DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
George K. Burgess, Director

STUCCO INVESTIGATIONS AT THE BUREAU OF STANDARDS

WITH

RECOMMENDATIONS FOR PORTLAND CEMENT STUCCO CONSTRUCTION

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FIG. 1.—*An overcoat job on brick finished with exposed aggregate*

(Siamese Legation, Washington, D. C.) (See fig. 14.)

STUCCO INVESTIGATIONS AT THE BUREAU OF STANDARDS WITH RECOMMENDATIONS FOR PORTLAND CEMENT STUCCO CONSTRUCTION[1]

ABSTRACT

During the past few years there has been a rapid and widespread growth in the use of stucco for the exterior finish of various types of buildings. The Bureau of Standards, in cooperation with interested associations and manufacturers, has carried out a number of investigations for the improvement of stucco construction. This paper summarizes briefly these studies and outlines the essential factors to be considered for satisfactory stuccowork. Several types of construction widely used for stucco are described and illustrations are given of the details of good design. The requirements of the commonly used materials are specified and methods are given for proportioning, mixing, and applying the mortar. Several of the finish treatments are described and illustrated and some suggestions are given for the repair and painting of stucco.

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[1] Prepared by Frank A. Hitchcock, engineer, Bureau of Standards, in charge of the cement and concreting materials section.

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I. INTRODUCTION

Stucco has been used for many centuries as an exterior finish of structures either as a decorative treatment or as a protective coating. For masonry structures it is used largely for decorative purposes, while for frame structures it serves both as an ornamental and protective finish.

In recent years the popularity of the stucco house has given rise to a comparatively rapid development of a type of building construction not new in principle but different from the older construction by the use of new methods and new materials. The rapid adoption of this new construction has been due to many conditions, among which may be mentioned the desire for a cheap but more permanent type of structure, the increase in cost and the decrease in quality of lumber, the rapid development in the use of Portland cement and the production of the metal stucco bases, hollow load-bearing tile, concrete building units, and other materials. While the production of these newer building materials has had a decided influence on this type of construction, perhaps the most important factor in its adoption is that the stucco house appeals to the prospective home owner because of its generally attractive appearance, its reasonable first cost, and the anticipated low maintenance charges.

With the widespread use of stucco there have been many unsatisfactory stucco constructions, and numerous letters have been received by the Bureau of Standards over a period of years asking for information regarding the best methods of application and the probable permanency and durability of good stucco construction. The failures of the past were undoubtedly due in a large measure

to lack of knowledge as to the proper methods of mixing and applying the stucco rather than to any inherent fault of the commonly used materials. For the past 15 years the Bureau of Standards, in cooperation with interested manufacturers and associations, has been carrying out investigations of stucco construction to determine the essential features of good practice in order to avoid a reoccurrence of the failures. The major portion of these investigations have dealt with Portland cement stucco.

II. INVESTIGATIONS

1. TESTS OF 1911

The first cooperative investigation carried out at the bureau was started in 1911. The bureau was requested by the Associated Metal Lath Manufacturers to cooperate with them in determining what factors play the most important part in bringing about the corrosion and consequent failure of metal lath under stucco and plaster.

At that time it was reported that the failures of metal lath were sufficiently frequent to be a matter of concern to the lath industry, and many persons were openly condemning the use of this material on the ground that its tendency to corrosion rendered it unsuitable for permanent construction. Reliable data were not at hand on the relative value of protective coatings for the lath itself nor on the corrosive properties of different plasters nor on the best method of construction for the preservation of the lath. Information was needed on these points not only by the lath manufacturers, but by all interested in building materials.

In compliance with this request the bureau planned a preliminary series of exposure tests which eventually took form in the erection of some 300 panels of metal bases about 18 by 24 inches in size, plastered with various combinations of the commonly used plastering materials, such as cement, lime, and gypsum. Approximately one-half of the total number of panels formed a part of the exterior walls of a storage building on the bureau grounds, and the remainder were erected on partitions within the building. Figure 2 shows quite clearly the exposure of these panels. There were 39 varieties of lath used, and with cement, lime, and gypsum as cementitious materials there were some 20 different mixtures applied to the lath. After two years exposure to the weather a careful examination was made of all the panels.

The general conclusions established by this series of tests as to the order of merit or durability of the lath as determined by the two-year exposure and confirmed by subsequent observations are as follows:

First, lath galvanized after expansion; second, lath cut from galvanized sheets; third, painted ingot iron lath; fourth, painted

steel lath; fifth sherrardized steel lath; sixth, plain ingot iron; and seventh, plain steel lath.

It was also the purpose of the test to determine in so far as possible the protective qualities of the different stuccoes and plasters, but as many of the mixtures were criticized as being oversanded the comparative results in this respect were open to question. However, it may be said, in general, that the degree to which moisture has access to the lath either through oversanded plasters or imperfect embedment of the lath has apparently more to do with the development of

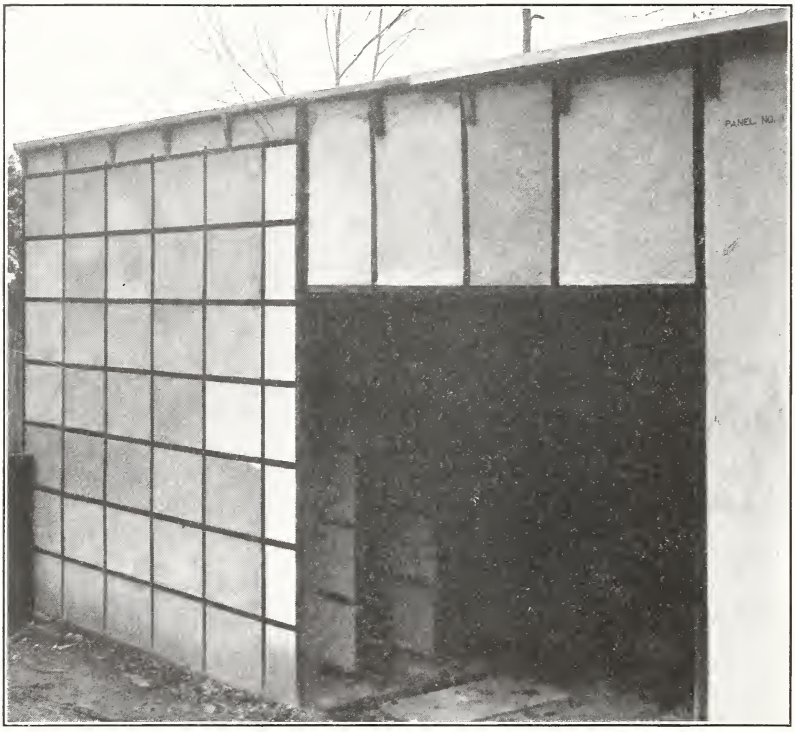

FIG. 2.—*Test structure erected in 1911 for the study of factors affecting the life of metal lath*

rust than the nature of the cementitious materials. Many of these panels are still in excellent condition after 15 years' exposure, which is particularly interesting in view of the fact that the building is not entirely weatherproof and all of the panels are of open-back construction, so that the plaster keys and the metal base where exposed can be readily inspected.

2. TESTS OF 1915

The foregoing series of tests aroused considerable interest among manufacturers and users of stucco materials in investigations for the

improvement of stucco construction. As there had been some criticism of the 1911 work, it was decided to outline a more comprehensive series of tests on a larger scale. Inasmuch as there were failures of stucco on other bases besides metal lath in which corrosion could have played no part, the general feeling was that all types of stucco construction should be studied. In order that further work might be carried out efficiently and preclude as far as possible all subsequent criticisms of materials, proportions of plaster, ingredients, and workmanship, it was decided to place the entire program in the hands of a committee invited by the bureau to act in an advisory capacity and to inspect and be responsible for the satisfactory construction of the test panels. The cooperation of the industries concerned was obtained, and an advisory committee of experienced and well-qualified representatives from the various national associations was formed. The membership of this committee gave a great deal of time and thought to a comprehensive program of tests, and in the summer and fall of 1915 the stucco-test building was erected at the Bureau of Standards.

The members of the advisory committee were unanimously of the opinion that the proposed investigation should not be limited to the tests of stucco and plaster on metal lath, but should include in so far as possible all common types of exterior plasters. It was believed that the plastering faults directly due to the corrosion of embedded metal are a comparatively small portion of all the objectionable features which are generally indicated by the development of cracks with consequent disfiguration and gradual disintegration of plaster coatings. A study of the origin and method of prevention of cracks in various types of plasters was, therefore, one of the chief purposes of the investigation. The committee decided unanimously that the test panels should be of relatively large size, not only to enable the plastering to be done on a scale comparable with that of ordinary residence construction, but also large enough to contain window and door openings at the corners of which structural cracks or cracks due to expansion and contraction of stucco or plaster are most likely to develop. The size of the exterior panel eventually decided upon was approximately 15 feet long by 10 feet high. Most of the panels contained a window 2½ by 3½ feet at the center. Since the very large number of possible combinations or even desirable combinations of different stuccoes on different bases would have required an enormous test structure, it was decided to select approximately 50 of the most typical combinations and embody these in construction on the walls of the building erected in such a manner as to compare favorably in rigidity and solidity with good residence construction.

The building erected was of composite construction, about 200 feet long, 26 feet wide, 25 feet high, and provided wall space for

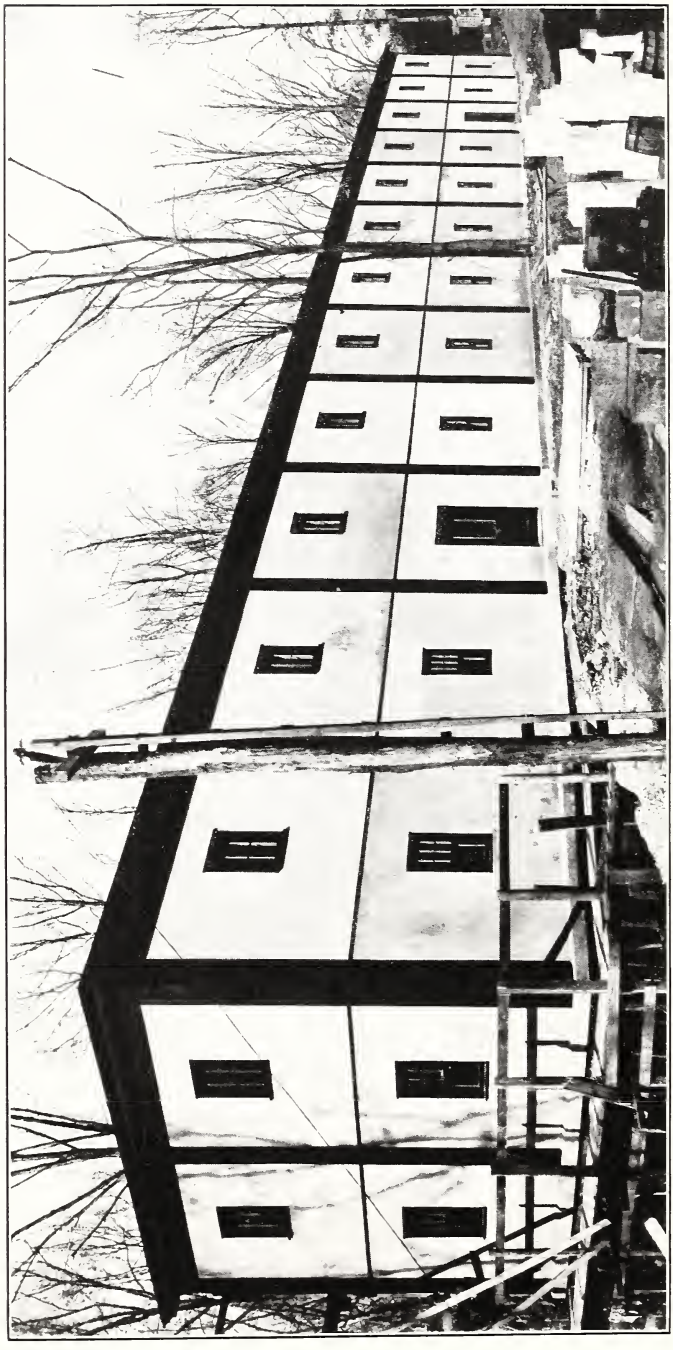

FIG. 3.—*Main stucco test structure erected in 1915*

56 exterior panels. Figure 3 shows this building as erected in 1915. The lower story was largely of masonry construction, including panels of monolithic concrete, hollow load-bearing tile, brick, concrete block, and gypsum block. The upper story was of frame construction and provided space for panels of metal lath, with and without sheathing, wood lath, gypsum plaster board, and proprietary materials.

The bases used were divided into 11 groups, the grouping being based either on the type of material, the method of construction, or the means used in applying the plaster. Group 1 was metal lath on ½-inch crimped galvanized furring, spaced 12 inches apart, over sheathing and sheathing paper. Hair was used in the scratch coat, and there was more or less space between the stucco and the sheathing. Group 2 was metal lath on ½-inch crimped galvanized furring, spaced 12 inches apart, over the sheathing and sheathing paper. No hair was used in any coat, and the plaster was pushed through to thoroughly embed the lath. Group 3 consisted of metal lath on ½-inch crimped galvanized furring attached directly to the studs, which were spaced 12 inches on centers. No sheathing was used, and the lath was back plastered on the inside between the studs. The outer faces of the studs were coated with a waterproofing material. Group 4 consisted of wood lath on ⅜-inch thick by 1¼-inch wide wood furring placed 12 inches apart over sheathing and sheathing paper. Plain lathing was used with the joints broken every twelfth lath. The spacing of the lath was ⅜ of an inch. Group 5 consisted of wood lath over sheathing and sheathing paper with no furring, but counterlathed. The spacing of the lath was 1 inch, and the slope of the lath was such that the 4-foot lath spanned 3 feet horizontally. Group 6 was of gypsum plaster board, ⅜-inch thick, nailed directly to the studs, spaced 12 inches on centers. Four-inch spacing of the nails was used, and while it was intended that there should be a ¼-inch space between boards, in many instances they were laid close together or spaced considerably less than ¼ inch apart. Group 7 consisted of glazed and unglazed hollow load-bearing tile and concrete block. The load-bearing tile was well burned with dovetail ragged scoring. Group 8 was of brick, common, rough, and well burned, set with cement mortar, the joints being raked out to a depth of ⅜ to ½ inch. Group 9 was gypsum block, both smooth and grooved. Group 10 consisted of monolithic concrete.

Of the 6 panels in this last group 3 of them were poured as the first-story walls were being erected some 9 or 10 weeks before plastering and 3 were poured after the remainder of the structure was completed, 2 days before plastering. The concrete was 8 inches

thick and was composed of 1 part Portland cement, 2 parts sand, and 4 parts gravel. The surfaces were generally smooth and free from pockets except the upper section of the three last poured, where the construction would not permit thorough spading.

Group 11 consisted of 3 panels of which the bases were two proprietary materials. The first of these bases was a proprietary stucco or plaster base consisting of wood lath backed with paper which is first given a heavy coat of asphalt compound on the lath side. This compound serves as a waterproof coat and as an adhesive between the lath and the paper. The lath are dovetailed in order to afford a firm key for the plaster. The second type of base consisted of a series of parallel No. 13 gauge wires spaced 3 inches apart and running horizontally, welded to a series of similar wires spaced 8 inches apart and running vertically with tarred felt or sheathing paper laid between the two sets of wires before welding. The paper is punched at the points where the wires intersect which permits welding and affords a small key for the plaster at each intersection. The material was applied directly to the studs 16 inches on centers with the horizontal wires outside. The plaster was applied directly against the felt and embedded the horizontal wires completely between the points of support.

All the mortars were proportioned by weight. The proportion of cementing material to aggregate varied from 1 to 2½ to 1 to 4 parts. There were some 16 combinations, and the several types can be referred to as cement-lime where the cement was the predominating material and lime-cement where the reverse was true, straight lime, straight cement, half-and half cement-lime, cement with integral waterproofing; and white Portland cement finish coat. In all cases three-coat work was used over wood and metal lath bases and two-coat work over all other bases. All the panels were finished in the sand-float finish because it was commonly used in practice and because it was well adapted to the detection of small defects.

As the tests included a large variety of bases on which stucco mixtures of various proportions and types were applied only conclusions of a general nature can be drawn. In summarizing, it may be said of the bases that the results indicate that stuccoes applied to the monolithic concrete were of the first order. Those on metal lath applied directly to the studs and back plastered were second, those on the brick and tile panels were third, those on metal-lath backing over wood sheathing were fourth, those applied to wood lath were fifth, and those over gypsum block and plaster board were at the bottom of the list.

All of the panels over diagonal sheathing developed large and prominent cracks. These cracks invariably first appeared off the

corners of the windows and ran across the direction of the sheathing, and it is felt that they were brought into prominence if not actually produced by the shrinkage of the sheathing.

It was noted that the stuccoes on gypsum block and monolithic concrete coated with bituminous waterproofing materials were in poor condition, especially after they had passed through the second winter. All of these panels were stuccoed with a mixture of 1 part cement to 3 parts of sand to which was added 10 per cent hydrated lime to weight of the cement. The results obtained on these panels do not indicate that the stucco is unsuitable, but that the combination of stucco and a base giving a weak bond gives poor results.

The committee in approving this extensive and expensive program felt that honest mixtures and honest application in accordance with existing specifications would demonstrate the general satisfactoriness and dependability of stucco construction. It was, therefore, a great disappointment when a majority of the panels developed defects of one kind or another. Most prominent was the almost universal crazing and map cracking which is so unsightly. It had been specified that a sand-float finish should be used, and this finish should be given in the shortest possible time after laying on the finish coat. The purpose of this was to avoid disturbing the so-called initial set of the cement. In consequence, a very great majority of the panels were floated when the mortar was too soft, which resulted in bringing to the surface a rich mixture of cement or cement and lime subject to high shrinkage upon drying out. It was also thought that the excessive crazing and map cracking was possibly due to the use of too much water, not necessarily too much mixing water but too liberal soaking of the bases and the undercoats just before the application of the plaster.

The observations of these panels indicate that the cement mixes with a small proportion of lime were the most satisfactory and the indications were that the leaner mixes gave better results than the ones commonly specified at that time.

The prominence which the smooth sand-float finish gives to fine cracks, unevenness of texture, blotches, and other small defects suggests the advisability of finishing stucco exteriors with the rougher surfaces, such as " rough-cast " or " pebble-dash " finishes.

3. TESTS OF 1916

Following the suggestions obtained in the 1915 series of tests the advisory committee went to work on a supplemental program. It was decided to pay more attention to the method of application in the next series of panels and to investigate further the use of the leaner mixtures.

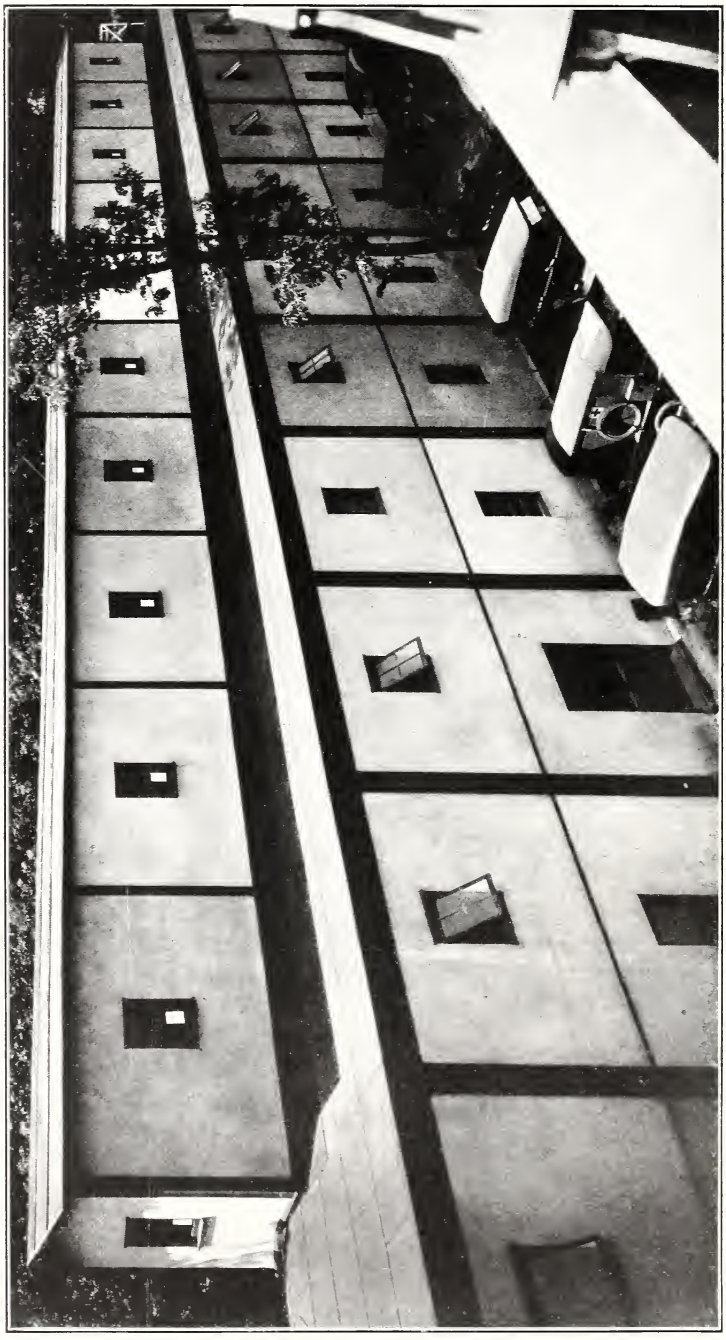

FIG. 4.—*Monitor or pent house on main stucco test structure erected in 1916 for the study of stucco on frame*

All of these ideas were embodied in 22 new panels erected on the roof of the original test structure. These addditional panels formed the walls of a closed monitor or penthouse. This location precluded all but frame construction. One side of the penthouse was generally of open-stud framing without sheathing. On this side were two types of fabric or proprietary stucco board, two plaster-board panels, and the remainder were typical back-plastered metal-lath construction including two or three experimental fasteners for lath. The other side of the penthouse was fully sheathed with 6-inch sheathing placed diagonally, the direction of the sheathing alternating on adjacent panels. These panels included metal lath and wood lath plastered with a variety of stucco mixtures. The deductions from the 1916 tests may be summarized as follows:

Diagonal sheathing of unseasoned wood is apparently an unsatisfactory backing for stucco. With only unseasoned wood available, horizontal sheathing would appear to be better construction provided sufficient bracing of the wood frame is assured. Back-plastered construction appears to be the best for frame structures so far as the integrity of the stucco is concerned. This carries with it, however, a need for attention to the insulating qualities of the walls so constructed and attention to the rigidity of the framing. Lean mixtures give better cement stucco, provided the necessary plasticity and density can be maintained by the grading of the aggregate.

The change of the method of finishing partly in the use of less water on the undercoat and partly waiting for the stiffening of the finish coat to develop before final floating produced a great improvement over the previous work, and as a result craze cracks were largely, if not wholly, eliminated. The larger pattern map cracks were also greatly reduced, and this was particularly noticeable in the case of those panels which were stuccoed with radically lean mixtures.

4. LABORATORY STUDIES

During the war period active work on the stucco investigation was suspended, but immediately afterwards some laboratory studies were carried out on the shrinkage of Portland cement mortars. It has been indicated that crazing and map cracking in cement stucco seems to be related in some way to the overwetting of the bases or undercoats, and it seemed desirable to study the behavior of some of the stucco mixtures in the laboratory. A special comparator was built, by means of which it was possible to measure the shrinkage or expansion of mortars at any time before, during, or after set. These tests were continued over two years, and at the end of that time a great deal of valuable information had been obtained. It was found that the mortars showed very erratic behavior during

the time that they remained plastic; that is, before set occurred, and that by control of the water in the mix, either through removal by absorption or evaporation or through retention by covering or placing in a damp atmosphere, one could produce shrinkage, expansion, or no change at all. The condition under which minimum change took place both before and long after set occurred was that in which the water in the mortar or plaster was removed by an absorptive backing so that set or stiffening occurred from this removal of water before chemical set occurred. The application of this knowledge to the actual conditions which prevailed in the stuccoing of the test panels explained why some of the panels were good and

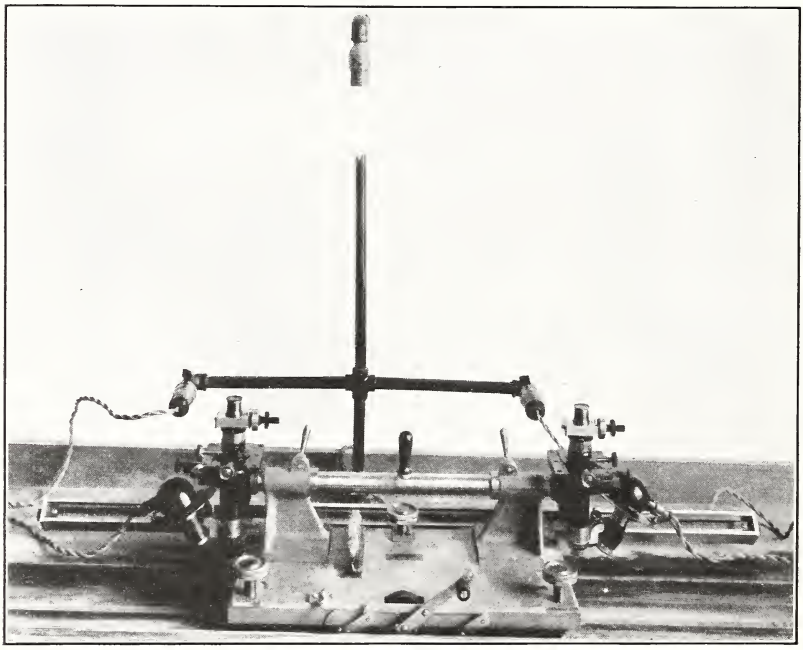

FIG. 5.—*Comparator used in the measurement of expansion and contraction of Portland cement mortars*

others poor and enabled specifying a procedure which can be depended upon to largely eliminate crazing and map cracking. These defects are simply due to excessive shrinkage, and the excessive shrinkage can be avoided by proper control of moisture in the base or under coats as an essential part of the finishing operation.

5. TESTS OF 1922

The first opportunity to apply the information obtained from this laboratory study came in 1922 when, through the cooperation of the National Steel Fabric Co., 10 of the sheathed panels in the pent-

house were replaced with new panels. Aside from the demonstration of improved finishes these panels were designed to afford a comparison of the effectiveness of three types of metal backing; that is, expanded metal lath weighing 3.4 pounds per square yard, 20-gauge galvanized woven wire lath with V-rib stiffeners, and three weights of 2 by 2 inch mesh-steel fabric.

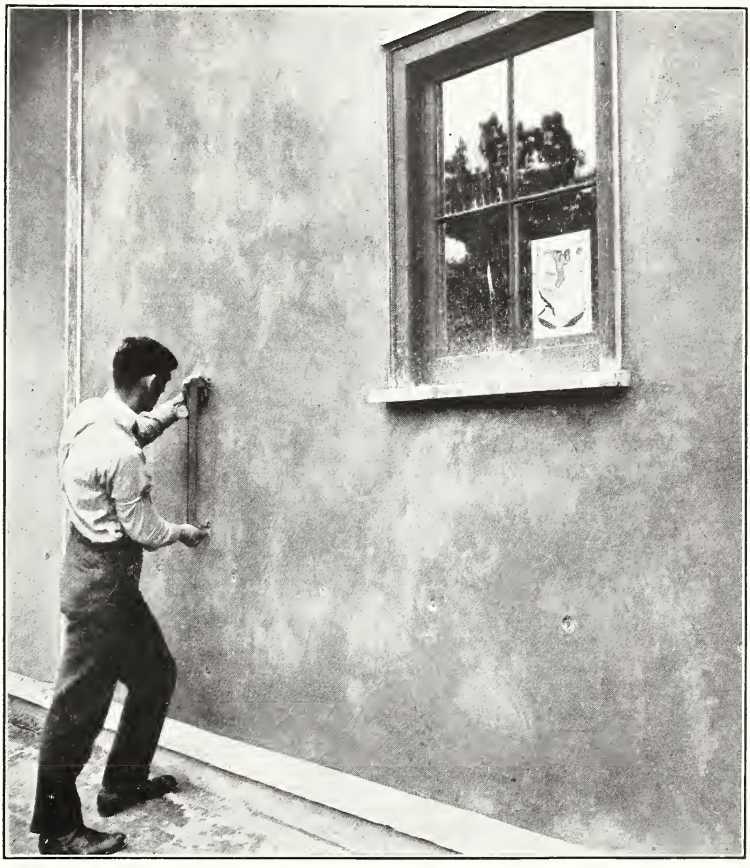

FIG. 6.—*Use of the strain gauge in measuring the expansion and contraction of the stucco test panels*

The study of the conditions of these 1922 panels indicate that by water control, crazing and map cracking may be eliminated. The reinforcing value of the lath used was not shown conclusively. This is due to the fact that although the penthouse was nearly 6 years old when these tests were carried out there was considerable shrinkage and expansion of the sheathing which had a greater destructive effect on the stucco slabs than any restraining effect of the reinforcing fabric. It was seen that for the best results in frame and stucco

construction sheathing should be placed horizontally and at right angles to the studs. The results also suggested that if sheathing is to be used some means of providing a flexible tie of the stucco slab should be developed.

6. TESTS OF 1923

It seemed desirable to build at least one more series of test panels on frame to dispose, if possible, of certain unanswered questions in the present practice for cement stucco. These questions were substantially as follows:

1. Is wood sheathing or open framing best for stucco finishes?
2. Is the reinforcing value of the lath or fabric of sufficient importance to warrant a recommendation for heavier lath and higher cost?
3. What method of attachment of lath or fabric to sheathing will most effectually minimize the transmission of strains to the stucco slab?
4. Is curing of stucco to be recommended and to what extent is it worth the additional cost?
5. Is it beneficial to delay the application of the finish coat of stucco for an interval of several days?

The bureau thought it well worth the cost to try to answer these questions, but its appropriations were not sufficient to provide for the erection of the required number of panels unassisted. The matter was laid before the National Lumber Manufacturers Association, the Portland Cement Association, the Associated Metal Lath Manufacturers, and individual manufacturers of wire lath and steel fabric. These groups responded most generously, and through their cooperation a program was drawn up and carried out involving the replacement of 32 of the stucco panels on the test structure.

Of the 32 panels of this series 20 are backed with horizontal sheathing and 12 are either back-plastered or paper-backed construction on open studs. These panels were completed in November, 1923. After they had been exposed for a round of seasons or for a period of approximately one year a committee composed of 6 members—3 from the commercial stucco interests and 3 from the cement division of the bureau—was designated to inspect and rate the panels.

While this series of tests may be too limited in scope to give final and definite answers to these questions the progress conclusions may be stated as follows:

1. That in so far as the stucco itself is concerned back-plastered and possibly paper-backed construction seems preferable to sheathed construction. The questions of insulation and proper bracing of the

frame, of course, have to be considered in this connection, and it appears that when sheathing is used it should be placed horizontally.

2. The four types of metal bases used in these tests were painted flat and self-furring diamond mesh metal lath, 24 gauge, weighing 3.4 pounds per square yard; 18-gauge wire lath, 2½ meshes per inch, weighing 4.05 pounds per square yard; 20-gauge wire lath, 2½

FIG. 7.—*Applying the finish coat to a stucco test panel*

meshes per inch, with three-eighths-inch V ribs at 8-inch centers, weighing 2.48 pounds per square yard; and 14-gauge paper-backed steel fabric, with 2-inch openings, weighing 2.0 pounds per square yard. As each type of base has some distinct feature not contained in the others, definite conclusions as to the comparative merits can not be drawn. If the wire laths and the steel fabric are considered of similar construction, being made of wires at right angles to each

other, the results tend to indicate that the heavier members have a greater reinforcing value, but the relation of proper spacing and size of member requires further study.

3. There seems to be no positive indication of advantage of one type of furring over another in attaching metal lath to sheathing. While there appears to be some slight indication in favor of the loose tie, the number of panels involved was so limited that a more extensive study would be necessary before any recommendation for a change in the present practice could be made.

4. A certain amount of curing is considered beneficial, and it is believed that if new stucco can be protected from too rapid drying out that the ultimate shrinkage is less and an early development of strength is obtained.

5. The results of these tests did not indicate that a delay in the application of the finish coat was particularly beneficial, and it would appear that as good or possibly better results would be obtained through greater thickness of the plaster body by having the coats applied on successive days.

7. OTHER PUBLICATIONS

The foregoing paragraphs have summarized somewhat briefly the stucco investigations carried out thus far at the Bureau of Standards. For those readers interested in a more extended study of any series of tests there is given below a list of papers which have been prepared at the bureau on the several phases of the work.

1. Some comparative corrosion tests of plastered metal lath, J. C. Pearson, Proc. Am. Conc. Inst., **10**, pp. 445–458; 1914; also Concrete Cement Age, **5**, p. 38; 1914.
2. Durability of stucco and plaster construction. R. J. Wig, J. C. Pearson, W. E. Emley, B. S. Tech. Paper No. 70, January, 1917.
3. Tests of stucco, J. C. Pearson, Proc. Am. Conc. Inst., **14**, pp. 109–123; 1918.
4. Shrinkage of Portland cement mortars and its importance in stucco construction, J. C. Pearson, Proc. Am. Conc. Inst., **17**, pp. 133–148; 1921.

III. RECOMMENDATIONS FOR PORTLAND CEMENT STUCCO CONSTRUCTION

1. GENERAL

While, as experience of the past has shown, Portland cement stucco may develop certain small defects which can not always be guarded against, the product may be depended upon if properly applied to be structurally sound, durable, and capable of giving satisfactory service for long periods of time with little or no outlay for repair or maintenance. In the use of stucco there are four fundamental factors which must be taken into consideration. First, the building must be designed and properly constructed for stucco; second, the material must

be applied to a suitable base; third, the mortar must be properly proportioned and carefully mixed from good materials; and, lastly, it must be applied by workmen having a knowledge of the material and skilled in its application, because workmanship can not be written into specifications.

2. DESIGN OF BUILDINGS

In the design of a new building or the remodeling of an old one for the application of stucco the designer should detail so as to prevent water from getting back of the stucco and avoid having it wash in a concentrated flow over the face of the walls. These requirements can be generally met by an overhanging roof, by suitable flashings, and by the use of drip grooves. It is better to confine the use of stucco to vertical surfaces, and for sills, cornices, and copings use other materials which can be expected to take the more severe exposure. Whenever it is necessary to use stucco on surfaces other than vertical, the surfaces should be given the greatest possible slope to prevent water from standing on them. Stucco is often run to the ground, and probably on masonary bases it suffers no ill effects other than that of appearance from splash and efflorescence, but it is better to stop stucco at least 1 foot above grade to protect it from ground moisture. This should always be done in the case of metal backings on frame construction.

The foregoing paragraphs are supplemented by Figures 8, 9, and 10, which show suggested details for stucco on sheathed and backplastered construction and on masonry walls.

3. MATERIALS

(*a*) Cement.—A good quality of cement should be always used, and on large contracts it is generally required that the cement meet the specifications of American Society for Testing Materials.

The ordinary Portland cement is usually grayish in color, but varies from yellowish gray to a slate. The color is largely affected by its composition, particularly by the amount of the iron oxide content and in some cases by the manganese content.

White Portland cement is one which contains a very small amount of iron oxide content. It is largely used in the finish coat because its white color permits the attainment of desired color effects, either with white or yellow sands or added pigment materials.

(*b*) Fine Aggregate.—The fine aggregate mixed with the cement to make the mortar is usually a natural sand or screenings from crushed stone. It should be well graded from fine to coarse within the limiting sizes. When dry, it should all pass the No. 8 sieve having square openings of 0.0937 inch on a side and from 20 to 25 per cent passing the No. 50 sieve with openings of 0.0117 inch. It

should be free from loam, vegetable, or other deleterious matter. If there is reason to believe that the sand may contain organic matter, it can readily be tested by the colorimetric test as given by the Standard Method of Test for Organic Impurities in Sands for Concrete (C40–22), A. S. T. M. Standards, 1924.

(*c*) Water.—The water used for mixing stucco mortars should be suitable for drinking purposes. The usual specification requirements are that it should be clean and free from oil, acid, strong alkali, or vegetable matter.

(*d*) Hydrated Lime.—Small amounts are often used in stucco mixtures, and when used it should meet the requirements of the specifications of the American Society for Testing Materials for Structural Lime. Hydrated lime should be specified to the exclusion of lump lime chiefly for the reason that quicklime slaked on the job can not be so thoroughly hydrated or so thoroughly mixed in the mortar as the prepared hydrated material.

(*e*) Hair or Fiber.—Hair or fiber is often used in the scratch coat of stucco applied on metal lath, especially if the work is to be back plastered. It should be of first quality long hair free from foreign matter or a long fiber well combed out. It should be carefully incorporated so as to insure good distribution through the mortar with freedom from clots.

(*f*) Coloring Materials.—Various materials are used for coloring stucco through their incorporation into the mix. Most of them are mineral pigments. The use of oil paints for coloring is open to question, and considering the permanency of the colors it is advisable to adhere to the mineral pigments, most of which are oxides.

The variety of available colors is given briefly below. The colors of the iron oxides will vary according to their origin.

Natural iron oxides.—Red, brown, chocolate.
Iron hydroxide.—Yellow.
Manganese dioxide.—Black.
Lampblack.—Black (grayish).
Carbon gas black.—Black.
Ultramarine.—Blue.
Chrome oxide.—Green.

As in preparing paints so in stucco, many desired tones or shades may be secured through combinations of the various pigments. A variety of color effects may be obtained by the selection and combination of white and gray cements and suitably colored natural fine aggregates.

(*g*) Metal Bases.—At the present expanded metal lath, wire lath, and wire fabrics are used largely as bases for stucco on frame construction. These materials are not generally closely specified. Expanded metal lath is either galvanized or painted and generally is

required to weigh not less than 3.4 pounds per square yard. Sometimes the gauge of the metal is also required to be not less than 24 gauge. Woven wire lath may be galvanized or painted and has 2½ meshes to the inch. It is generally woven from wire not lighter than 19 gauge. It is furnished with or without ribs, and where ribs are included they are generally spaced 8 inches on centers. The wire fabrics are usually of 14-gauge wire galvanized before fabrication and may be either spot welded or woven. The openings are either triangular or square of approximately 2 inches on a side. There are several added features in the different types, such as self-furring attachments and paper backings.

4. CONSTRUCTION

(*a*) Gutters and Down Spouts.—All roof gutters should be fixed, and down-spout hangers and all other fixed supports should be put in place before plastering is started in order to avoid breaks in the stucco.

(*b*) Flashings.—Flashings should be provided before starting the plastering at the top and on the sides of openings wherever projecting wood trim occurs. They should be provided also across masonry walls under coping, cornices, and sills with mortar joints. The flashings should be made of materials that will not oxidize and stain the stucco and should extend beyond and slightly over the face of the finished surface.

(*c*) Wood Trim.—All trim should be placed in such a manner that it will show its proper projection in relation to the face of the finished stucco.

(*d*) Half Timbering.—Embedded trim or half-timbering should be securely nailed to the sheathing or studs and the sides of the pieces grooved so that the mortar of the scratch coat can be forced into the grooves to form water-tight joints.

(*e*) Framed Construction.—Framed structures to be finished with stucco should have special bracing to prevent racking and be set on well-built foundations to avoid the possibility of settlement. Small movements due to these causes would have no effect when the structure is finished with wood siding, but when stucco is used they may cause unsightly cracking. Diagonal braces of 1 by 6 inch boards 6 to 8 feet long let into the studs on their inner sides at the upper and lower corners of each wall and bridging between the studs at least once in each story height add much to the rigidity of frame walls. If sheathing is used, this bracing is not so necessary, but it is an added factor for the stability of the structure.

The studs are usually 2 by 4 inches, placed 16 inches on centers when sheathing is used and 12 inches in back-plastered or open-frame construction. The studs should be run from the sills to the eaves

without intervening horizontal members to avoid any lack of uniformity or point of weakness in the wall construction.

The frame stucco structure may be sheathed or not, but the present tendency in so far as the stucco is concerned is to omit the sheathing and use either the back-plastered or the open-frame construction. If sheathing is used, it should be placed horizontally across the wall studs and not diagonally, although in many sections of the

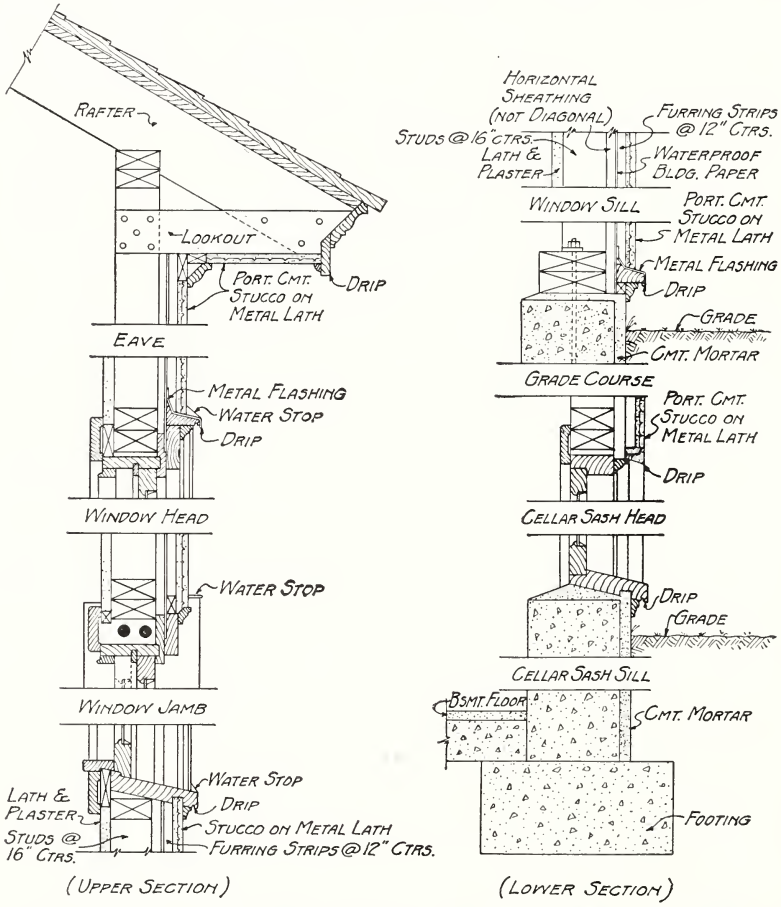

FIG. 8.—*Suggested details for stucco on sheathed frame construction*

country diagonal sheathing is used to furnish greater rigidity to the frame. Good rigidity will be obtained by using the system of bracing described above, and by placing the sheathing horizontally a considerable saving will be effected in both labor and material.

(*f*) WATERPROOF PAPER.—Over the sheathing should be laid a good grade of waterproof paper, beginning at the bottom of the wall. The bottom strip should lap over the baseboard at the bottom, and each succeeding strip should lap the one below at least 2 inches. It should

be well fastened by large-head roofing nails. The paper should lap the flashings at all openings.

(*g*) Application of Furring and Metal Base.—If separate furring is used, this is applied over the paper along the lines of the studs. There are several types of furring, and probably that most widely used is ⅜-inch crimped furring made from 22-gauge metal. The metal base should be applied next in such a manner as to

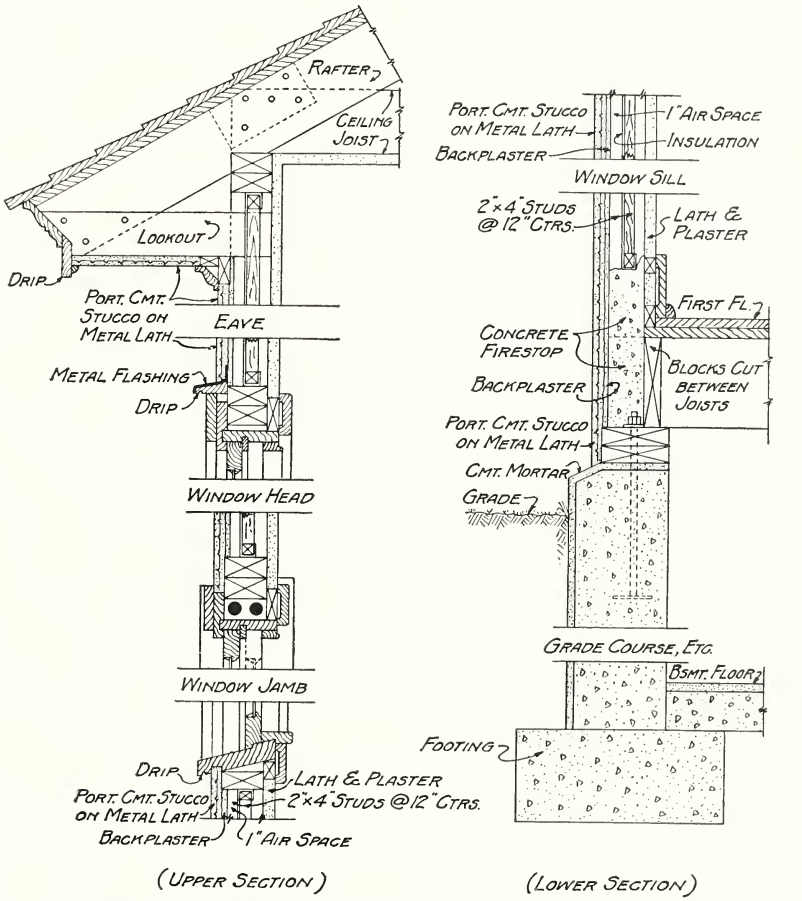

Fig. 9.—*Suggested details for stucco on back plastered frame construction*

form as nearly as possible a uniform fabric over the structure. Particular attention should be given to thoroughly tying and lacing the joints of the base with galvanized wire. The nailing or stapling should be not more than 8 inches apart along the furring lines. Several types of self-furring bases are on the market, and by their use a saving is effected by the elimination of the furring operation. The use of butt joints well tied gives greater uniformity of

base section than do lap joints, and rigidity and uniformity in the metal base are essential to satisfactory stucco on frame construction.

(*h*) Back-Plastered Construction.—In this type of construction the base is nailed or stapled directly to the studs over the furring. After two coats of plaster have been applied to the exterior face the wall is back plastered on the inside between the studs to

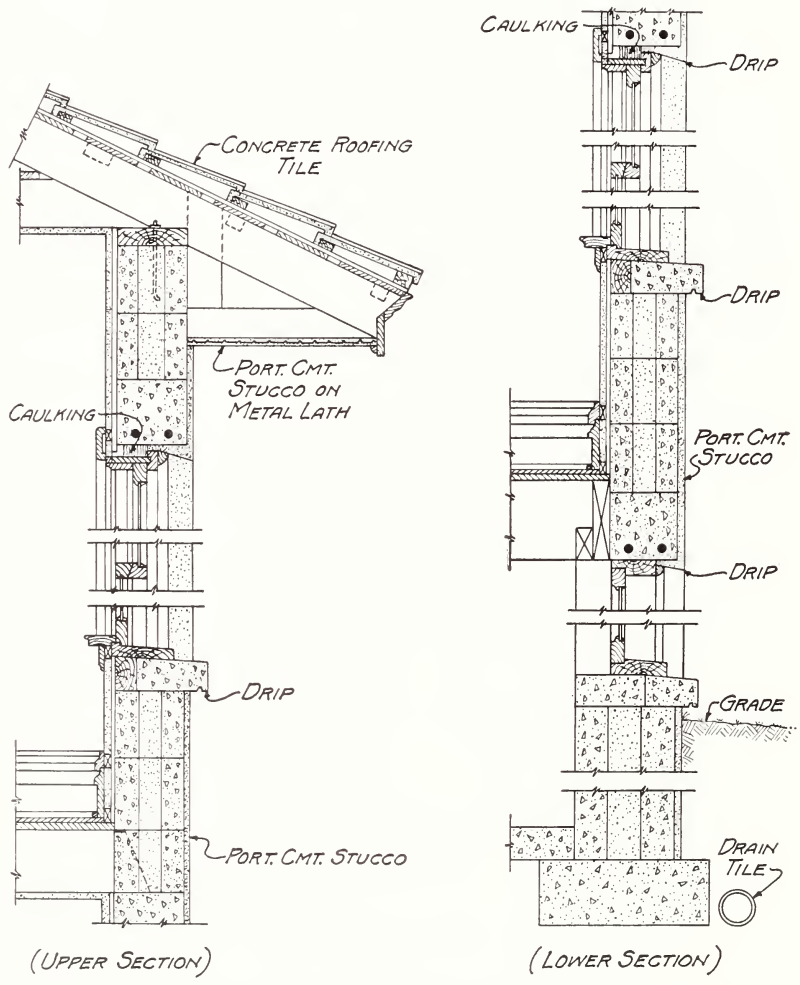

Fig. 10.—*Suggested details for stucco on masonry construction*

embed the base completely and to form a thicker wall. Often the back plastering is done after the first coat has hardened, but it appears logical that when the scratch and brown coats are applied first there is less likelihood of injury, the greater thickness caring for the necessary pressure used in applying the backing coat. The back-plastered coat usually finishes one-fourth inch or more back

of the outside face of the studs and helps to stiffen the entire frame. A wall of this type loses the insulating value of the sheathing and paper, and to compensate for this a layer of felt or other insulating material is usually applied between the studs in such a manner that a double air space is formed between the inside plaster and the outside stucco.

(*i*) Open Construction.—There are several types of paper-backed self-furring metal bases on the market which are made up in convenient sized sheets for applying directly to the studs. The advantage of these is that paper, furring, and base are applied in a single operation. The paper is fastened to the base sufficiently loose so that the pressure of the trowel in applying the mortar causes the paper to bulge enough to embed practically all the strands of the metal. This type of construction is quite similar to the back-plastered except that the three coats are laid on from the outside face of the wall. The same type of wall is also constructed on the ordinary bases without paper and the self-furring features. First, a good tar or asphalt-saturated paper is loosely applied to the studs, and the furring is attached over it at the stud lines. Then the metal base is applied. In this type of construction, as well as in back-plastered work, special attention should be given to proper bracing and adequate insulation.

(*j*) Masonry Walls.—Masonry walls are superior to frame walls for the application of stucco because of their greater rigidity. In order to keep the stucco coats of uniform thickness walls of monolithic concrete, concrete units, brick, and hollow load-bearing tile should be reasonably straight and true and should be constructed on unyielding foundations.

The units of all masonry walls should be set with a Portland cement mortar or Portland cement lime mortar. The joints should be cut back even with the face of the wall, and if the joints are raked three-eighths inch an additional key is furnished. Wood lintels should not be used over wall openings. The surface to which the stucco is to be applied should be rough and of coarse texture and be free from dust, dirt, and loose particles. Monolithic walls where necessary should be roughened by hacking and wire brushing. Clay tile should be well burned with dovetail or heavy ragged scoring. The clay brick also should be rough and well burned.

When overcoating an old wall which has been painted or treated with a waterproofing material, the wall should be covered with a metal base before applying the stucco.

5. MIXING AND APPLICATION

(*a*) Tools.—The tools needed for the mixing and application of stucco are few and simple and are those which have been used by

the plastering trade for many years. The mixer or hod carrier requires the ordinary tools, such as shovels, hoes, water barrels and buckets, hods, and mixing box. The plasterer uses the more specialized equipment, such as the mortar board, the hawk, trowels, floats, brushes, rods, and darbies.

At the present time on large operations there is a tendency toward the use of machines for mixing the mortar. There have been developed also machines for applying the stucco but these have not come into general use and probably will never replace the skilled craftsman. The cement gun may be an exception and has been used to a considerable extent on some larger projects with good results. However, in the finest work the application of the finish coats calling for skill and an appreciation of color and texture will continue to be done by experienced workmen.

(*b*) Mixing.—The thorough mixing of the stucco mortar is of first importance. Dry mixing of the ingredients should be carried on until the batch is uniform in color and the wet mixing until the consistency is uniform. All the ingredients including the water must be carefully measured for each batch, and all the batches should be proportioned exactly alike in order that the same consistency and color be maintained throughout the work. In machine mixing, the machine should be run at least five minutes after all the ingredients are placed in the mixer, and in hand mixing the batch should be hoed back and forth in the box from 10 to 15 minutes after the water has been added to the mix.

(*c*) Proportions.—The present tendency is toward the use of leaner mixtures than those specified in the past. A good general proportion which is widely used for stucco mortar is 1 sack of cement to 3 cubic feet of sand or stone screenings and 10 pounds of lime. If the sand or screenings are well graded from fine to coarse within the limiting sizes or contain a considerable amount of fine material, larger proportions of aggregate can be used. The reason for the use of the lean mixtures is that the tendency of cement mortars to expand and contract under varying moisture conditions is in a measure proportional to their cement content. As this volume change is the chief cause of structural defects in stucco, the advantage of using the lean mixtures is apparent. However, on the other hand, there must be maintained a balance between the leanness and the strength, bond, and durability of the mortar. Further, workability must be considered because if a mix is harsh and short working the time required for the plasterer to apply it is greatly extended.

The plasticity of the mixtures can be improved by the addition of fine sand or hydrated lime. When lime is used, it is generally

specified that not more than 10 pounds of lime shall be used to a sack of cement.

For field measurements a cubic foot measuring box can be used to advantage. Using such a box 16 cubic feet of sand can be measured into the mixing box and leveled off. The top of the sand can be marked on the sides of the box with a colored crayon, and in succeeding batches the box can be filled even with this mark. To the 16 cubic feet of sand can be added 5 sacks of cement and one 50-pound bag of hydrated lime. This will be very close to a 1:3 mortar by volume, to which has been added 10 per cent of hydrated lime by weight of the cement. The additional foot of sand is added to care for possible bulking of moist sand.

(*d*) Quantities of Materials.—The following table may be used for estimating the amounts of materials necessary for 100 square feet of wall surface for various thicknesses of the stucco coats. As the character of sand and its moisture content vary greatly it should be used for approximate quantities, and it is well to add 10 per cent to the totals obtained to care for waste and the keys formed back of the lath.

Thickness of coat	Proportions 1:3 with one-tenth hydrated lime		
	Cement	Lime	Sand
	Sacks	*Pounds*	*Cubic feet*
¼ inch	0.73	7.0	2.20
⅜ inch	1.10	10.3	3.30
½ inch	1.47	13.8	4.40
¾ inch	2.22	20.8	6.60
1 inch	2.94	27.6	8.80

(*e*) Consistency.—Only enough water should be used in mixing to produce a mortar that can be readily worked and applied. The exact amount for the materials at hand will have to be determined by trial. However, after the proper amount is once determined it should be closely adhered to in all the mixes.

(*f*) Retempering.—Retempering mortar by the addition of water should never be done, and mortar which has started to stiffen should be cleaned off the board or box and thrown away.

(*g*) Waterproofing Materials.—In properly proportioned and applied stucco it does not appear necessary to use waterproofing materials in the mortar mixes, nor have tests shown that any benefit is derived by waterproofing the face of the studs in back-plastered construction. Stucco will absorb water to some extent during rainy weather, but this will not injure it.

(*h*) Number and Thickness of Coats.—For first-class work on frame structures three coats of stucco should always be applied.

Often when stucco is applied to masonry walls that are nearly true planes only two coats are applied. However, if the wall is not true it is desirable to apply three coats as for the frame construction.

The first coat, commonly known as the scratch coat, should thoroughly cover and bond firmly to the base, since it attaches the stucco to the wall and transmits the weight of the other coats. It should be at least one-fourth inch thick over the face of the base in order to receive fairly deep and rough scoring which provides a mechanical key for the second coat. The second, or brown coat, is generally applied the day after the application of the scratch coat. Its function is to straighten the wall, and it should have an average thickness of from three-eighth to one-half inch. When the brown coat has been straightened and has partially stiffened, it should be gone over with a wooden float to compact it properly, and then it should be lightly scored to receive the finish coat. The stuccowork is now ready for the last or finish coat, which serves merely as a decorative treatment and is usually about one-fourth inch thick. While there are many advocates of allowing the first two coats to cure several days before applying the finish coat, it has been noted at the Bureau of Standards that shrinkage cracks which developed in the scratch coat later appeared in the brown coat, and finally these same cracks showed through the finish coat. Therefore, it would seem more logical to apply all three coats one day apart, building up a fairly heavy thickness of mortar and keeping this uniformly wet for several days than to expect a finish coat of one-fourth inch to permanently seal cracks which had already worked through the first two coats.

(*i*) Wetting of Surfaces.—Immediately preceding the application of the scratch coat the surface of the wall (particularly masonry walls) should be wetted down, but it should not be saturated, so that there will be free water on the surface. Too dry a surface will absorb all the water from the mortar before it has had time to set. On the other hand, a wall completely saturated has lost all its absorptive power or "suction," a slight amount of which is necessary to secure the proper bonding. A slight amount of suction tends to draw the fine cement particles into the pores of the wall, and upon this action the bond of the stucco depends. If this bonding is to be as strong as possible, the surface should be neither dry nor completely saturated. This same condition of wetting of each coat is necessary before applying the succeeding coat to prevent excessive absorption.

(*j*) Application of Coats.—The application of the stucco coats should be carried on continuously in one general direction without allowing the stucco to dry at the edges. If it is impossible to work the full width of the wall at one time, the jointing should be at some

natural division of the surface, such as the side of a door or window opening.

(*k*) Curing and Protection.—To obtain the best results, the stucco should be thoroughly wetted nights and mornings for several days after the final coat is applied and sufficiently hardened to allow it to be sprayed with water. Freshly applied work should be protected in so far as possible from sun, rain, and freezing weather. As a general rule, no exterior plastering work should be attempted when the temperature is below 40° F. unless some protection can be given the stucco for at least 48 hours.

6. FINISHES

(*a*) Classes.—The finish coats of stucco may be divided into three general groups according to the texture and method of application. These are, first, dash finishes of the wet and dry type; second, the smooth finishes comprising the various modifications of the float finish; and, third, the exposed aggregate or surface treated concrete.

(*b*) Wet Dashes.—The wet-dash finishes include the "rough cast" or the "pebble dash," which is obtained by throwing with a paddle a mixture of cement grout and pebbles of a definite size against a fresh coat of mortar. The "spatter" dash is obtained in very much the same manner as the rough cast except that a very thin mixture of cement and coarse sand or stone screenings is dashed against the fresh mortar. The "sand spray" or "broom dash" is obtained by applying a creamy mixture of cement and sand with a whisk broom or a long fiber brush. The broom is dipped into the grout and then struck across the forearm or a stick held in the left hand, spraying the mixture on the finish coat of mortar.

All these finishes are of comparatively low cost and are readily executed by workmen of ordinary skill. Owing to their rough texture they have the advantage of hiding the fine shrinkage cracks which develop to a greater or less extent in Portland cement stucco on hardening. These features contribute to the widespread use of the wet-dash finishes, and for the usual run of stucco work they are recommended.

There is considerable objection to the wet dashes because of their dull and cold uniform cement color. This objection may be met by using the white cement in the finish coat and dash or by tinting with mortar colors.

(*c*) Dry Dash.—The dry-dash finishes are generally obtained by throwing with considerable force clean pebbles, stone chips, or pieces of shell against the finish coat before it has hardened. The aggregate should be largely of one size and should be uniformly distributed over the surface. The pieces may be pushed into place by the

use of the float, but there should be no rubbing of the surface after the pieces are embedded. This finish is quite difficult to execute properly, but when well done it produces an acceptable color and texture quite different in character from those of the wet dashes.

FIG. 11.—*Rough-cast finish*

(*d*) FLOAT FINISHES.—The sand-float finish is produced by carefully floating the finish coat after it has taken its initial hardening. A lean finish coat is necessary, and it should be carefully straightened before floating is started. After the stucco has well stiffened, water is dashed on it by means of a brush and the final floating carried

out until the sand tones predominate. It is probably the most difficult of all the finishes to execute and obtain acceptable surfaces. As the surface is smooth, imperfections of workmanship and defects show very conspicuously, and this finish should only be undertaken by workmen with considerable skill and experience.

FIG. 12.—*Sponge-float finish*

(*e*) TEXTURES.—In order to obtain finishes of a pleasing texture and to avoid the monotony of the dashes and the difficulties of execution of the float finishes, a number of finishes have been developed by specialists and manufacturers of colored stucco. Color tones are introduced, and with combination of colors and methods of finishing there are unlimited possibilities as to number of surface effects which

can be devised. One of these finishes has been named "floated rough cast." The wall is prepared for a rough-cast finish, and then the high points are lightly smoothed off with a plasterer's wood float. This finish lends itself readily to a two-color combination. First, the finish coat of one color is applied and partially floated and

FIG. 13.—*Floated rough-cast finish*

while still plastic another color is dashed on and then the high points smoothed off and the two colors blended together. Another has been called the "sponge-float" finish and is produced by carefully working the plastic finish coat with a softwood float drawing the float away from the surface at random. The suction between the float and the stucco gives a roughness of surface which is between the

extremes of the roughness of the wet dashes and the smoothness of the sand-float finish. When executed in colored stucco, it gives a very acceptable finish.

(*f*) EXPOSED AGGREGATE.—Although the name "exposed aggregate" has been applied to the ordinary troweled or floated surface

FIG. 14.—*Exposed aggregate finish*

(See fig. 1)

which is given a final scrubbing treatment with brush and water or a cleaning with an acid wash, the name will be used here in connection with a finish which should be more properly designated as a surface-treated concrete. The exposed aggregate finish is obtained by applying a finish coat which in itself is a concrete with miniature aggre-

gate. The cement and fine sand bear a definite relation to the coarse aggregate which predominates the mix. The coarse particles have to be sized and proportioned to the fine material in keeping with the architectural features of the building and in accordance with the effect which it is desired to produce when the structure is viewed from a given distance. Usually the coarse particles are of one size from ⅛ to ¼ inch and upward and are proportioned into the mix to give a maximum density. This coating is applied and after it has stiffened the surface film of cement and finer aggregate is removed by gentle brushing with a wire brush and then the coat is left to harden and dry out. Next, it is washed with dilute acid and clean water. By removing the cement and fine particles the color of the surface is determined by the color of the aggregate and its texture by the size and shape of the coarse particles.

While this treatment ranks first as a stucco finish, it is also the most difficult of stuccowork to plan and execute. By the use of colored aggregates the most beautiful of color tones can be obtained and due to its density and texture many of the common structural defects are eliminated. To carry out the work successfully requires the selection, grading, and proportioning of the aggregate from a knowledge of size effect and color tone, and to obtain a uniformity of appearance over the entire surface requires the highest type of workmanship in the application and finishing of the coat.

7. MAINTENANCE OF STUCCO

(*a*) Cleaning Stucco.—As stucco construction becomes more common the cleaning of stucco also becomes an important problem. Portland cement stucco is not injured by the application of water or by the application of water and cleaning materials. It may be cleaned by hose applications of water and brushing with a wire or fiber brush, or it may be first cleaned by vigorous scrubbing with soap solution and fiber brush and then thorough rinsing with clean cold water. These treatments will usually remove all dust and smoke stains. If the stucco is unusually dirty, it may be washed with a solution of muriatic acid, 1 part of acid to 6 or 7 parts of water brushed on with a fiber broom, after which it should be thoroughly rinsed with cold water to remove all traces of acid. For white cement stucco it is better to use a sulphuric acid solution, as the muriatic acid has a tendency to produce a yellowish tinge on white cement.

(*b*) Repair of Stucco.—Due to alterations to a building it is often necessary to repair stucco construction. The methods are few, being limited to replacing the entire wall, which is expensive, or to patching areas and pointing up the cracks. Large cracks can be

cut back and pointed up and defective spots and new areas chipped back and patched. In the pointing and patching it is desirable to use the same brand of cement and the same proportions in the mixture as were used in the original work. Before applying the mortar the adjacent stucco should be thoroughly wetted. The repaired areas should be sprayed night and morning for several days to prevent rapid drying out. Should the renovated portions show up badly in contrast with the original wall after drying out the entire wall, or perhaps better, the entire structure may be gone over with a thin cement wash as described later which will tend to eliminate the difference in color and texture.

(*c*) Painting.—If it is desirable to change the color of a stucco or to bring a repaired structure to a uniform color, this can be accomplished by the application of either a cold-water wash or an oil paint.

(*d*) Cold Water Washes.—Cement washes of practically any color can be prepared by using the proper portions of gray and white cement and using light or dark sand with a small amount of mineral pigment. A mixture of 1 part white cement and 1 part yellow sand all passing the No. 20 sieve with 5 per cent of hydrated lime to weight of the cement will give a good, practically white color. In preparing the mix the cement, lime, coloring material, and sand should be properly proportioned and thoroughly mixed dry. The dry batch should be large enough to do the entire job or at least one side of the structure in order to maintain uniformity of color. Using a container full of clean water the dry material should be poured into the water and stirred vigorously until it has the consistency of a stiff oil paint. In applying, the mixture should be stirred with the brush from time to time to keep all the material in suspension. In refilling the container all the old wash should be cleaned out and thrown away and the same amount of clean dry materials and water used in preparing each batch.

Just before applying the wash the area to be coated should be thoroughly wetted, but as in the application of stucco coats there should be no free water on the surface. Starting at the top and one end of the wall the wash should be applied and brushed to the thinnest possible coat which will cover, as a thick coating is apt to craze or peel. The work should be carried on so that jointings come at natural breaks in the surface, and care should be taken to blend the adjacent areas together to prevent lines showing between them.

After the coating has been applied it should be gently sprinkled with water for several days. If it dries out before the cement has attained its set, the wash will eventually dust off. If a 4 per cent solution of calcium chloride, made by dissolving 4 pounds of com-

mercial crystals in 12 gallons of water, is used to gauge the wash, the calcium chloride assists in securing an early set and strength, so that the sprinkling need be carried out but for a short period of time.

(*e*) Oil Paints.—Oil paints can be applied to cement stuccoes, but there has been many failures of this combination, and it should only be undertaken by workmen having considerable knowledge and experience in this type of work. Too much emphasis can not be laid on the thorough drying of all concrete and cement work before painting. It should be remembered that such structures when new contain much water, and unless sufficient time under proper conditions of temperature and humidity is allowed for thorough drying the water remaining in the wall will eventually seriously injure any oil-paint coating. It should be pointed out that a wall may appear to be dry on the surface but be still damp in the interior. Even when properly dried new structures of this kind may contain free lime; hence, it is advisable when the structure is less than a year old even if it is known to be dry, to apply before painting an aqueous solution of zinc sulphate (3 to 4 pounds crystallized zinc sulphate to 1 gallon of water). Allow this to dry thoroughly before applying the paint. The surfaces can then be painted the same as wood, using either a white lead mixture or mixtures of white lead and zinc oxide. The priming coat should contain some boiled linseed oil.

Washington, May 20, 1926.