Painting on Concrete Surfaces

*Report of Committee 407**

BY F. O. ANDEREGG, AUTHOR-CHAIRMAN†

This report has been compiled from information received from a large number of manufacturers, users and others interested. It aims to give fair and concise information concerning: (1) the effect of factors arising from the concrete and the nature of its surface, (2) the various painting materials that are being used and (3) the best probable practice in their application to produce satisfactory decorative coatings. The subject of waterproofing as such is not considered, although any paint applied to exteriors must show reasonable resistance to the elements.

The colors, sometimes in attractive combinations, which may be obtained with most of the surface treatments, afford the architect suitable means of expression.

THE CONCRETE

Surface Conditions

"A paint is no stronger than its foundation." If the surface to be painted is covered with laitance, form-oil, soot, loosely held material or efflorescent salts, it is useless to expect satisfactory results with any paint, unless the surface is first vigorously wire brushed or lightly sand blasted. Mechanical anchorage improves the strength and durability of the film very greatly and where the surface is glassy, from excessive trowelling, it is often helpful to remove part of the glaze.

The question of removal of form marks is determined by the architectural effect desired, while sand streaks, honeycombing or tie-wire holes should first be cut to a depth of ¾-in. with square shoulders and painted with neat cement slurry. They should then be plastered

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*It is noteworthy that this report was produced promptly by Dr. Anderegg, the Author-Chairman of the Committee; that it is brief, that it has in general the approval of all critic members of the committee, four of them representing paint producers: A. E. Horn, R. A. Plumb, E. W. Scripture and Howard I. Servey and two of them respresenting user interests: P. H. Bates and C. H. Chisholm and by several non-members of the Committee to whom the author submitted it, prior to presenting it for publication. "Wherever differences of opinion have arisen, as is to be expected where information is received from manufacturers of competing materials, I have endeavored to make all statements as fairly as possible," writes Dr. Anderegg. "The unqualified approval generally received seems to indicate a treatment fair to all and without bias."—Editor with a slight excess of mortar, using as much pressure as possible. After the cement has partly hardened the excess should be removed and the patch finished with a carborundum stone to match the rest of the surface.

Suction

The suction to be left in the concrete is of importance. With hydraulic paints the absorption should be largely satisfied so as to provide ample curing moisture. With oil paints and lacquers, the concrete must be quite dry and, if very porous, the first coat should be suitably diluted with vehicle and solvent; many prefer to use vehicle only.

Green Concrete

Concrete recently placed, is more or less saturated with *moisture* and in a highly *alkaline condition.* These facts impose fundamental limitations which must be recognized in securing successful painting.

Moist concrete

The greater affinity of portland cement and the common concrete aggregates for water than for vegetable oils, makes it poor practice to try to apply paints of largely organic character to moist concrete. Moreover, as a result of this greater affinity, moisture penetrating concrete from behind will often bodily push an oil-paint film from the concrete. This phenomena is called, very expressively, "preferential wetting". If the paint film is permeable, evaporation may take place so that the film is not shoved off. A good test for dryness is to place a sheet of linoleum or glass against the concrete, observing after 24 hours any condensation of moisture.

Alkalies in concrete

Portland cement on hydrating releases considerable lime as hydroxide. Any moisture present is saturated with this compound. As air comes in contact therewith, it is slowly carbonated and rendered relatively inert. In addition, the cement contains sodium and potassium compounds which are set free partly as very *caustic* hydroxides. These alkali metal compounds react with vegetable oils and some guns saponifying them and radically changing their character. Even after carbonation, they are alkaline and still harmful. They are very soluble, however, and as the concrete dries out, are brought to the surface where they are readily removed by the rain or by systematic washing. In other words, they are more or less fugitive.

Various methods have been proposed for taking care of the alkali in the concrete: treatments with zinc sulfate, alum or magnesium fluosilicate. Some people prefer the first, but the last seems generally regarded as best and has the advantage, probably, of partial filling of the pores in the surface of the concrete. It may be obtained under various brand names. This sort of treatment, while helpful, cannot be considered as completely efficacious.

Efflorescent crystal pressure

It is difficult satisfactorily to paint a concrete within which an appreciable quantity of soluble salts has accumulated.

Where alkali-metal compounds are not almost completely removed; where concrete is in contact with the soil so that the soil solution diffuses into the concrete; where it is in contact with cinders, or with floors in dairies, food factories, pickle factories or packing houses; or where rain water has had prolonged opportunity to build up the sulfate content of the concrete; it is extremely difficult to secure a satisfactory coating of paint. The molecular forces involved in oriented crystal growth are tremendous, involving hundreds of thousands of pounds per square inch. While the force exerted by a single cyrstal is not great because of its small area, the cumulative effect of the millions found in many concretes will push off most paint films.

Proper precautions should be taken in the design by the use of proper flashing, calking and waterproofing to prevent moisture entering the concrete which is to be covered with any treatment other than hydraulic cement paints.

PAINTING MATERIALS

A variety of paints have been applied to concrete ranging from cold water paints to nitrocellulose lacquers. Each material has its limitations, but some are much better than others. They fall into two large groups; those largely inorganic and those largely organic in composition.

The *permeability* of the paint film is very important in determining its successful use under various conditions. There are two schools of thought: One holds that moisture must be kept out of the concrete, insists on having a film as nearly impervious as possible; while the other school, realizing that moisture very often gets into the concrete from behind, believes opportunity should be provided for the wall to "breathe." If moisture has a chance to escape through pores in the surface paint, the film will not be pushed off as a whole by preferential wetting.

The ability of the paint material to transmit the salts in solution in the moisture affects the pushing off of the film by efflorescent crystal pressure. Damage will depend on whether the crystals grow on the outside of the film or back of it.

A. Largely inorganic

These treatments are not generally applied with success to surfaces which have been painted with oil paints unless the latter have been completely removed.

1. *Cold water paints*, which usually contain lime with glue or casein as the cementing agent, together with pigments. Sometimes portland cement is added, but its hardening properties are reduced by the glue or casein. These paints are not suitable usually for exterior use, and where the concrete base gets damp, their durability is low, due to the decay of the casein or glue. Their use should be limited to dry, interior walls. These films are probably less permeable than those of cement paint so that the accumulation of salts near the concrete surface often pushes the paint film off.

2. *Portland cement or hydraulic paints*, which contain a large amount of portland cement, suitable pigments and other ingredients. Some of these are diluted with more or less lime. The effect of the lime is to reduce the durability and to decrease the opacity when wet. On the other hand, the ease of spreading is slightly increased, as is the flexibility of the paint film. Sometimes organic waterproofing materials are added, which greatly increase the ease of spreading. If stearate is used the durability is probably not impaired, but the effect of other waterproofing admixtures in this regard has hardly been satisfactorily demonstrated.

Portland cement paints are suitable for inside and outside application to walls, but are not recommended for painting floors except the floors of swimming or wading pools. These paint films offer reasonable resistance to the weather, often effecting a perceptible improvement in this regard over the original surface. These films are not impermeable to the passage of moisture, so that a wet wall has a chance to "breathe" or dry out. Any efflorescent salts in the concrete tend to pass through the cement film to be deposited on the surface without much damage to the paint.

3. *Proprietary chemical treatments*, whereby colored stains, mostly inorganic, are deposited within the pores and over the surfaces of the concrete. Very beautiful effects are claimed for these methods, but their best application would seem to be for interiors, for most of the compounds deposited are susceptible to weathering, resulting in gradual fading. The permeability of the surface to moisture is reduced by this treatment by an estimated one half to three fourths, but the nature of the deposit does not lead to probable detachment by preferential wetting or crystal pressure. Unless concrete in contact with the

ground or other source of moisture has been waterproofed, a deposit of efflorescent salts often causes a fading of the colors.

B. Largely organic

These paints are best applied in warm, dry weather.

1. *Oil paints*, which are composed of a vegetable drying oil vehicle, pigment and sometimes solvents or gums. The oils vary from linseed, which is probably most easily saponified by the alkalies found in concrete, to tung (china wood) oil, which seems to be least affected by these reagents. Hence the increasing popularity of the latter and the efforts to produce this oil in the southern part of this country. The former seems to be, however, more durable against weathering.

The gums may vary from rosin through the rosin esters, the fossil gums to some of the new condensation resins. Sometimes these require special plasticizers and solvents which are added in conjunction with the drying oil. The gums vary in their degree of resistance to the action of alkalies and to weathering. The permeability of these drying-oil films is slight so that the film may be bodily displaced if the concrete becomes wet. When solvents are used, it is difficult to fill completely the larger pores in the concrete.

Paints containing aluminum powder alone or in conjunction with other pigments have been applied with apparently satisfactory results on a number of jobs. The reflecting power of the aluminum reduces the deterioration of the film by light, but on the other hand, the presence of the leafed-out metal probably lessens the opportunity of moisture escaping from the concrete. A bituminous-aluminum paint has been developed for giving a decorative finish to a bituminous waterproofing treatment of concrete. Another, somewhat similar treatment, involves alternate coats of vegetable drying oil and micaceous sands.

2. *Lacquers*, which usually contain synthetic plastics as bases, suspended in suitable solvents with the aid of plasticizers. Very often all of the materials entering these lacquers are synthetic. The most notable examples of these plastics are cellulose nitrate or acetate. These have apparently low permeability and therein seems to lie their danger, for the whole film is readily pushed off the concrete surface by moisture in the concrete. Glyptol and phenol resins are also frequently utilized in this way.

Certain of the vinyl resins have been used with fairly good success on concrete. Some of the films allow moisture to evaporate to some extent and when properly applied become mechanically well bonded to the surface. They have, however, a tendency to darken a bit on exposure to light. A number of other materials are coming on the market but opportunity to make adequate tests has been lacking.

3. *Hybrides.* In order to get better bond between the cellulose esters and concrete surfaces sometimes vegetable oils or some of their fatty acids are added. These admixtures greatly increase the rate of penetration into the concrete, allowing the film to secure a much more effective mechanical anchorage with marked improvement in quality, but the corrosive action of unsaturated fatty acids on portland cement products must not be disregarded.

4. *Conclusions.* Where the concrete is quite dry and free from moisture ingress from behind, an oil paint of a high degree of impermeability may be used to advantage: but where moisture is likely to get into the concrete, a paint that is porous enough to permit the moisture to evaporate is apt to give better satisfaction.

METHODS OF APPLICATION

The wide variation in nature of the painting materials applied to concrete requires special methods of application. Several points having to do with application have already been discussed. A few additional methods need discussing.

Generally speaking, the paints of largely organic character may not and must not be applied to damp concrete surfaces. The concrete should have aged until the alkaline reaction has been largely neutralized or some treatment such as fluosilicate should have been given it and it should be allowed to dry out pretty thoroughly. The importance of securing adequate mechanical anchorage should be emphasized; a priming coat should be selected which penetrates well down into the concrete.

Coldwater paints are generally applied to a surface more or less dry; as their setting-up depends mostly upon a drying action, the presence of excess moisture is not desirable.

For the production of chemically precipitated color treatments the concrete should not be moist because the action depends upon drawing of the solutions down into the pores.

With portland cement paints, mechanical anchorage is not so essential because the cement bonds to the surface in the same way in which the concrete itself has hardened, but a highly troweled, smooth surface should be roughened a bit to give proper bond.

To secure the best possible results with portland cement paint the wetting of the concrete surface and the subsequent curing of each coat of paint are highly important and must be carefully carried out. The following points are essential:

The surface must be moistened before the paint is applied and the first coat of paint should be wet down as soon as possible after the paint is hardened sufficiently to prevent injury to the surface.

Before the second coat is applied the first coat should be dampened by spraying. The second coat of paint should be moistened with a fine spray as soon as it is hardened sufficiently to prevent the surface from being marred and should be kept wet as long as practicable.

During warm, hot and windy weather the paint film will harden or "set" quicker than during cool or cold weather, so that the paint film will need to be sprayed during the warmer weather sooner than during the colder weather. In order to get best results under these conditions it is wise to make the application in the evening.

Readers are referred to the JOURNAL *for January 1933, for discussion which may develop. Such discussion should reach the Secretary by November 1, 1932.*

The Mortar Voids Method of Designing Concrete Mixtures*

BY MARK MORRIS†

The selection of a combination of materials to compose the batch which will produce concrete of a given unit strength offers one of the most fascinating problems associated with the use of concrete. To the designer of the concrete mixture, it is something of an adventure, for there is, as yet, no well-defined, thoroughly dependable and generally accepted method of solving the problem. Even though he must attain his objective by following some devious path rather than traveling a broad, safe, well-marked highway leading directly to it, he has available for his use many landmarks and direction signs which have been erected by those who have preceded him. These guide posts establish limits, or boundaries, and mark danger points. A combination of art and science enables him to chart his way through the forest of possibilities to the selection of the one or several proportions which will most probably be satisfactory. Final selection, consisting principally of slight adjustments of the chosen proportion, must usually await results of strength tests upon the concrete as produced under actual construction conditions. The suspense attending the approach of this climax contributes considerably to the fascination of the problem.

Much has been accomplished toward the provision of a method for designing concrete mixtures, and much remains to be done. Considerable success has attended the design of mixtures for the preparation of laboratory specimens and for the fabrication of concrete on the job, but the effect of differences between the field and the laboratory in the mixing, placing and consolidating operations upon the composition of the concrete requires assumptions during the progress of the designing that call for considerable experience on the part of the designer, with the class of concrete to be made. A particularly difficult problem is the predetermination of the quantity of water re-

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quired in the batch. Unless this can be known with some accuracy, the estimate of the quantities of the solid materials required will vary from the actual quantities by more than the percentages considered as satisfactory tolerances, that is, about two per cent for the cement, four to seven per cent for the sand, and three to five per cent for the coarse aggregate. To establish values which must now be assumed, the research worker should go to the field and become as familiar with the composition of the fresh concrete deposited under actual job conditions as he is with that in the laboratory specimens. To a limited extent, this has been done. When the recorded experiences of a number of investigators for a considerable range of conditions have become available and have been studied, it seems likely that rapid progress will be made toward the goal so long sought, that of designing, after a brief examination of the available materials, a concrete mixture that can be used with very slight adjustment, if any, when taken to the field or job to produce concrete having at a given age, within five per cent of the desired unit strength, and containing well within the limits of the satisfactory tolerances the estimated quantities of materials, including water.

During the last quarter of a century many researches in concrete have had as their objectives the discovery of the basic laws, principles or relationships existing between combinations of the essential materials and the unit strength of concrete. Invaluable contributions to the store of knowledge regarding the composition of concrete have been made. Some of these researches have revealed sufficiently portions of what appear to be the basic laws outlining the relationship between the composition of concrete and its unit strength to permit the use of a method, or of methods, of designing concrete mixtures that may be based on this knowledge. It is the purpose of this paper to describe some of the experiences of the author with the study and use of facts revealed by one of the more comprehensive of these investigations, the work of Talbot and Richart, an account of which was published October, 1923, in the University of Illinois, Engineering Experiment Station, Bulletin Number 137.

The method developed by Talbot and Richart for obtaining data to determine the concrete-making ability of different sands has been used by the Iowa State Highway Commission to acquire detailed knowledge of the characteristics of a large number of sands available for use in Iowa. Circumstances surrounding some proposed paving projects have been such that departure from the standard proportions of concrete materials was imperative, from an economic standpoint. Using the data derived from the study of the sand, or sands, involved and using either the method of design of concrete mixtures proposed by Talbot and Richart, or an amended form of it, a special mixture was designed for these cases. Success has attended this action in every instance. Experience with the mortar voids method of Talbot and Richart soon indicated the desirability of slight variations from the original method, at least for conditions encountered in Iowa.

This paper presents briefly the original method, calls attention to the variations as now practiced in Iowa by the author, and gives examples of the results obtained, both in the laboratory and in the field. For this presentation, the scope of the paper has been confined to a statement of experiences. Discussion of the laws of the composition of concrete as revealed by the work of Talbot and Richart, and and corroborated by the Research Division of the Iowa State Highway Commission have been deferred until opportunity permits the preparation of a more extensive presentation in which theoretical phases of the problem can be given more consideration.

The notations used by Talbot and Richart to represent each of the ingredients of the mortar and the concrete are used throughout this paper:

a = absolute volume of fine aggregate in a unit of volume of freshly placed concrete
b = absolute volume of coarse aggregate in a unit of volume of freshly placed concrete
c = absolute volume of cement in a unit of volume of freshly placed concrete
d = density or solidity ratio of the freshly placed concrete
v_m = voids (air and water) in a unit of volume of the mortar mixture of cement, fine aggregate, and water as it exists in the concrete
v = voids in a unit of volume of concrete. This, of course, will be equal to $1 - d$

It is evident that

$$a + b + c = d = 1 - v \qquad (1)$$

Since the mortar and the coarse aggregate together make up the unit of volume, it is also evident that

$$\frac{c + a}{1 - v_m} + b = 1 \qquad (2)$$

A third equation derived from equations (1) and (2) will be found useful:

$$v = v_m(1 - b) \text{ or } b = 1 - \frac{v}{v_m} \qquad (3)$$

The essential features of the original mortar voids method of comparing the concrete making ability of sands and selecting proportions of materials for concrete of a given strength, are the determination