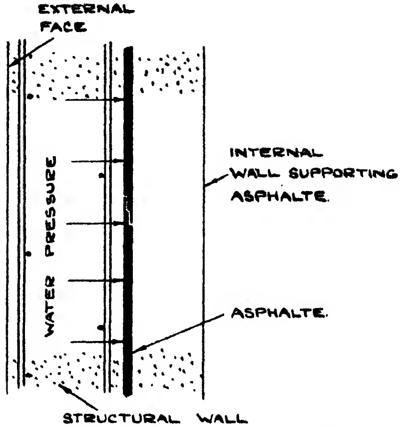


Fig. 50. Provision of Inside Wall Supporting Asphalte Against Water Pressure

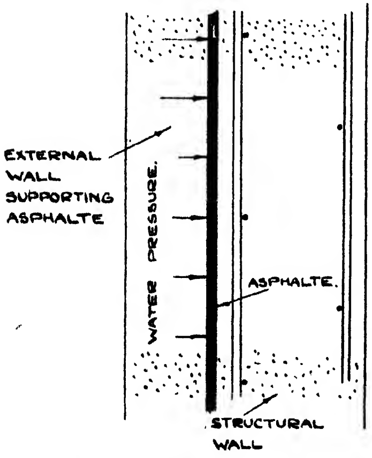


Fig. 51. Provision of External Supporting Wall for Asphalte

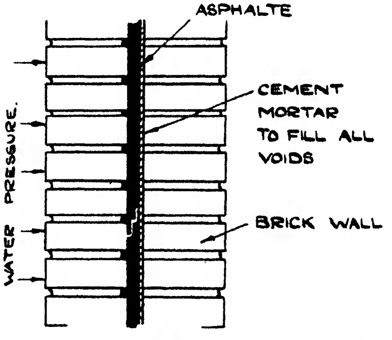


Fig. 52. Treatment of Brick Wall Built Against Asphalte

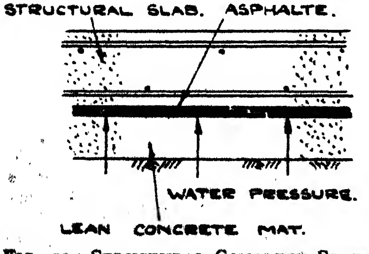


Fig. 53. Structural Concrete Slab Forming Loading Slab

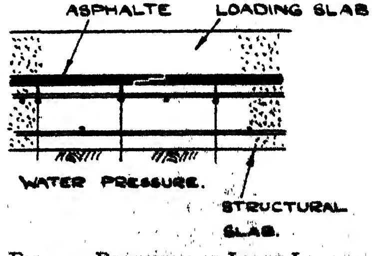


Fig. 54. Provision of Light Loading Slab Over Asphalte

When reinforcement is laid on top of asphalte for the construction of the main slab, great care should be taken that no damage is incurred by the asphalte as a result of the weight of the reinforce-

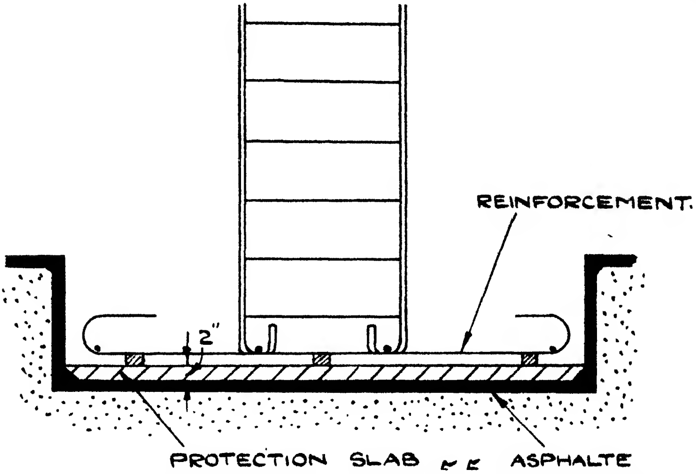


FIG. 55. PROVISION OF PROTECTION SLAB UNDER REINFORCEMENT

ment, which in some heavily loaded slabs is considerable. Good judgment should be used, and where the rods are of considerable diameter and closely spaced it is preferable to lay a mat of lean concrete $1\frac{1}{2}$ in. to 2 in. thick on top of the asphalte previous to fixing the steel reinforcement (Fig. 55). The latter can then be laid directly on to the top of the mat with the minimum of cover. This precaution is especially necessary when column footings are asphalted. The weight of the vertical rods is otherwise directly imposed as point loads on to the asphalte, causing penetration of the mastic at least, if nothing more serious.

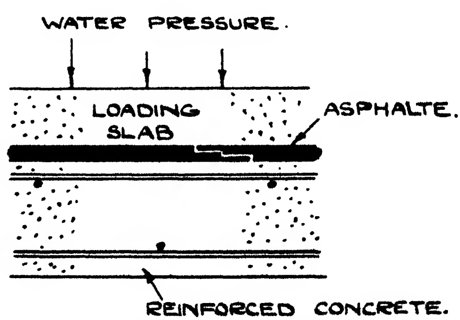


FIG. 56. PROVISION OF LOADING SLAB TO SWIMMING POOL

In the waterproofing of swimming-pools and baths, the water pressure is downward on the floor. If the asphalte is laid on top of the reinforced concrete slab, then support to the mastic is completely guaranteed. A protecting slab, some 2 in. to 3 in. thick, can be provided, forming a base for the setting of the tiling or the painting of the pool bottom as the case may be (Fig. 56).

When swimming-pools are constructed with a tiled finish they can be waterproofed in three different ways. Those recommended by the R.I.B.A. for tiled finishes, and a fourth method which is

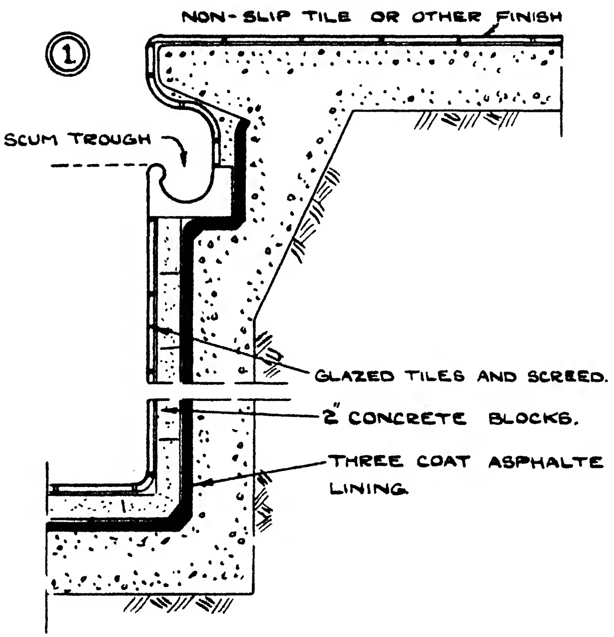


FIG. 57. POOL WITH 2-IN. CONCRETE BLOCKS USED AS A PROTECTION OVER THE ASPHALTE

applicable to either and is approved by the N.A.M.M.C., are as follows—

1. Glazed tiles on a screed over a layer of concrete blocks placed on asphalte.

2. Glazed bricks or tiles on a screed laid on asphalte.

3. Glazed tile lining on a screed over concrete blocks placed on asphalte with a tiled floor laid on weak concrete laid *in situ* on asphalte.

4. Glazed tiles on a screed placed directly on to asphalte.

When a swimming-pool is to be waterproofed it is always preferable to place the asphalte on the main construction floor and walls, which always should be monolithic. Generally, reinforced concrete is considered the best construction for swimming-pools. Frequently in open-air pools, the finish to the bottom of a pool is completed in cement rendering. This is not a satisfactory finish,

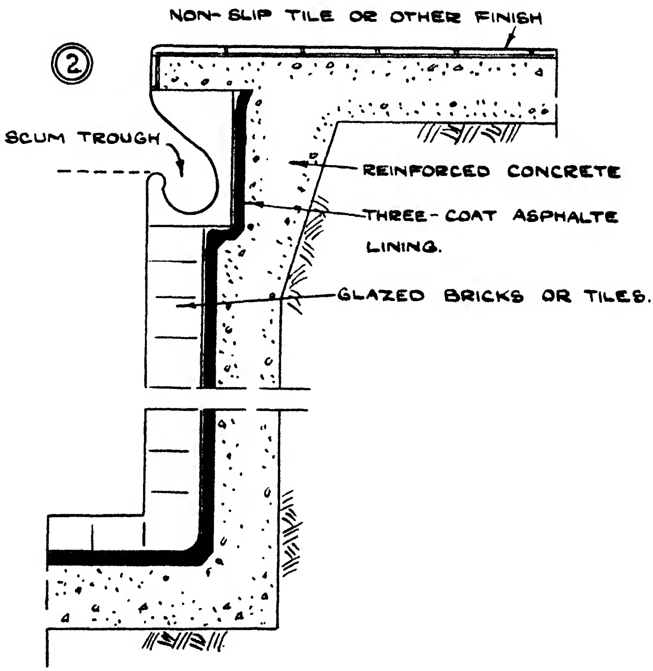


FIG. 58. POOL WITH GLAZED BRICKS USED AS A PROTECTION OVER THE ASPHALTE

and does not have such a good appearance as tile, nor is it as hygienic.

1. Concrete blocks are normally of 2 in. in width, and can be laid directly on to the asphalte lining in this case. The tiling is placed on a thin screeding. The foregoing applies to both floor and walls (Fig. 57).

2. In this case the finish can be a glazed brick or tile over the asphalte for both the floor and walls (Fig. 58).

3. This construction and treatment is suitable when the space

beneath the surround is to be utilized and a separate scum-trough is not provided. The surround can be constructed in weak concrete 2 in. to 3 in. thick on top of the asphalte, which should be carried over the space to be used. Two-inch thick concrete blocks are placed on to the asphalte. The finish consists of a screed upon which are placed glazed tiles. An alternative to a concrete block floor is to

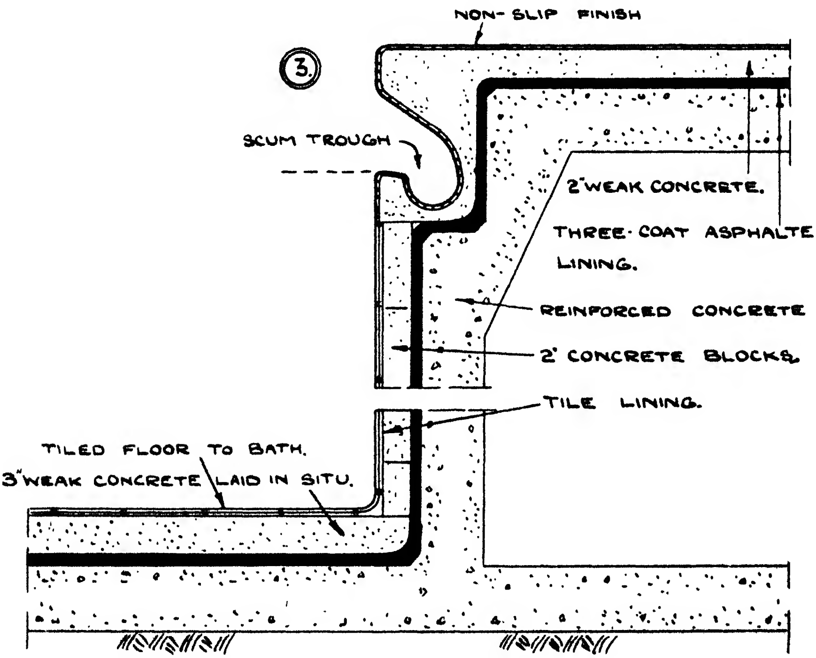


FIG. 59. ALTERNATIVE FINISH TO FLOOR OF SWIMMING POOL

provide a layer of weak concrete on the asphalte. This is completed with glazed tiling (Fig. 59).

4. When the tiling is applied directly on to the asphalte lining it is necessary to leave horizontal grooves in the asphalte. This forms a key on to the asphalte for the tiling. The grooves can be chamfered recesses made by embedding patent rubber strips in the asphalte while warm. These are subsequently removed before the screed is placed. It is essential in all cases to provide a three-coat dressing of asphalte, and, owing to the reduction in thickness at

the grooves, unless a three-coat application of asphalte is made, insufficient thickness is obtained (Fig. 60).

In all cases in tanking work double angle fillets should be used at all angles. To achieve this end, the angles should be carefully arrised by the building contractor.

A feature of good swimming-pool construction is to ensure sufficient fall to the surround so that any drainage water cannot

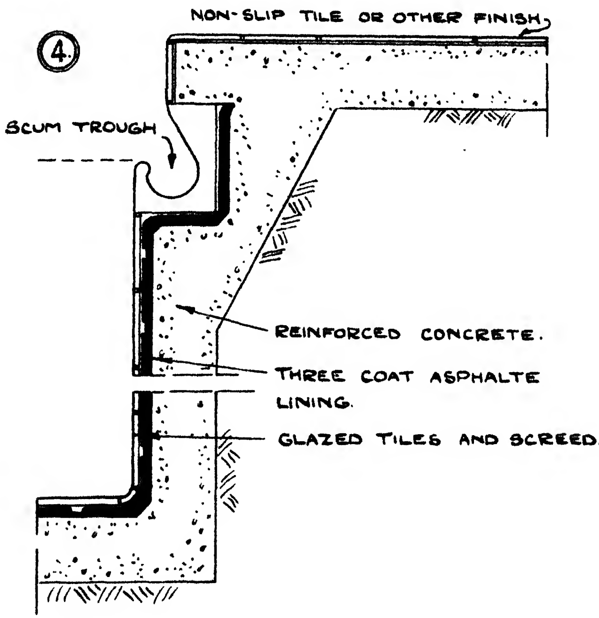


FIG. 60. USE OF GLAZED TILES OVER ASPHALTE IN SWIMMING POOL

flow back into the bath. Surface channels should be provided some distance away from the pool itself.

For the finished surface to the pool, glazed tiles containing alumdum or corborundum or having grooved back faces are necessary and are easily obtainable. The cleaning of these tiles is very simple.

When a loading slab is used, the slab itself should be designed to withstand water pressure, if it is to form a relief to the asphalte; otherwise the latter takes the pressure which in turn is countered by the resistance of the structural slab.

Wherever possible, at all side corners and junctions of walls and floors, splays should be provided to the concrete, since the addition of these renders the structure more rigid at the corners and reduces the rapid change of section from floor to walls, consequently rendering the variation in stress of a more even nature.

The roofs of basements are not generally waterproofed, but when a structure is buried below ground and has an earth fill covering above the roof, if it is highly desirable to render the complete

FIG. 61. LINING OF STANCHION PITS WITH THREE COATS OF ASPHALTE MASTIC

Note reinforced concrete loading coat below grillage over asphalte.

structure entirely insulated against water pressure, the tanking should be carried over the top of the roof and over the remainder of the ancillary parts to the structure, such as entrance tunnels, doorways, etc., where these occur under cover of the soil. Such a case is shown in Fig. 62 of a pump-house to a petrol-filling station. The pump-house is completely buried and the entrance tunnel protrudes out of the earth. Sumps included in the building are also waterproofed completely. Complete protection is highly necessary in a case of this kind, where electric power cables enter the building, and where important electrical gear is housed.

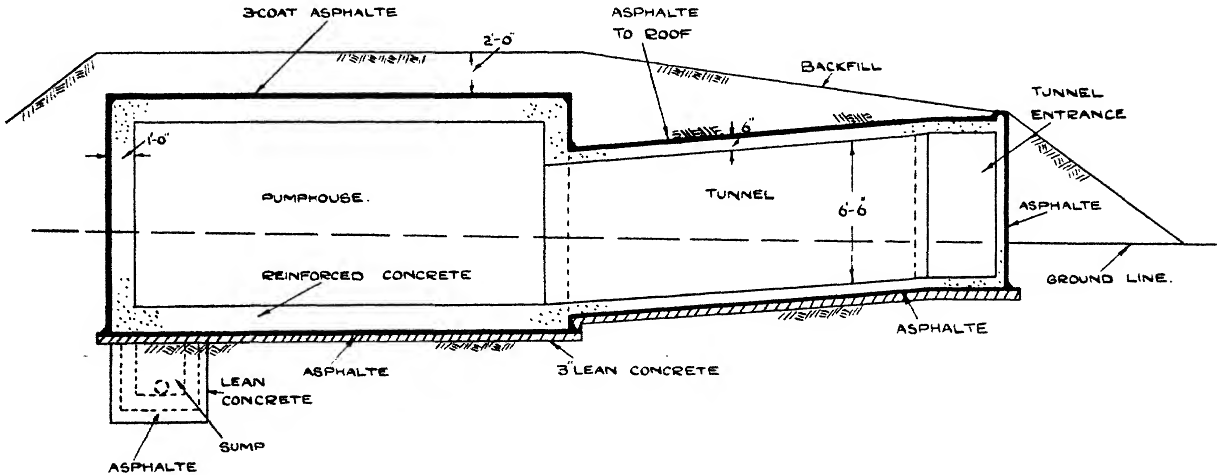


FIG. 62. TYPICAL WATERPROOFING TO BURIED STRUCTURE

It is well known that water pressure at any given point is exerted equally in all directions. It follows that the walls, floors and roof of a structure imposed upon by water pressure should be carefully and skilfully designed to resist the full pressure expected, according to the depth below the maximum height of water. This is in addition to the earth pressure. If it is borne in mind that a height of water of 20 ft.—by no means uncommon—will produce a

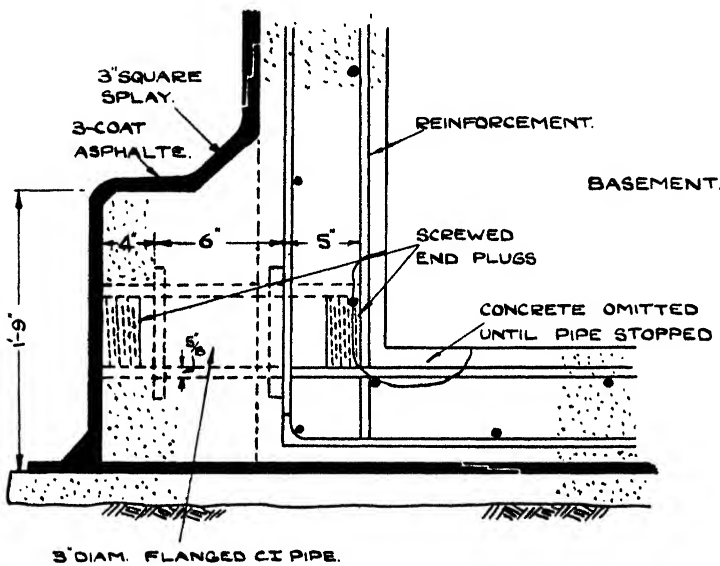


FIG. 63. C.I. VALVE TO PREVENT FLOTATION OF REINFORCED CONCRETE BY WATER PRESSURE

pressure of 1247 lb. per square foot, the serious nature of water pressure will be realized.

One of the most prevalent dangers in waterlogged ground is the risk of flotation of the basement, tank or pool during construction, due to the dead weight of the partly-built structure not being able to overcome the buoyancy caused by the pressure of water. Countermeasures usually take the form of providing an outside toe to the floor slab which can be partly backfilled before the wall is more than one lift of shuttering high. This is not a good method and hampers the subsequent tanking. A better method is to load the floor slab down by means of concrete blocks dispersed along the surface of the floor. When the site is severely restricted, the extending of the floor slabs to provide a toe is not practicable. When the work is tidal and when the main structural walls are to be undertaken before the asphalting is started, a sounder method than either of the above is to provide holes for the ingress of water to the tank or basement. With the receding of the tide the basement is left dry and work can be commenced on the structure. This method has the disadvantage that it is subject to tidal conditions and a full working day in the basement can rarely be obtained.

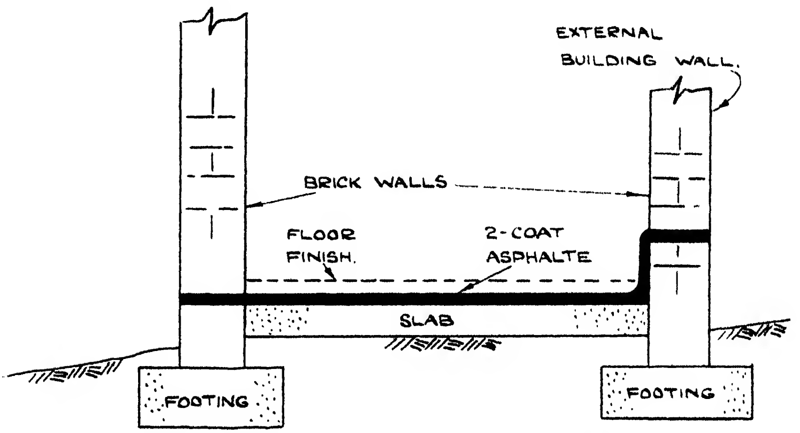


FIG. 64. COMBINED DAMP-PROOF COURSE AND PAVING CARRIED THROUGH WALLS AT DIFFERENT LEVELS TO FORM D.P.C.

When the work is completed and it is required that the access of the tide be cut off, the holes are closed and the asphalte "made good" at these positions.

The type of valve used at the holes can be a cast-iron pipe of 3 in. to 4 in. diameter, slightly longer than the width of the wall. Puddle flanges should be provided, whilst the ends should be screwed internally; the holes are stopped by inserting screwed stoppers on both sides of the pipe. Where the pipes occur, the concrete should be thickened locally. The asphalte is carried up, after sealing, over the external face of the pipe. Fig. 63 shows a typical example used in a grain silo in the Great Western Docks, Plymouth, built in 1941.

Generally the above references have been to structures of reinforced concrete, but similar methods apply to brick-built structures.

DAMP-PROOFING

The asphalte work is the same in principle for both tanking and damp-proofing. With damp-proofing, however, there is no need to provide structural precautions against the water pressure. A typical case is the frequent one in which the ground floor and walls of a building have to be protected against rising damp. The asphalte

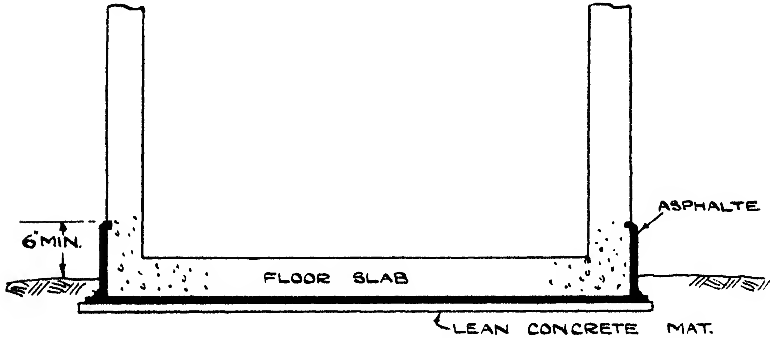


FIG. 65. DAMP COURSING TO SMALL CONCRETE BUILDING AT GROUND LEVEL

is laid over the slab. If the walls are of brick, it may be advisable to take the asphalte up the inside face of the brickwork, and then through the wall (Fig. 64) to form a damp course. When the building is of concrete floor and wall construction it is probably simplest to provide the damp-proofing as shown in Fig. 65. The

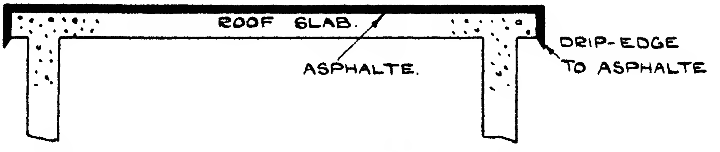


FIG. 66. PROVISION OF DRIP EDGES AND SKIRTING TO ROOF OF A SMALL CONCRETE BUILDING

asphalte can be laid on a mat of lean concrete. When the building slab and walls are completed, the asphalte is taken up the outside of the walls for a distance of not less than 6 in. above the ground level outside.

When small roofs have to be protected against the penetration of rain, it is advisable to provide a cornice to the slab. The asphalte is then taken over the edge of the cornice and a skirting and drip-edge formed (Fig. 66).

When an asphalte layer is laid on the ground, a reasonably good surface must be provided. For this purpose, a 3 in. thick mat of lean concrete should be used. No thinner mat should be allowed, since breakage of the concrete will probably cause damage to the asphalte layer on top of it.

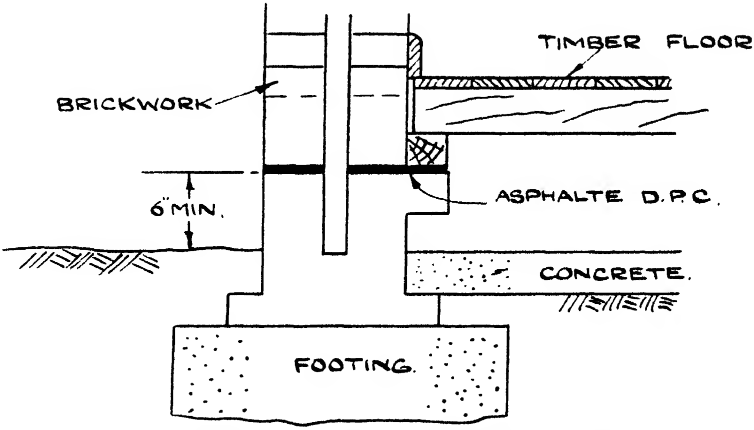


FIG. 67. PLACING OF A D.P.C. IN RELATION TO A TIMBER JOIST FLOOR

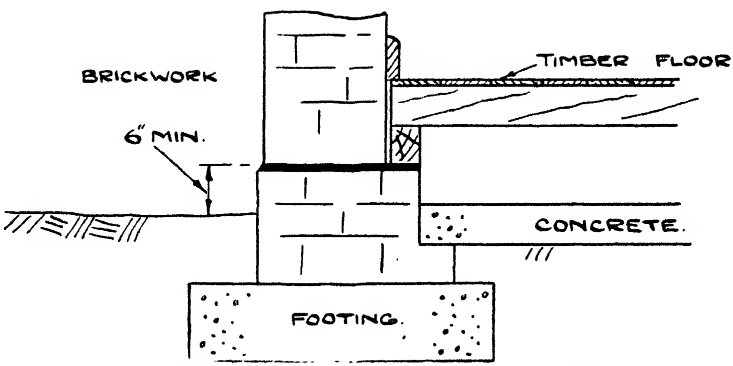


FIG. 68. CONSTRUCTION OF ASPHALTE D.P.C. TO A TIMBER FLOOR FOR A SOLID WALL

DAMP COURSES

These may occur at either foundation or roof level. When the foundations have to be damp-proofed it is necessary to ensure that all points are protected at the common level of the damp course.

The simplest form of D.P.C. is a layer of asphalte ½ in. thick placed 6 in. to 9 in. above the finished ground-level (Figs. 67 and 68). It is usual to keep the asphalte ½ in. back from the exposed face, so that the joints can be pointed with cement or lime mortar.

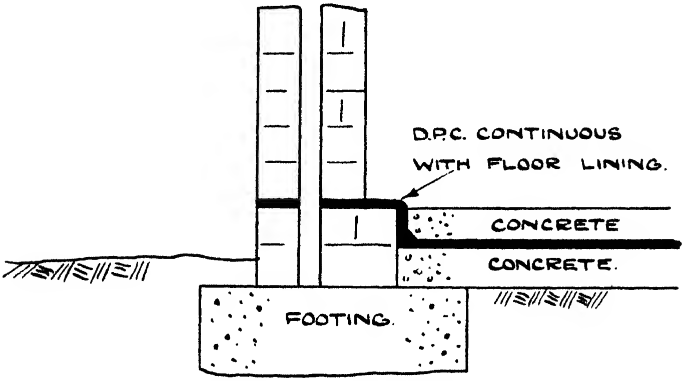


FIG. 69. PLACING OF D.P.C. IN RELATION TO CONCRETE SLAB IN CONTACT WITH EARTH

A frequent source of trouble occurs when concrete floors come in contact with the earth and the walls are carried down to separate footings. It is generally advisable to asphalte up the internal face

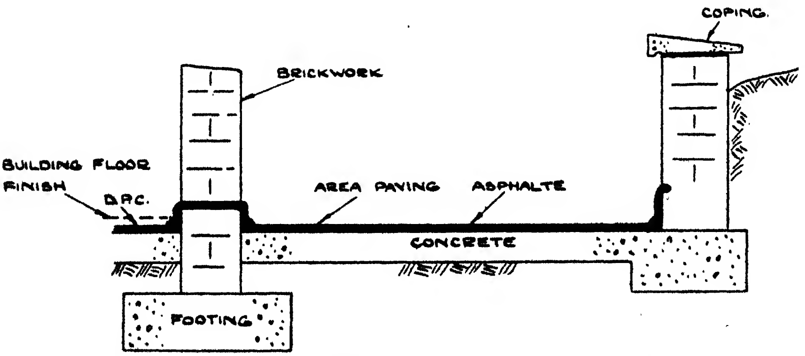


FIG. 70. ASPHALTE DAMP-PROOFING ON PAVING TO AREA

of the wall to 3 in. or 4 in. above the slab level. The asphalte is laid horizontally on the brick wall course at this point, and the concrete slab is then poured (Fig. 69). It is necessary to undertake the vertical and horizontal work in one operation. The asphalte D.P.C. and facing prevent the infiltration of water from the wall footings to the brick wall above, and also from the concrete slab to the brickwork.

However, more complete protection is provided by laying asphalte horizontally below the whole of the concrete slab. This lining should be taken through the wall at a minimum height above the soil of 6 in.

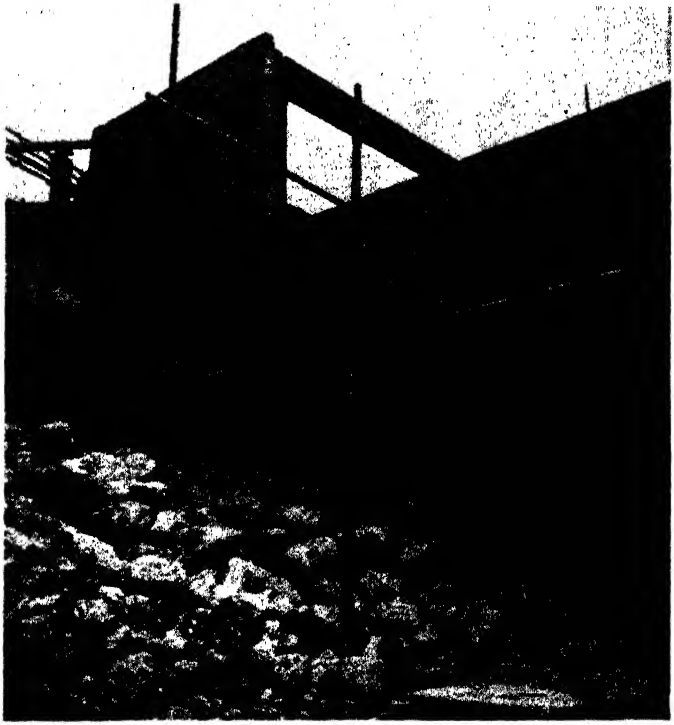


Fig. 71. Exterior Asphalte Damp Course on a Sloping Site

It should be remembered that ordinary concrete itself is not waterproof and unless the mixture is of exceptional excellence, some porosity must always be anticipated. It frequently happens that a building adjoins a shallow area which may be bounded by an external wall. In such cases the damp-proof course is often stopped off short at the wall of the building. It is better practice to continue the damp-proofing over the whole area, the end being tucked into the boundary wall (Fig. 70).

With reference to copings and parapets to flat roofs, the Building Research Station states: "With many forms of coping, there is the possibility that joints may open, which will allow moisture to enter the wall, and the use of reliable damp-proof courses immediately under the coping is to be preferred."

This statement was part of a note contributed by the Building Research Station on 9th May, 1936, to the *R.I.B.A. Journal.* It

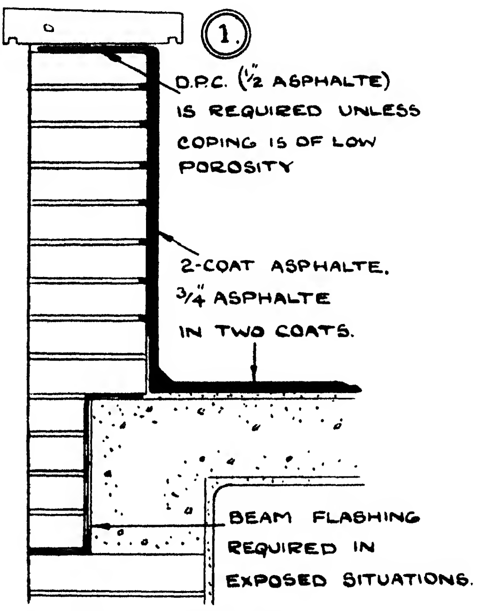


FIG. 72. PARAPET WITH BRICK EXTERNAL FACE AND ASPHALTE-COVERED INTERNAL FACE

refers essentially to parapets rendered on the face, but is applicable to all types of parapet. It is clearly evident that there is need for a damp-proof course under a coping. Such a course should consist of ½ in. thickness of mastic asphalte. If the coping is high and to be impermeable to water, a thinner layer (⅜ in.) can be used with excellent results. There are many methods of providing such protection for parapet walls, some of which are described below.

Methods Nos. 1 and 2, as shown by Figs. 72 and 73, are forms of construction, whereby a protective coating is applied to the back of a solid parapet wall to prevent moisture penetration. The formation

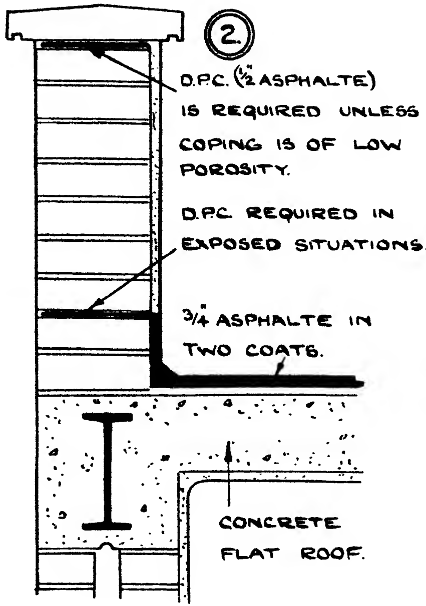


FIG. 73. PARAPET WITH BRICK EXTERNAL FACE AND RENDERED INTERNAL FACE

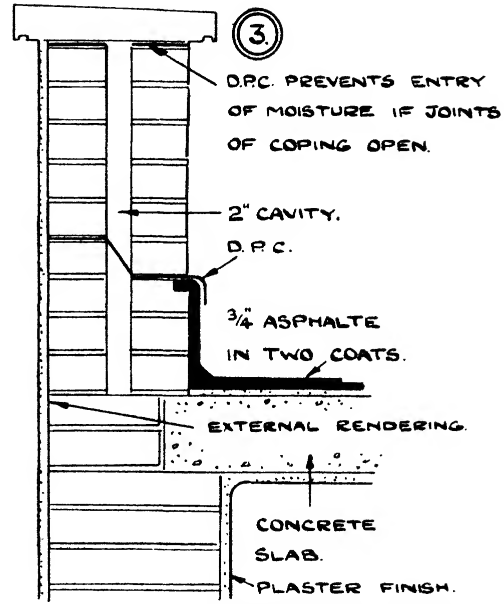


FIG. 74. HOLLOW PARAPET WITH RENDERED EXTERNAL FACE

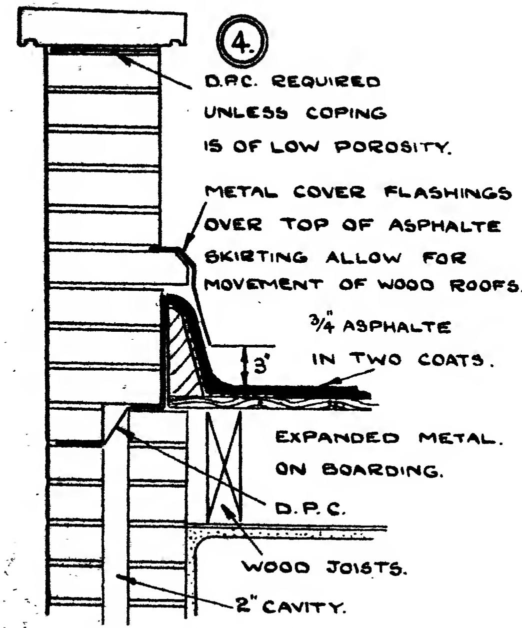


FIG. 75. PARAPET SHOWING ASPHALTE FINISH ON TIMBER ROOF

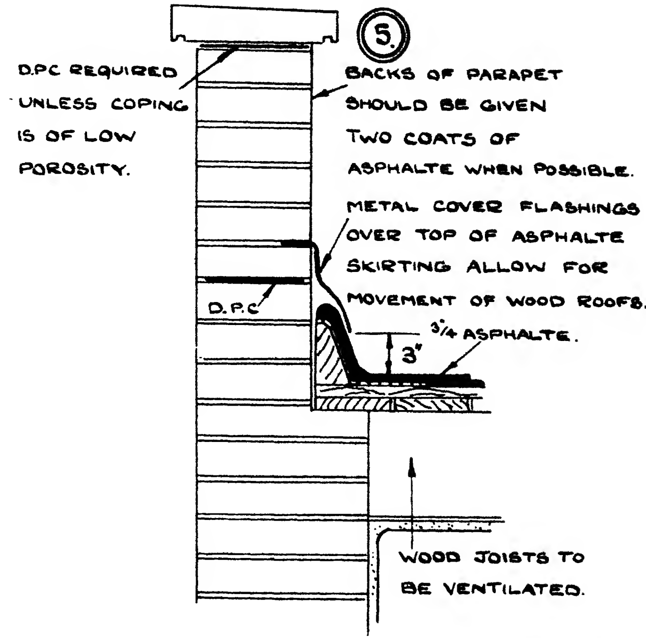


FIG. 76. ALTERNATIVE ASPHALTE FINISH ON TIMBER ROOF

of a cement rendering may produce efflorescence at the external face of the parapet which is exposed. Furthermore, a cement rendering is sensitive to any structural cracks that may occur. There is always the danger of the rendering leaving a space between the edge of the asphalte and the rendering. This will in all cases produce a line of water penetration, thus nullifying the effect of the parapet damp-course. When the asphalte is carried up the parapet wall, an unbroken face is produced and there is no joint to cause seepage.

Method No. 3 embodies a cavity wall, and the method is recommended by the Building Research Station (*R.I.B.A. Journal*, 9 May, 1936) for use where the external face of the parapet is to be rendered. In this case, the rendering of the external face of the wall necessitates a different treatment from those for solid walls. It is necessary to prevent the moisture seeping through the wall to the rear of the rendering. To counteract this it is recommended that when a cavity wall is used a D.P.C. be placed under the coping with a stepped flashing to bridge the cavity and overlapping the top of the asphalte skirting (Fig. 74).

Methods Nos. 4 and 5 each show a practical means of finishing and flashing asphalte against a parapet, when the roof is of timber. The skirting is to be continued up a timber fillet attached to the timber roof and proud of the brickwork. The angle of the asphalte should be reinforced with expanded metal, which ensures that the asphalte is fully supported and cannot be damaged by any movement between the timber and the brickwork. The asphalte skirting should be covered by a metal flashing, which should be finished not less than 3 in. above the roof level. To avoid capillary action between the asphalte skirting and the flashing it is advisable to leave a space between the two (Figs. 75 and 76).

ROOFS

The essential function of asphalte mastic covering to a roof is to provide a continuous and durable impervious membrane over different types of structures which are not entirely waterproof. Particularly when the roof consists of concrete or precast beams or hollow clay tiles, it is advantageous to provide a smooth screed on which to lay the asphalte with suitable water drainage falls. The fall should not be less than 1½ in. in 10 ft. and can be made up by adding a screed to the top of the slab or by the provision of a

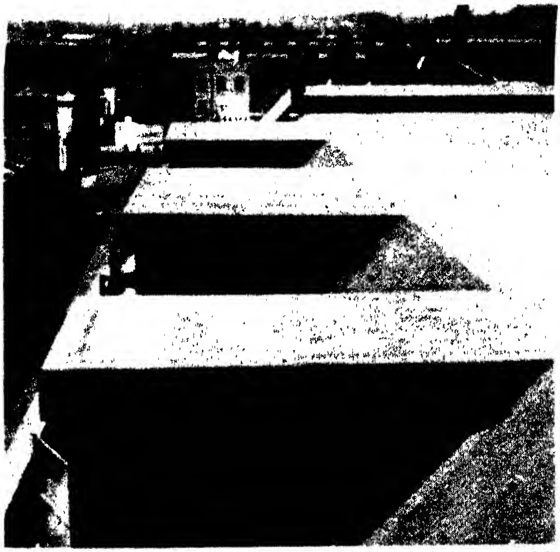


FIG. 77. DORMERS AND MANSARD SLOPE COVERED WITH MASTIC ASPHALTE

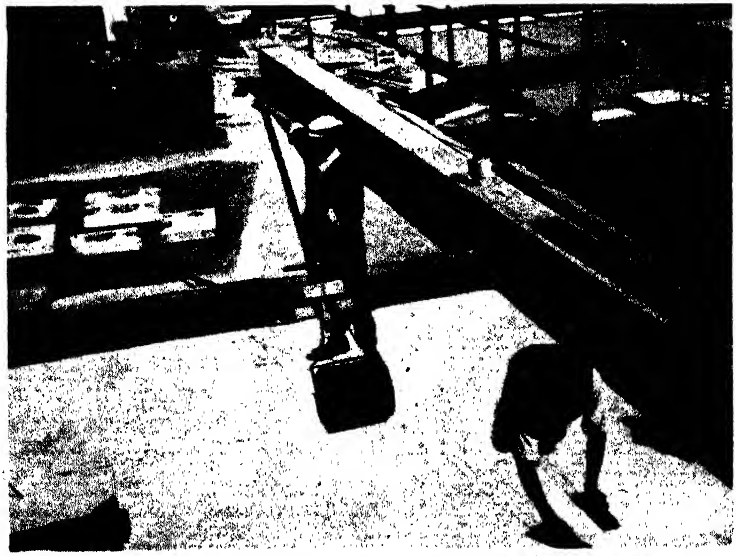


FIG. 78. APPLICATION OF WHITE SPAR CHIPPINGS OVER AN ASPHALTE ROOF SURFACE TO PROVIDE A HEAT-REFLECTING SURFACE

sloping top surface to the roof slab. It is uneconomical to fill unevenness by means of asphalte. Mastic is a costly material in comparison with concrete screeding, the rates of cost being three or four times that of a concrete screed. As roof construction is always open to the elements, care should be taken to produce a dry surface for the application of the asphalte. In the case of timber roofs falls are provided by furring.

If the surface is too wet, it is a certainty that the laying of the hot mastic will produce vaporization of the moisture. This causes blisters and blowholes, which have to be cut out with consequent waste of labour and time. Conversely, asphalte should not be applied to any concrete surface which is in too dry a condition.

Normally, it is deemed a good rule to wait at least seven days after concreting has been completed before asphalting is commenced on the particular section. As with other classes of work, the interposing of a medium such as felt ensures that the asphalte does not move with every deformation of the structure, and the inherent plasticity of mastic asphalte is brought into action. The use of a fabric medium such as felt underlay also acts as a preventive against the formation of blowholes and blisters.

For roofs of flat or small inclination, less than 1 in 8, no key to the concrete is necessary. For mansard roofs and vertical walls it is preferable to provide a key.

In summer, at the hottest part of the day, a flat roof tends to absorb heat at a rapid rate. This is more accentuated than in a sloping roof which is not subject to the hottest period of a day for such a long time, owing to the inclination. This rise in temperature of the roof causes expansion during the period of maximum temperature. This may have a serious effect upon the building structurally. It is usual—and necessary—to provide expansion joints in large structures to allow for this expansion. Joints should always occur over a beam, since it frequently happens that an expanded slab does not return to its original position and that consequently there is a gap in the joint. When it is decided to waterproof the roof, consideration should be given to the limitations of asphalte as a heat insulator. Whilst asphalte is an excellent absorbing material for solar radiation, it has been found that the temperature at the face of the concrete roof is very much the same whether asphalte is used or not. The extra heat absorption is always counterbalanced by the thermal capacity of the asphalte. When it is desired to produce a waterproof roof covering which at the same time shall have high heat insulating properties, it is necessary to interpose an insulating material such as cork beneath the asphalte. A 1-in. thickness of cork will generally provide all that is necessary to keep the atmosphere of the room below the roof in a cool condition (Fig. 79). The

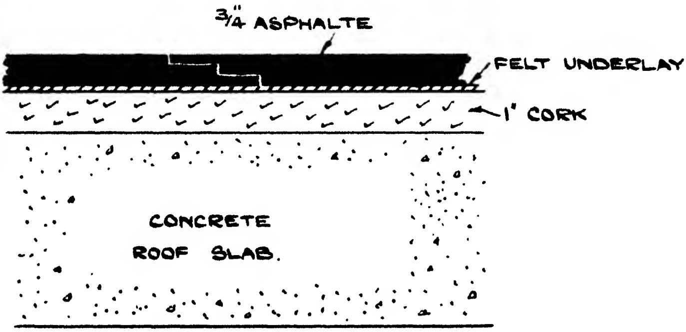


FIG. 79. TYPICAL WATERPROOFING AND HEAT INSULATION FOR CONCRETE ROOF SLAB

cork is laid in rectangular blocks of some 3 ft. by 1 ft. A two-coat application of asphalte on top of the cork, with a layer of felt interposed between, will render the roof both waterproof and cool.

When considerable hot weather is likely to be encountered, it is a great advantage to utilize a light-coloured dressing of mineral particles, such as white marble chippings or a light-coloured grit. This is best applied when the mastic is laid, but it can be applied subsequently by means of an adhesive coating of bitumen emulsion.

CHAPTER IX

TECHNIQUE AND SPECIFICATIONS FOR ASPHALTE CONSTRUCTION

THE practical application of asphalte is a highly skilled operation. Into this work must go not only the experience of the individual spreaders but the co-operation of the persons responsible for the design and building construction. They must make the asphalte work as simple in detail as possible; at the same time using the elementary rules that ensure a sound basis for mastic application. All concrete surfaces should be clean and provide a good key for asphalte. On vertical surfaces, it is preferable to provide horizontal grooves, unless a suitable rough face is derived after striking the shutters.

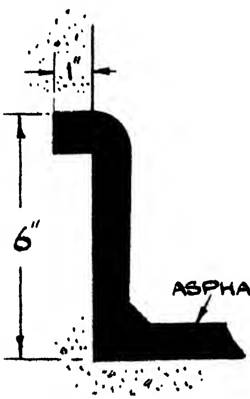


FIG. 80. TYPICAL TWO-COAT SKIRTING

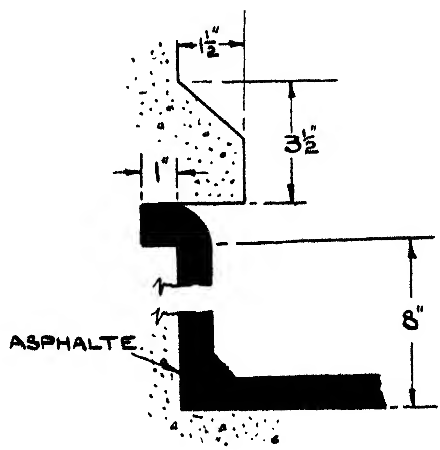


FIG. 81. TYPICAL THREE-COAT SKIRTING

When chases have to be formed—which should be at the top of all vertical asphalte work—a chase in the concrete of at least 1 in. square should be allowed. The depth of a skirting may vary considerably, 6 in. being a common depth resorted to. Fig. 80 shows a typical skirting for a two-coat surface, and Fig. 81 a skirting when three-coats are used.

Internal angles are waterproofed by bringing the asphalte up on each side of the angle, which is filled with an angle fillet. A normal internal angle fillet for three-coat work has a length of approximately 2 in. (Fig. 82). It is advisable to provide all external angles with a chamfer of not less than 1 in. square, which allows

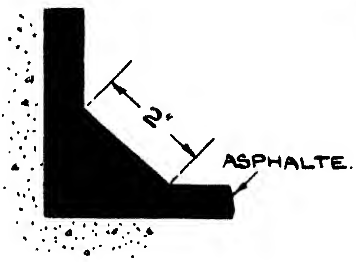


FIG. 82. DOUBLE ANGLE FILLET FOR THREE-COAT WORK

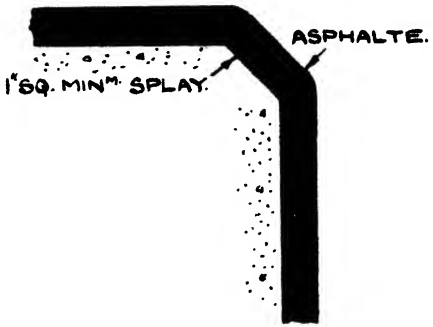


FIG. 83. TYPICAL EXTERNAL ANGLE SPLAY

the asphalte to bend freely round the corner without diminution in thickness (Fig. 83).

When more than one coat is used it is necessary to provide an

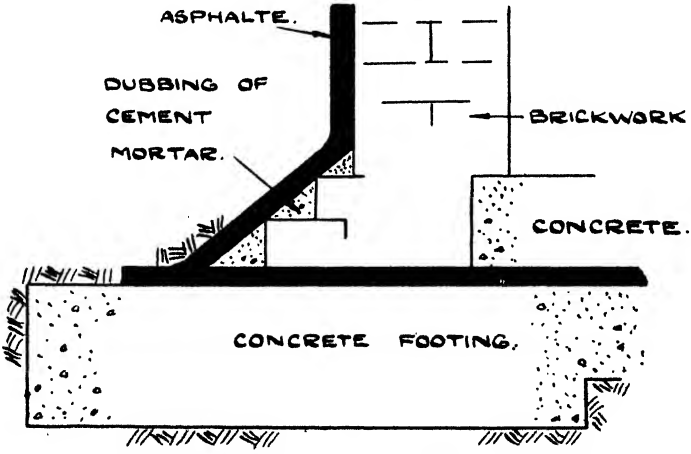


FIG. 84. TREATMENT AT TOE OF WALL ON FOOTINGS

overlap, which should not be less than 3 in. If asphalte is used to waterproof a building with a brick wall which is stepped at the lower part resting on the concrete footing, it is essential to dub out the stepped part of the brickwork with cement mortar (Fig. 71).

This provides an internal splayed angle which helps the laying of the asphalte very considerably. It is usual to lay the horizontal asphalte first in all such cases, the asphalte being extended beyond the toe of the brickwork to a distance of 4 in. This is necessary in order to provide a proper connection (which embodies a double-angle fillet) to be made between the horizontal and vertical asphalte. The latter is applied subsequent to the erection of the wall. The horizontal asphalte layer is shown in this case beneath a reinforced

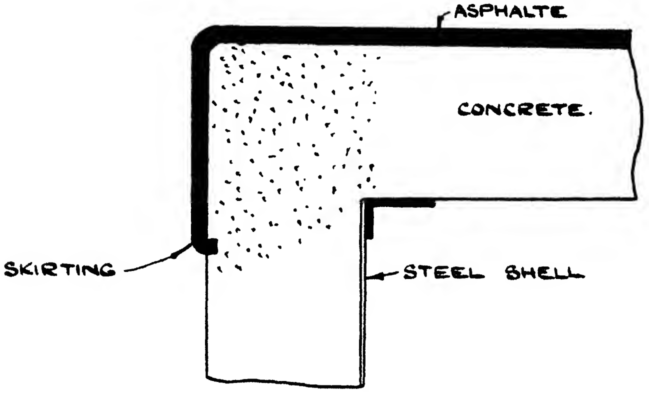


FIG. 85. VERTICAL SECTION OF CONCRETE WALL SKIRTING

concrete loading slab (see Chapter VIII under "Tanking"). This protects the asphalte from water pressure from below and also serves to carry the wall load.

When a structure is to be provided with a preliminary brick skin wall, it is most essential to rake out all the joints. These should be left rough to provide a key for the asphalte. An internal double-angle fillet is obtained. If the corners are splayed the asphalte construction is much improved in quality.

It must always be borne in mind that all asphalte linings should be made continuous. Where for some reason it is impossible to avoid the continuity of asphalte being broken by stanchions or pipes, the asphalte should be carried up or round such stanchions or pipes to the height of the main vertical asphalte. Loading coats, both horizontal and vertical, should have such inherent strength that they are able to withstand any expected water pressure. When brick walls are chosen to support the vertical asphalte, such walls should be solidly grouted on to the asphalte during construction. In the case of external vertical asphalte, the back-fill should be free of loose bricks or other similar material; this obviates damage to the asphalte face.

When existing surfaces have to be asphalted, if the surface is glossy, lime-washed painted, distempered, etc., it is essential to

FIG. 86. ASPHALTE FINISHES TO ROOF KERBS

hack and wire-brush thoroughly all lime or other material from the surfacing.

Damp-proofing needs an application of only one or two coats. Three-coat work is necessary for tanking construction. Damp-proof

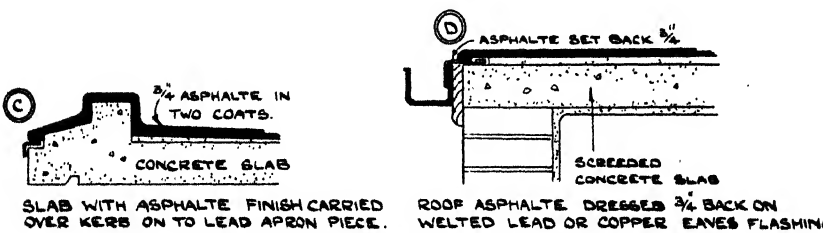


FIG. 87. ASPHALTE FINISHES TO ROOF EDGES

courses to walls require a thickness of not less than ½ in. through the full width of the wall.

When deep aprons have to be provided, in cases such as the waterproofing of petroleum tanks, it is necessary that the asphalte should overlap the top of the steel shell (Fig. 85), so that no water can enter the tank from external sources.

Figs. 86 and 87 are asphalte finishes to roof kerbs and edges.

MEMBRANOUS WATERPROOFING

Structures coming under the heading of reservoir walls and dams which hold back high heads of water are frequently treated by means of surface waterproofing. An admixture of bituminous compounds can be used. Reservoir walls, foundations and walls in

FIG. 88. WATERPROOFING INSIDE A WATER TOWER

(By courtesy of the Natural Asphalte Mine-owners' and Manufacturers' Council)

damp locations are preferably waterproofed by asphalte with a membrane placed near the face of the waterside of the wall. An admixture may be used separately or in addition.

Membranous waterproofing is one of the oldest methods used. It has exceptionally fine qualities as a waterproofer. It is very flexible and can withstand handling without cracking, particularly in cold weather. The material is very tough, and its fibres prevent

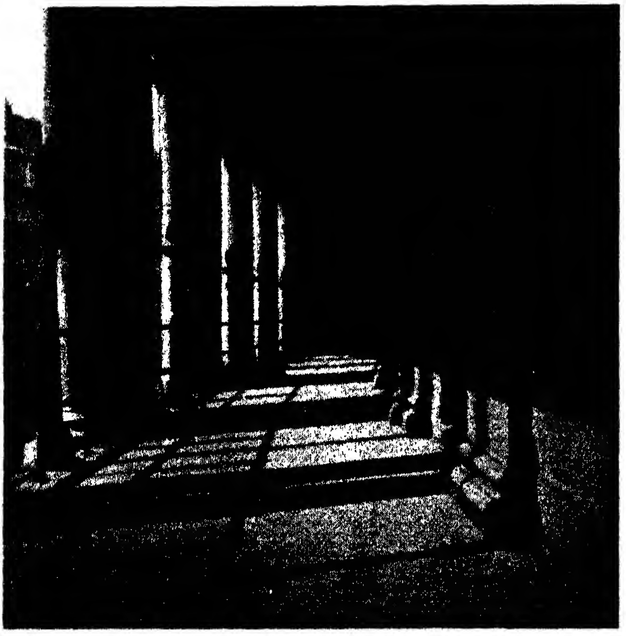


FIG. 89. ILLUSTRATING THE LONGEVITY OF NATURAL ASPHALTE MASTIC
Photograph taken at the Gaiety Theatre, London, in 1939, nearly fifty years after the surface was laid.

cutting or tearing of the fabric. Its tensile strength and elasticity ensure that the material is able to withstand the pressure head and any slight movement, such as settlement of the foundations, cracks, etc. It should be able to withstand bending round a $\frac{3}{4}$ in. bar without cracking and a tearing resistance of from 40 lb. to 50 lb. per in.

All membranous material used on any structure should be fully absorbent of the compound used as waterproofing. The whole complete membrane should form an impermeable barrier, which will remain waterproof for the full life of the structure.

The original membranous fibres used were prepared tarred or bitumen covered roofing felt. Nowadays, many special fabrics are made from hemp, cotton, wool felt, lead sheets $\frac{1}{12}$ in. thick, or other material. These are used in several layers, with the addition of a tar filling. Some fabrics are treated before being placed in position.

Membranes have been highly successful in reservoir walls, basements, and foundations to buildings and retaining walls, where dampness occurs. They may be placed either on the top surface, when they are known as External membranes, or 2 in. or 3 in. below the surface. The former is the usual type of membrane adopted.

Usually the binder is bitumen, but coal-tar pitch products are also used for this purpose, though not considered so effective as bitumen. An effective method of waterproofing consists of four coats of the binder and three of the membrane. Sometimes a primer of fluid bituminous composition is added first to the surface of the concrete. When dry, the first coat of the binder is placed upon this. The first ply of the membrane is then placed in position, and this is covered by the bricks, the binder being the last coat. The rotation is as follows—

1. Dilute asphalte on concrete surface	
2. Bituminous binder	1
3. Membrane	1
4. Bituminous binder	2
5. Membrane	2
6. Bituminous binder	3
7. Membrane	3
8. Bituminous binder	4

As for all work involving the laying of asphalte, the concrete surface should be prepared by trowelling to a smooth finish and all dirt removed. Waterproofing should not be applied in wet or damp weather. As with non-membranous asphalte, it should not be applied on a wet surface. Correct lapping of the membrane is necessary, and it should not be folded or creased. It is essential to protect the membrane against damage during backfilling operations, and also against deterioration caused by the penetration of impurities such as oils, sewage, etc. A timber backing may be used to advantage for combating the former. To protect the coatings against the attacks by liquids and fumes, it is necessary to provide a skin wall similar to that necessary for non-membranous asphalte. It is best to place the membrane directly on to the outside of the wall, but this is not always possible. When structures cannot be approached from the outside, it is then an advantage to make use of a skin wall, as previously described.

Membranes of the bituminous felt type are exceptionally plastic materials and are fully able to allow without cracking the inevitable movement due to expansion or other causes. By providing a fabric to carry the bitumen the life of the waterproofer is thereby considerably lengthened. The cost of providing a reinforced waterproofer of this nature is very considerably more than that of normal asphalte.

The use of membranous waterproofing with an asphalte filler is not usual in this country, but is frequently adopted in the U.S.A. One instance of this is the Lincoln Tunnel, New York City.

CHAPTER X

THE CEMENT-GUN PROCESS

GENERAL DESCRIPTION

THE cement gun process consists of the application of sand and cement under pneumatic pressure from a machine termed a "cement gun." The mixture is generally known as "Gunite" and possesses several characteristics which make it particularly suitable for repairs, reconstruction, protection, waterproofing, and preservation of new or existing concrete or masonry structures. By means of the cement gun, the mixture is forced into position under an air pressure of 40 lb. to 50 lb. per square inch. The plant necessitated consists of an air compressor, a cement gun and a suitable length of hose for transferring the mixture to the point of application. Water is added at the nozzle. The required dimensions of the machine vary with the extent of the contract to be undertaken. Machines can be obtained which require from 50 cub. ft. to 60 cub. ft. per minute at 40 lb. to 60 lb. per square inch to plants that require 200 cub. ft. to 250 cub. ft. of air per minute at 50 lb. to 80 lb. per square inch.

The cement gun is a vessel designed to withstand these high pressures, and consists of two compartments, each compartment being of inverted truncated conical shape. The compartments are separated by a conical-shaped valve which is worked by an external hand lever. The upper compartment is termed the feeding chamber, and the lower the working chamber. Into the feeding chamber, through the top conical valve, are fed the requisite proportions of cement and sand. The proportions can be varied to suit the strength of mix required. When the material has been placed in the feeding chamber, air pressure from the compressor is introduced into the chamber by means of an air valve in the top of the receptacle. On initial filling the middle conical valve is open and both compartments are subjected to compressed air. The feeding wheel, which is driven by an air motor, discharges the dry mixture into the supply nozzle. The air supply to the nozzle is situated immediately above it. When the feeding chamber is empty, the middle valve is closed, the top air valve shut, and the top valve opened. Through the aperture is poured another filling of cement and sand. The top door is now closed, the upper chamber filled with compressed air and, in consequence, owing to the superincumbent weight of material, the middle valve opens, and the lower chamber is refilled. This provides a constant stream of material. The mixture, which is in a dry state

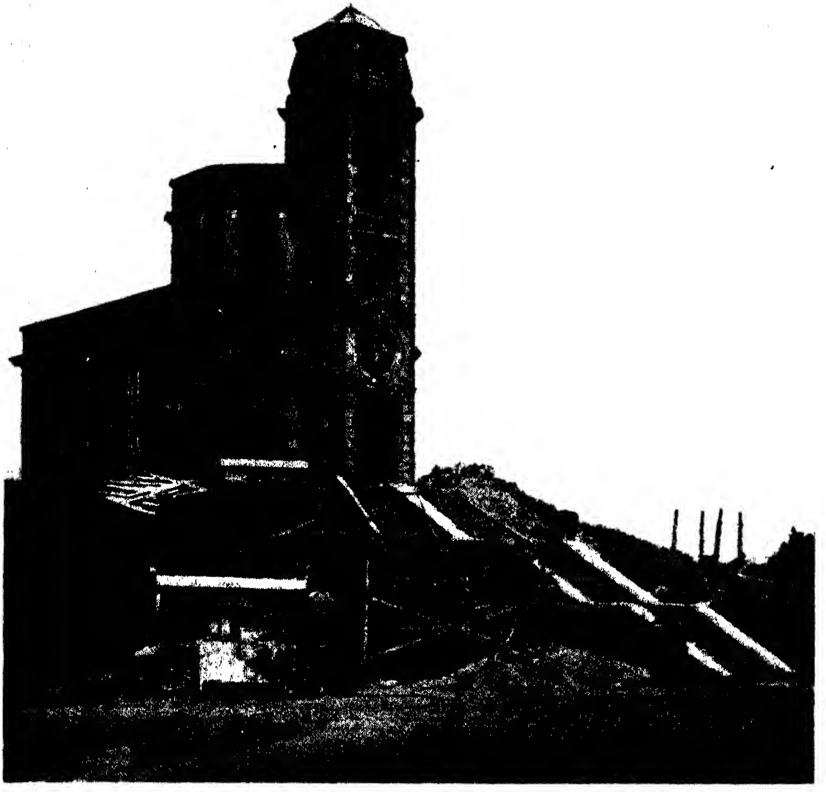


FIG. 90. TYPICAL GUNITE PLANT
(By courtesy of the Cement Gun Co.)

up to the nozzle, receives its water from a ring of jets placed circumferentially on the nozzle itself and are directed radially towards the centre of the pipe. The jets can be adjusted to suit the required mix. Generally, only sufficient water is allowed to provide a satisfactory mix on impinging on the receiving surface. The resulting mixture is known as Gunite, and may consist of three,

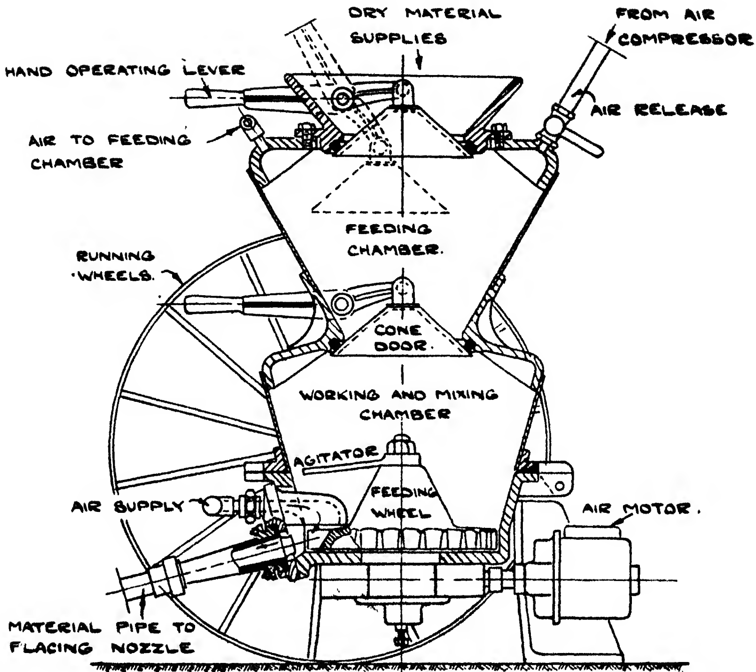


FIG. 91. CEMENT GUN

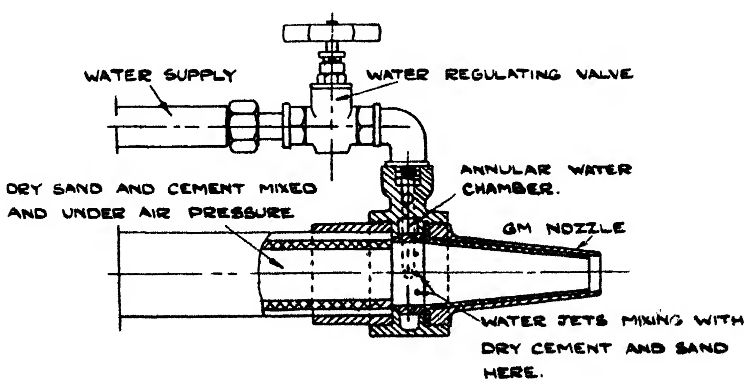


FIG. 92. GUNITE PLACING NOZZLE

four or five parts of sand to one of cement. Fig. 91 is a sectional elevation of a typical cement gun machine whilst Fig. 92 is a detailed sketch of the nozzle. The main properties of gunite are adhesion, density, strength, water impermeability and water cement ratio.

1. **Adhesion.** A considerable number of experiments in practical construction have demonstrated that the adhesion between the material and the applied gunite is stronger than the material itself. An excellent proof of this was shown by tests made at the University of California to estimate the working strength in order that collars of gunite could be designed for supporting a building which had to be underpinned. The jacking was executed against beams under the collars. The shear values ascertained in the tests were found to be 600 lb. per square inch in the concrete, whilst the bond between the concrete and the gunite was intact. A more practical illustration is that of a brick wall of a building in Canada. Very severe damp conditions imposed on the inside of the buildings caused the owners to have the outside of the building lined with a 1 in. thickness of unreinforced gunite. Four years later, approximately 100 sq. ft. of the gunite coating fell away. In falling, the gunite facing pulled with it from ¼ in. to ½ in. of the entire brick surface. A simple means of testing the adhesion qualities of gunite is to cast a block of concrete, say 6 in. square in section and 1 ft. long. A wire mesh is fitted all round the block's long sides, providing 1 in. of cover on all four sides. When gunited and after a hardening period of not less that four to five days, this block can be sawn across. If any joint is incorporated in the process, this will be visible in the cut cross-section.

2. **Density.** The density of gunite is due to the method of application, since the material is transported in a dry state to the nozzle, where water is added just as it is propelled at high velocity against the surface to be protected. This density is of extreme value in waterproofing of buildings and water-bearing structures, since a dense substance of a cement-sand nature is really what is lacking in the normal course of concrete construction if the structure concerned is to be impervious to water. Many laboratory tests have been undertaken to show the impervious nature of gunite, but the real test, as for other properties, is in practical application, where it has been found to withstand very rigorous conditions in all kinds of structures imposed to water pressure or sea erosion.

3. **Compressive Strength.** The high value of gunite in compression is illustrated by tests undertaken by the Staatlichen Materialprüfungsamt, Berlin-Dahlem, in 1923. Testing followed eleven weeks after the placing. The cement mortar was hand-placed in large slab-moulds, the mix containing 7½ per cent of water. The "shot" samples of gunite were 2¾ in. thick. Generally the gunite was a 1 : 4 mix, except in one case. It was seen that when the testing load was applied perpendicularly to the plane of lamination, a slightly increased compression strength was obtained.

Tests undertaken by the Birmingham Gas Department Industrial Research Laboratories in 1933 on cubes cut from gunite cast slabs have shown that with a local single-washed sand containing organic matter and comprising a 1 to 3 cement-sand mixture, a crushing stress at seven days of 3700 lb. per square inch has been attained. This compares favourably with the strength of 3000 lb. for normal good concrete after seven days' hardening. With clean sand, the crushing strength developed was found to be 6000 lb. per square inch. When a 1 : 3 mix was used with high-quality clean sand, the compressive strength at seven days was found to be 10,000 lb. per square inch.

4. **Fire-resisting Qualities.** Tests have been made subjecting gunite work to extreme fire conditions and quenching. It has been proved that gunite will withstand high temperatures and very formidable heat conditions. Floors and columns coated with gunite are especially good fireproof members in any type of building.

5. **Coefficient of Expansion.** The coefficient of expansion of gunite is in the region of 0·0000065, which ensures that the minimum of cracking occurs when used in coatings to normal concrete.

6. **Water-cement Ratio.** The proportion of water used in gunite work is, unlike concrete construction, efficiently controlled. Generally only the minimum quantity of water is used to ensure complete hydration of the cement.

7. **Resistance to Absorption or Percolation.** The characteristic density and strength make gunite an exceptionally useful material to be employed for structures subjected to destruction from the attack of fresh or salt water, alkalis or acids. Concrete made under normal conditions is usually porous. Gunite prevents the infiltration of water and the consequent formation of either chemical crystals or crystals formed by frost action. The resistance to liquid percolation by gunite makes it a good remedy for repairing, renewing or

building structures that contain water or resist water pressure. Sewage disposal and water infiltration plants have to be carefully constructed, so that the chemicals in the water cannot dissolve the cement. Gunite forms a hard, dense unpenetrable surface that resists destruction by chemical action far longer than ordinary cement does.

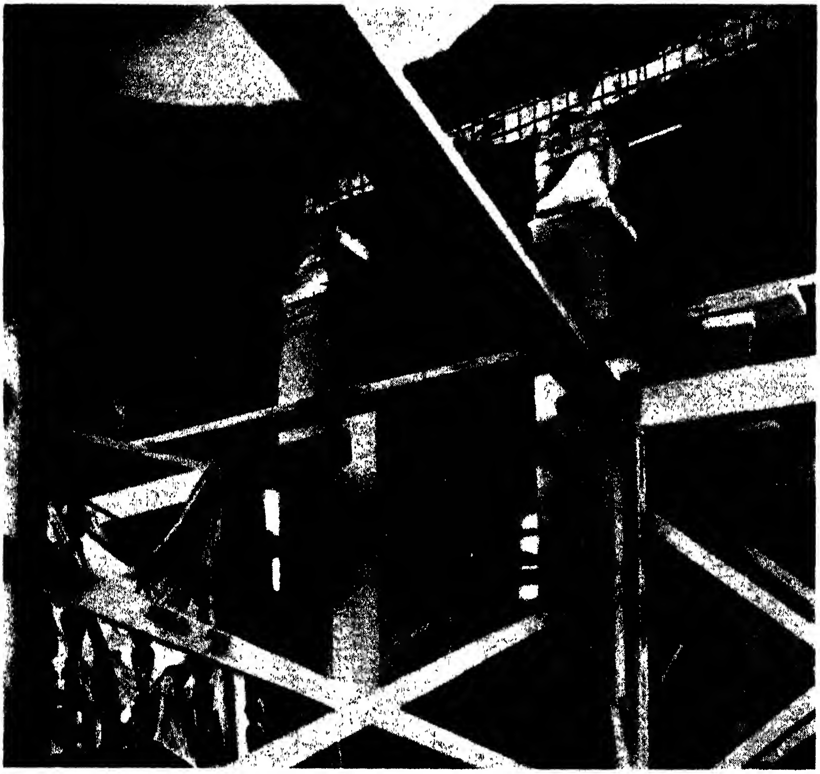


FIG. 93. GUNITING IN PROGRESS
(By courtesy of the Cement Gun Co.)

APPLICATION OF GUNITE

In the use of gunite, the stream should always be projected at right angles to the surface which has to be covered. The end of the nozzle should be from 2 ft. 6 in. to 3 ft. away from the surface. These conditions of use are necessary, since when the stream strikes an obstacle and movement still continues, the sand is liable to separate out or rebound further than the heavier and finer cement. If the mixture hits the surface at right angles, the minimum of rebound takes place and the gunite is consolidated. It is for this reason that the reinforcing mesh is placed from ¼ in. to ⅜ in. away from the surface of the existing concrete. In the event of the mesh

FIG. 94. GUNITING IN PROGRESS
(By courtesy of the Cement Gun Co.)

being in contact with the concrete surface, sand which has rebounded fills the spaces to the side of the wires, and dispersal is very difficult, if not impossible. This formation of sand particles will reduce the strength of the gunite facing.

When gunite is used to effect repairs, whether for waterproofing reasons or for renewal of the structure necessitated by erosion, fire, etc., it is in the first place necessary to remove all loose and deteriorated concrete. When the surface to be covered is smooth, this should be hacked so that a rough surface is achieved. The reinforcement mesh (which should always be provided since it distributes the shrinkage cracks in the gunite), should be completely fixed on all

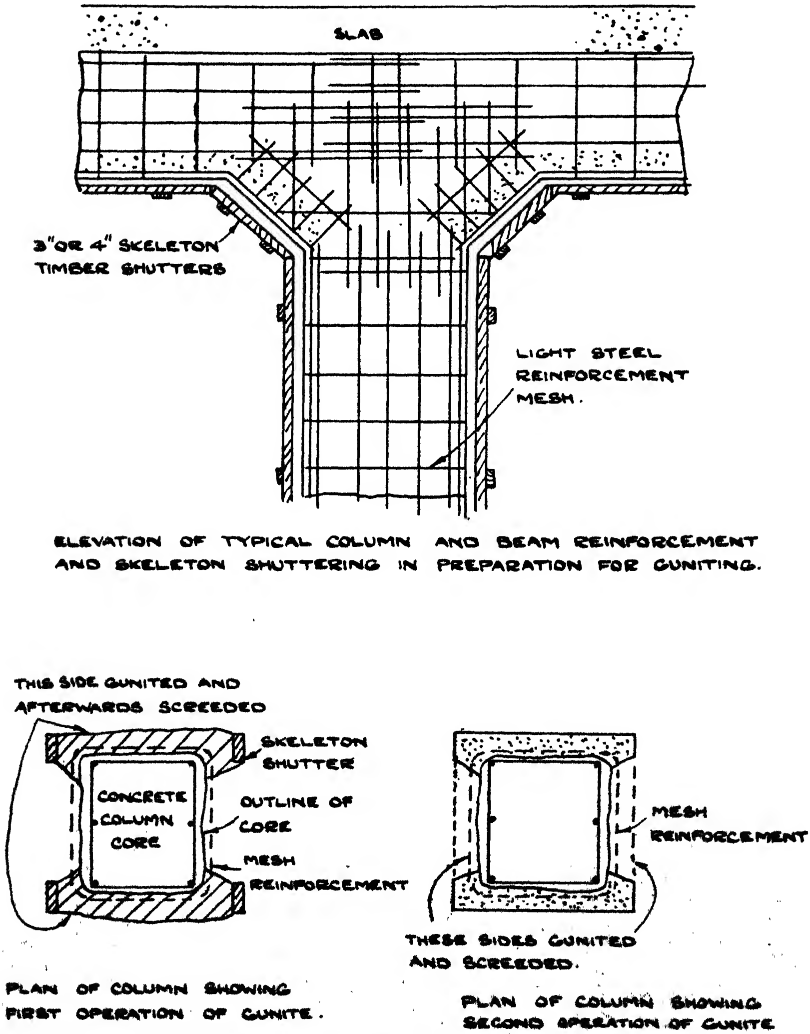


FIG. 95. TYPICAL METHOD OF REPAIRING CONCRETE WORK BY GUNITE

sides of the member to be gunited. Skeleton shuttering is necessary. In the case of a column or beam of usual proportions and dimensions, the shuttering can be 3 in. or 4 in. by 1 in. strips. These are attached to the corners of two sides of the member. The strips should project out to the adjacent sides to the depth at which these sides require guniting (Fig. 95). Guniting is now started and the shutters filled to the outside edge. After an interval of forty-five minutes, the gunite is screeded to the line of the shutters. Before the remaining two sides are filled, it is necessary to remove the shutters and clean the faces not yet gunited, since sand rebound will have accumulated

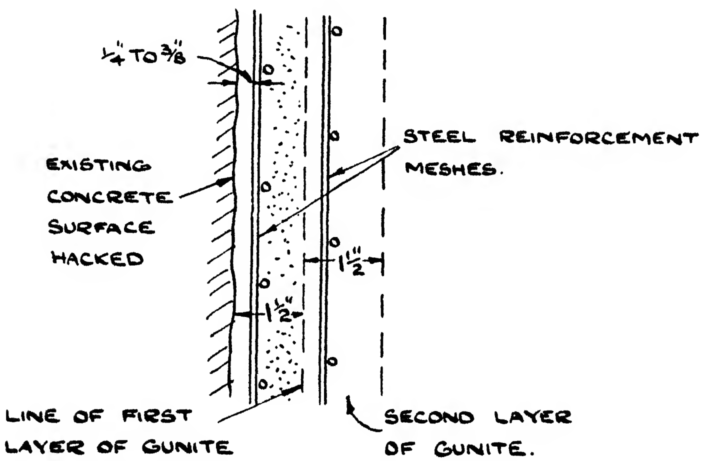


FIG. 96. SECTION SHOWING METHOD OF PROVIDING A THICK COVERING OF GUNITE

there. The second stage, as shown in the previously mentioned figure, requires no shuttering at all, since screeding can be guided by the line of the older gunite. For the sake of appearances, a finishing coat of gunite should be applied as soon as initial setting has started on the finished work. This coat should be about $\frac{1}{16}$ in. thick.

The maximum thickness of gunite that can be placed in one operation is from 1 in to 2 in. When a greater thickness is necessary, two layers are required, each with a mesh enclosed (Fig. 96). It is important that the mesh in all cases should overlap at its joints, to preserve lateral continuity. Further, a suitable cover is usually 1 in. to 1½ in. Spot welded fabric reinforcement is very adaptable and the spacing between rods should not be more than 4 in. (3 in. is usual). The diameter of the mesh should be from $\frac{1}{8}$ in. to $\frac{1}{4}$ in., $\frac{3}{16}$ in. being very suitable. Connection should be obtained to the concrete reinforcement at suitable places. This locates the mesh and restricts its movement. It will be necessary to trim the mesh to the shape of the member, and the mesh is usually most conveniently fixed in two halves.

It is necessary, in all cases, to clean exposed rusty concrete reinforcement. When deterioration has taken place at any side or

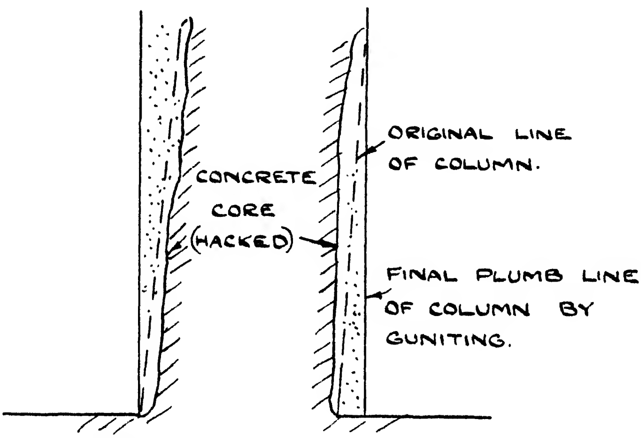


FIG. 97. VERTICAL SECTION OF A COLUMN INDICATING METHOD OF RESTORING TO A PLUMB CONDITION

corner of a member, the repair is not conclusive unless it extends all round the member.

Gunite's many uses include repairing damaged concrete members, and, in addition, gunite can be used for strengthening members which are overloaded or on which it is desired to increase the loading. In such a case, when beams have to be strengthened, it is necessary to place extra reinforcement alongside the existing beams, securely fixed to the member by means of stirrups.

The initial stage in such construction, is to hack back to the original reinforcement. It is normal practice to incorporate ties of $\frac{3}{16}$ in. steel from the original reinforcement to the mesh. Skeleton shuttering is used as for other gunite work.

Fig. 97 shows the method which should be adopted when it is necessary to correct the out of plumb of a column. In no circumstances should the thin end of the guniting be reduced to a feather edge. Rather should the concrete be hacked back locally to increase the depth of penetration.

When members are fractured in such a way that a complete break occurs over a portion of the length where failure has occurred, it is necessary to clean the reinforcement of all concrete by chipping. All cracked concrete inside the steel should be cut away. A mesh

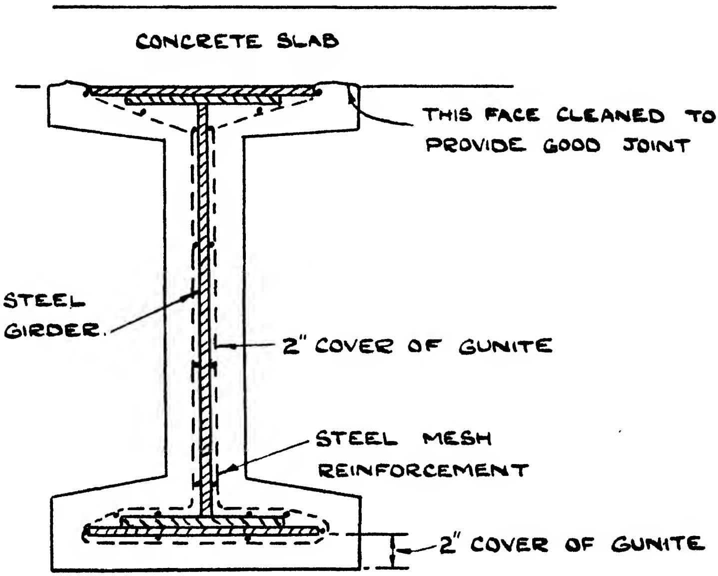


FIG. 98. SECTION OF STEEL GIRDER SHOWING ENCASEMENT BY GUNITE

can then be placed outside the bars, extending on either side past the fracture. If necessary, extra rods may be placed in the bottom of the beam which is widened. The shuttering and guniting is completed by stages. The middle section of the beam is first shuttered and gunited, then the shutters are removed and placed outside the bars. Gunite is placed to this boundary. The shutters are then removed to the faces of the beam and the full width of the beam is filled in.

Gunite has been very successfully used for the encasement of steel bridge girders. It is usual to provide a mesh covering which can be spot welded to ½ in. diameter rods running the full length of the girder. Gunite is then shot on to the girders to provide a complete covering all round. The finishing treatment is provided by screeding to the level of battens which have been previously fixed to the girder. A suitable thickness of encasement is approximately 2 in. (Fig. 98).

Gunite has many applications in waterproofing. It has been used extensively in dam restoration and construction. Examples of its use in dam construction are the large dam in the Nidd Valley,

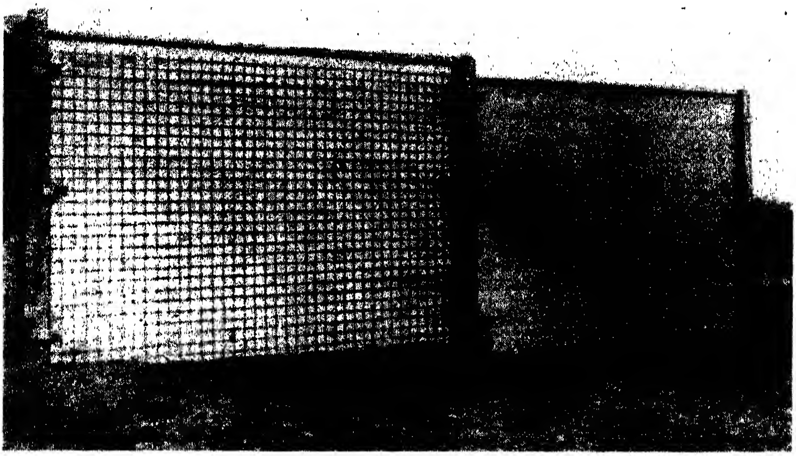


FIG. 99. GUNITING TO WALL PANELS IN PROGRESS

Yorkshire, and the Chendorah Dam, Perak, Straits Settlements, the Coolidge Dam, California, and the dam at Holmesville, Nebraska. These are typical examples of the renewal of the life of a structure under existing water conditions. When a suitable coating of cement mortar is applied to the upstream face of a dam, a very efficient waterproofing precaution is incorporated in structures where water conditions are not so exacting, and the quality of the bulk concrete can be reduced slightly in strength if the structure is of mass concrete design.

When gunite is used as a facing to reinforced concrete walls for waterproofing purposes, the wall can be constructed in normal shuttering, but the face of the extreme shutter should be placed at the outside layers of reinforcing rods. The concrete is poured in the normal method. When the concrete is sufficiently hard—say twenty-four hours old—the shutters are stripped and the external face hacked behind the reinforcement. When the walls are completed, the cement-gun method can be adopted in the usual manner.

PRECAUTIONS NECESSARY WITH THE USE OF GUNITE

The prime essential is that sufficient compressed air must be available at the machine. Moreover the air must be thoroughly dry, otherwise the delivery hose from the machine may become clogged with cement adhering to the sides. This type of stoppage is quite serious and in all cases the stoppage must be removed. Such an elementary precaution as cleaning out the machine thoroughly each night should never be neglected. A dirty machine will in the morning be much more difficult to clean, since the cement will have set.

In operation, the nozzle operative should keep the jet continually on the move. The gunite is by this precaution placed in thin layers, which avoids any lumpiness. In no case should the gunite be shot on to a surface which is at an oblique inclination from the jet. This causes excessive rebounding of the sand and consequent segregation of the mortar is the result. In all cases, the nozzle should be held at a distance of 3 ft. from the prepared surface and should be at right angles to the latter. The length of hose from the nozzle to the machine should not be excessive. It has been found that lengths from 50 ft. to 150 ft. are very suitable and give the best results. If a length of hose much beyond this range is required, it is necessary to provide a much larger air pressure. For instance, if 450 ft. of hose pipe are essential, and if the gunite has to be raised to a height of 80 ft. above the machine, then an extra air pressure of 15 lb. to 20 lb. per square inch is necessary. Further, by the use of a "booster jet" it is possible to perform gunite work at elevations of as much as 250 ft. above the machine.

The operatives handling the machine should be skilled, and thoroughly acquainted with the handling of the cement gun.

The cement gun is frequently utilized as a sand-blasting machine for cleaning the surfaces of concrete or masonry. The machine can also be employed for cleaning steel rods or sections. For such use, the sand should be absolutely dry. Furthermore the feed should be rotated very slowly, otherwise static electricity is developed. For the cleaning of masonry or concrete, water and sand alone are suitable. A preliminary to the sand blasting by this means is to wash the surface down with water and compressed air.

GENERAL REQUIREMENTS IN CEMENT GUN WORK

The cement should be a standard Portland cement, whilst the sand should be clean, sharp and reasonably free from impurities and should have a sufficient content of fine material to eliminate voids. The sand should not be absolutely dry, but should contain a normal amount of moisture of not less than 3 per cent. Screening of the sand is a necessity, and no lumps greater than $\frac{3}{8}$ in. in size should be included. Throughout the operation, the compressed air should be maintained at a steady pressure, which should not be less than 30 lb. per square inch. For long lengths of hose, a similar pressure is necessary at the nozzle. The water pressure at the nozzle should always be in the region of 15 lb. per square inch greater than the air pressure.

All loose sand must be removed from the previous surface before guniting is started. At the end of each day's work, or on stopping work for any other reason, the gunite should be sloped off to a thin edge. It is necessary to clean any wet section before restarting work. The gunite must be wetted during the first five days after placing. Furthermore, as in concrete work, gunite cannot satisfactorily be placed except by the use of special precautions.

For such work as waterproofing, fireproofing of columns, girders and beams, floors and roof slabs, and repairs, the proportions should be one part of cement to three of sand. For other uses, such as industrial building walls, a weaker mix of one to four can be used. Fireproofing and waterproofing are adequately ensured by a thickness of 2 in. of gunite.

In case excessive water conditions prevent the proper setting of the gunite, the contractor should arrange to lead away the water from the surface against which the gunite is being shot, by the provision of weep-holes. These should subsequently be capped and protected by the contractor..

CHAPTER XI

REPAIRS AND JOINTS IN WATER-BEARING STRUCTURES

REPAIRS

In water tank construction no leakage can be allowed at all. This applies to all comparatively small fluid-holding structures, since the cost of complete impermeability is not usually excessive. Furthermore, the points of seepage are usually comparatively easily found. In large structures such as reservoirs a major leak is usually not very difficult to determine if the faces can be uncovered. If this cannot be undertaken, it is necessary to ensure complete waterproofing by rendering the dry face of the concrete. This is not so positive as a waterproof coating on the waterface. If the reservoir can be emptied, a coating of rendering, bituminous paint or asphalte will provide the soundest method of stopping leakages.

If minor leaks still occur after the wall has been waterproofed it may be necessary to decide whether a complete stoppage of all leakage is worth while, in view of the considerable cost in providing this condition. The smaller the leakage, the more difficult it is to find, not to mention the doubt whether the latest discovered leak is really the last. At a certain point then, within the specified rate of leakage, it is best to finish the waterproofing precautions. The stage at which this is completed should be the engineer's responsibility, and he should decide whether the extra cost is worth the capital equivalent of the water seepage.

Seepages will frequently decrease as a result of impurities in the water getting into the fine leakage cracks. Chemical action between the water and the concrete may also cause this occurrence.

In new construction, especially when a bituminous paint is to be used, it is advantageous to start the waterproofing measures immediately the concrete is hard enough, but whilst it is still in the "green" condition. When steel forms are used, a smooth surface may result: wire brushing is necessary on this before any waterproofing work is undertaken. If the chosen waterproofer is asphalte, the earliest point at which work can be commenced is the completion of the drying-out period.

In many cases the repairs may be localized at construction joints in the wall. These are frequently major leaks and the stopping *of these is frequently an expensive item. The cracks should be increased to an incision of Vee or U shape of not less than a 1 in. by 1 in. horizontal section. A strong cement mortar of not less than* 1 : 2 mix with an incorporated waterproofing agent or in waterproofed cement is suitable. Alternatively a bituminous compound of not less than two coats can be used. An asphalte sealer would probably necessitate a vertical chase on each side of the joint together with a horizontal chase below and above it to ensure complete isolation of the crack.

It should be remembered that, wherever possible, joints should be sealed on the water face. Otherwise the water pressure will push the waterproofing away from the point of sealing. This applies to some extent to surface waterproofing over the whole area of the wall. It must also be borne in mind that the water surface of a wall is not subjected to the same extensive range of temperature as the outside face is, if the latter is exposed. Hence, the risk of the waterproofer cracking is decidedly less, whether it be a paint rendering or asphalte, when applied to the water surface.

In old reservoirs, the seepage may be caused by a crack in the wall, due to settlement or other reasons. In some cases the crack may result in the spalling of the edges of the fissure. The treatment of such individual leaks necessitates that all edges of crumbling concrete should be chipped off, the whole crack to be formed into a chase not less than 1 in. deep. An asphalte filling and side chases can be provided, but when the opening is deep it is best to fill the gap with gunite or cement mortar and a top layer of asphalte if the latter is used.

If extensive floor leakage is encountered an application of a suitable waterproofer is necessary over the particular portion affected. When expansion joints leak those should be cut away and a filling inserted in the space. An asphalte cover should be provided on top to ensure the watertightness of the joint.

If it is found that external water enters a tank or reservoir from the ground, it is essential to localize the leakage by drilling a hole or holes in the floor. The diameter of the holes depends on the extent of the seepage. The localized flow is taken away by pipe. The waterproofing of the floor is then undertaken. When this is completed and has dried, the pipe holes are plugged up by quick-setting cement mortar with the addition of sodium silicate or calcium chloride.

Gunite is a very useful method of waterproofing the faces of such structures, and because of its denseness it is very impermeable to water. Renderings of cement mortar should be laid in thin layers if the work is to be subjected to the daily atmospheric temperature variations.

In the event of any doubt concerning the waterproof qualities of the construction, it is preferable to err always on the right side, since in many cases the cost of returning to deal with small problems of waterproofing is prohibitive, not to speak of the delay in the utilization of the structure.

EXPANSION JOINTS

Cracking of long walls of concrete is inevitable if adequate provision is not made for expansion. A mass or reinforced concrete reservoir or tank wall should be watertight, but this ideal cannot be attained if the wall cracks. If a clay puddle backing is used, the cracking of the wall is not of paramount importance apart from unsightliness. When the structure is situated on a clay subsoil, it may not be necessary to provide any waterproofing measures whatever. Generally, the amount of waterproofing necessary is entirely dependent on the type of soil directly surrounding the excavation.

Furthermore, the choice of a waterproofer should be made bearing in mind the type of structure and the design and method of construction. It is of little purpose to use a means of waterproofing which will not withstand the movement of the walls if the latter expand and crack. Therefore, a resilient medium of water impermeability is necessary in cases of possible structural deformation. For this reason, a rendering or a gunite mortar is not so suitable in such problems as asphalte or a bituminous paint. A clay puddle surround has the tremendous advantage that it is entirely free of structural movement and has no cohesion with the concrete wall. Both asphalte and clay puddle are very expensive items in the bill of a small structure, but the inclusion of one or the other of these precautions is very necessary if the structure is to have a reasonable term of utility.

In successful design and construction, consideration must be given to both expansion and impermeability. For long walls, these two factors of precautionary measures are completely interdependent. In the course of construction especial care should be taken with construction joints, the quality of the concrete and the shrinkage. The importance of the water-cement ratio cannot be exaggerated. A mix which is workable yet not wet is the best answer for water tank or reservoir work. The use of vibration for such construction is an asset. It is desirable to use a suitable mix which is not deficient in cement. The more cement is used the greater the degree of impermeability derived. Further, it has been verified that concrete improves in impermeability with age.

The use of stop-end boards is now generally accepted as necessary, and it is a universal rule that such a requirement is included in specifications for concrete construction of all kinds. The use of expansion joints is now the rule rather than the exception, but there is considerable divergence of opinion among engineers as to

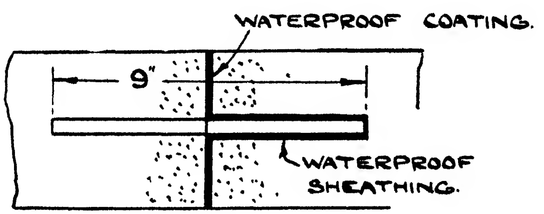


FIG. 100. PROVISION OF METAL EXPANSION PLATE IN A TANK OR RESERVOIR

the limits between joints. The range is very wide, but expansion joints placed at 25 ft. to 50 ft. are sound and will fulfil their purpose adequately.

In reservoir wall construction, the minimum number of lifts in which the wall can be concreted should always be used. Special precautions have to be taken in the case of high walls to ensure that the formwork is amply capable of withstanding the considerable wet concrete pressure without horizontal deflection of the shutters.

Expansion joints should be of necessity able to withstand the fluid pressure imposed upon them and should at the same time provide no appreciable resistance to movement of the structure at right angles to the joint.

The most elementary joint to the wall of a reservoir and tank in the ground is to provide a strip which should penetrate equally into the old and new concrete at the joint. The strip should be placed in the construction of the wall and incorporated in the stop-end. When the adjoining section of the wall is concreted the joint is fully formed. The strip may be anything from 6 in. to 9 in. wide. To ensure that the expansion shall be as free as possible, and to provide complete resistance to water percolation, it is necessary to coat the whole of the surface of the second portion of the strip and the original concrete face with a bituminous paint or asphalte. It should be noted that the concrete face of the first portion of the joint should be completely dry before applying the waterproofer. Fig. 100 shows this type of joint, which may be of metal, such as copper, steel or zinc. The thickness of the strip should not be less than $\frac{1}{4}$ in. If time cannot be allowed for the drying-out of the concrete, an alternative is to use ordinary felt to form a tube surrounding the strip and for the wall facing.

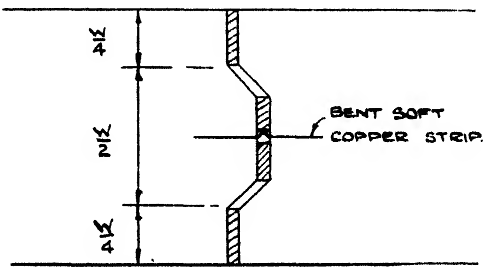


Fig. 101. Keyed Expansion Joint in a Tank or Reservoir Wall

Quite frequently the surface of the wall is constructed with a keyway and the expansion material can be cork, board, composition rubber, mastic filler or other compressible materials. To ensure complete waterproofing in addition, a strip of copper should be used which should be located on the pressure side of the wall. The keyways should always have bevelled edges and if the wall is for earth-retaining purposes, the joint should be Veed at the external face for the sake of appearance. The copper strip should be of relatively thin gauge with a U-bend in it for expansion at the face of the keyway. The filler can be nailed on to the original pouring after striking the shutters, but the copper strip has to be incorporated with the shutter at this stage. Fig. 101 shows such a typical joint. An asphalte filler is an advantage if the joint is in a tank or reservoir.

In the case of reservoirs or tanks, the pressure face is accessible. It may be deemed advantageous to provide an internal caulking, which also serves as an expansion joint in addition. A normal thickness of joint is used and this is filled with a suitable filler, leaving the inside of the joint open for a depth of ¾ in. A copper strip is bent into a U-shape to provide for expansion and is fitted into the joint, whilst the ends of the strip, which are turned inwards towards the wall, fit into vertical grooves already cut out for them. The grooves are tightly caulked with a mastic asphalte. This type

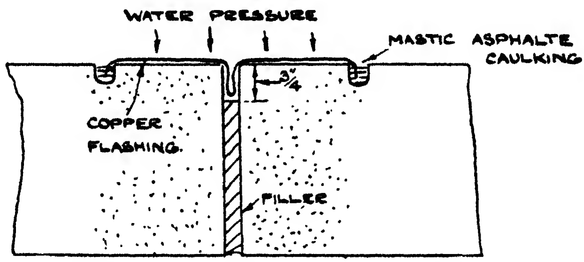


FIG. 102. EXPANSION JOINT WITH COPPER FLASHING AT WATER FACE OF A TANK OR RESERVOIR

of joint is shown in Fig. 102. Only the filler is placed in position before the wall is concreted. The rebates for the caulking can be formed in the shuttering, but the flashing is placed in position afterwards.

In thick mass walls it may not be economical to provide a filler. However, a recess of 3 in. to 4 in. wide should be provided in the middle of the joint in both the consecutive pourings. This forms a hole in the wall, the hole being square in plan. The construction joint will require a metal strip, which may be corrugated or have a middle U-bend in it. The strip is placed in the middle of the hole (Fig. 103).

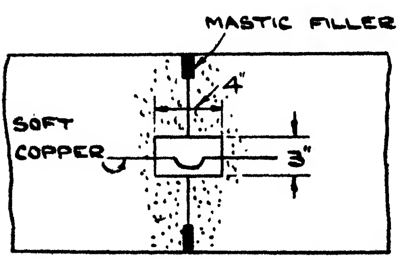


FIG. 103. EXPANSION JOINT IN A MASS CONCRETE WALL

When a mastic filler is used as a jointing material for either floor or walls to combat water pressure, it is an advantage to dovetail the joint so that the effect of the pressure is to tighten the latter. In two-course tank floor construction, it is only necessary to dovetail the top joints. In single-course floor construction the joint should be provided with a pad of concrete as shown in Fig. 104. Felt should be used on the top of the pad, which should not be less than 1 ft. wide. This forms an effective water seal. The use of a bent strip of soft metal, as in wall construction, can be equally recommended. When expansion occurs, any floor or wall rendering

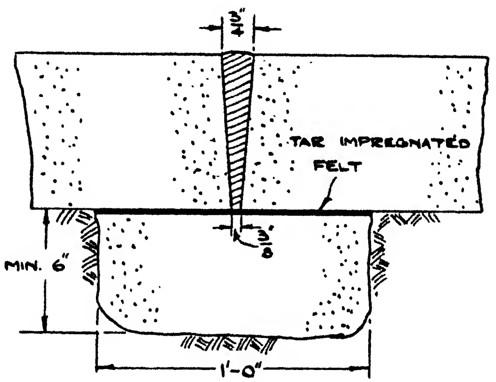


FIG. 104. SINGLE-COURSE FLOOR JOINT IN TANK OR RESERVOIR CONSTRUCTION

will crack, and therefore will not prove of any value to the structure for waterproofing. An asphalte coating over the top of the slab will prove adequate (Fig. 105).

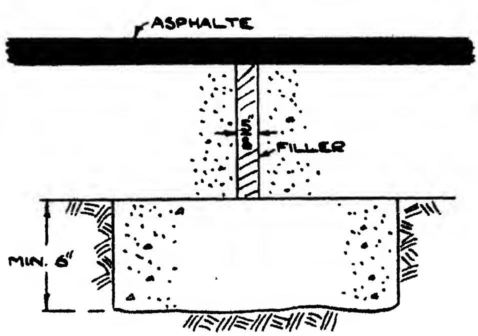


FIG. 105. ASPHALTE COVERING TO EXPANSION JOINT IN A SINGLE-COURSE FLOOR FOR A TANK OR RESERVOIR

The foregoing examples are only indicative of the general scope of expansion joint construction. The main essentials in water-bearing work are that the water must be fully restrained in its proclivity to seep through the medium of the structure, that joints should be as fully resilient as possible, whilst the life of the components comprising the joint should be the full length of the useful period of existence of the tank, reservoir or retaining-wall. Fillers should be very carefully chosen and tried out before being used. There are now on the market several good types of filler but, needless to say, none is perfect. Some, such as rubber products, have a good degree of elasticity but have not a very prolonged life, whilst others, such as cork, impregnated composition substances, mastic, etc., will last for a considerable period, but have variable and generally small elasticity. There are for sale now complete expansion joints consisting of a filler and precast ends to the slabs. These are mainly suitable for roadwork, but can be incorporated in building construction, although the joint between the precast unit and the *in-situ* concrete should be very carefully constructed.

The joints discussed in this chapter refer to all water-bearing structures usually encountered, such as small reservoirs, water tanks, swimming-pools, baths, and retaining-walls.

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