PLAINTIFF'S EXHIBIT

GP-989

AIA FILE NUMBER 21-A-2

Performance of Lath and Plaster

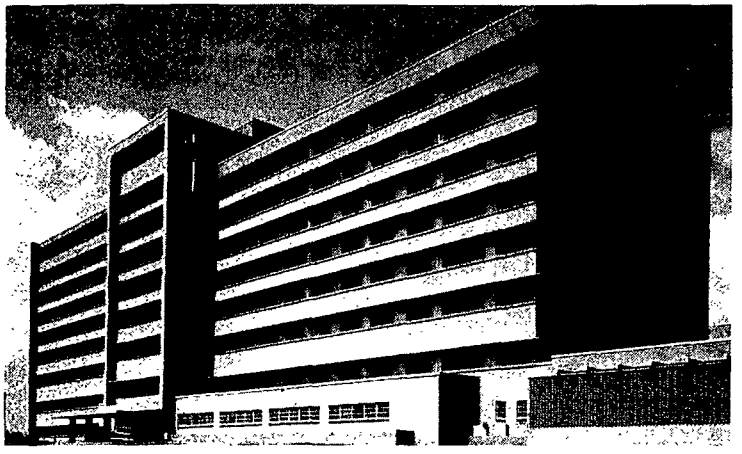
Research report
Recommendations



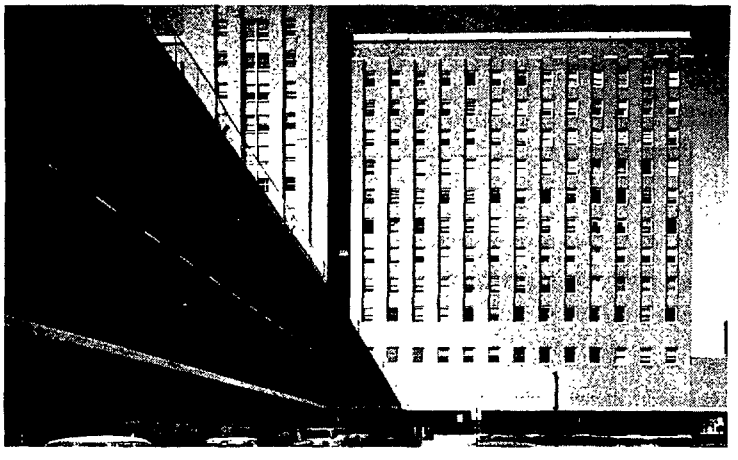
Gypsum Association
201 NORTH WELLS, CHICAGO 6, ILLINOIS

AIA FILE NUMBER 21-A-2

SGP 0003070



ST. VINCENT INFIRMARY
LITTLE ROCK, ARKANSAS



MAYO MEMORIAL MEDICAL CENTER
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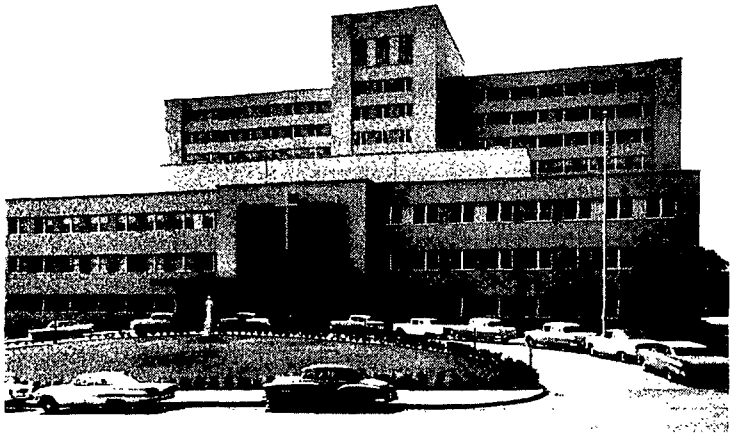

NEW SCHUMPERT MEMORIAL SANITARIUM
SHREVEPORT, LOUISIANA

For the past seven years, the Gypsum Association has conducted extensive research on the performance of lath and plaster ceiling systems. The purpose of this research was to develop plaster constructions that would provide a high degree of crack resistance. The phase dealing with small suspended ceilings is now virtually complete.

At the outset, it was determined from field experience that some 21 "variables" should be studied for their possible influence on performance. Since each variable was studied in a group of 3 ceilings, the final program included 62 such groups, requiring 186 ceilings.

The time element for conducting such a large-scale program in a laboratory was considered unacceptable. Furthermore, there was merit in making the study under job conditions, provided accurate controls and evaluation were possible.

So, the "laboratory was taken to the job" . . . to three large hospital projects, carefully selected for similarity as to construction, room size, etc.

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A study of the essential variables was duplicated in each of the three hospitals, separated geographically to provide some evaluation of the effect of climate. Except where noted, all lathing and plastering in this program was in accordance with the American Standards Association Standard Specifications A42.1 and A42.4 for Gypsum Plastering and Interior Lathing and Furring.

Since completion of plastering, the ceilings have been examined periodically and are still under observation. Although it is quite possible that future observations may slightly alter the current evaluation, definite trends and patterns have been established.

It should be emphasized that the conclusions here reported are based only upon the results of this study which is confined to suspended ceilings in rooms up to 20 square yards. It is reasonable to expect, however, that many of these observations are undoubtedly pertinent to other lath and plaster constructions.

CEILING SCHEDULE
SAND FLOAT 66 CEILINGS
TROWEL FINISH 120 CEILINGS

LATH	PERIMETER	AGGREGATE & PROPORTIONS
Gypsum	Restrained	Wood Fiber (Neat) & 1:3 Sand 1:2 - 1:3 Sand 1:2 - 1:3 Perlite 1:2 - 1:3 Vermiculite
Gypsum	Unrestrained	Same as above
Metal	Restrained	Same as above
Metal	Unrestrained	Same as above

From these extensive studies, it was found that the principal variables which affected resistance to cracking were:

types of finish coats
basecoat aggregates
plaster to aggregate ratio
type of lath
presence or absence of perimeter restraint

PERFORMANCE RATING SCALE

Relative performance with respect to cracking is expressed on a scale of 10. This rating reflects the actual measured length of objectionable cracking per unit area of ceiling. A rating of "10" represents best performance, with virtually no cracking, while a rating of "0" represents the most extensive cracking. The several ratings in this report have been calculated to show the effect of a particular fundamental variable, such as "restrained" versus "unrestrained" construction. That rating, for example, was arrived at by averaging the amount of cracking in the "restrained" ceilings, averaging the cracking in all the counterpart "unrestrained" ceilings, and expressing the comparative result on the standard scale of 10.

Obviously, a single figure such as this cannot fully describe the condition of a ceiling without further qualification. In certain cases, the type of cracking was such as to make successful patching or concealment almost impossible. Conversely, some ceilings showed cracking that was readily covered with normal decoration (paint). This cracking was considered non-objectionable and was not included in calculating the results.

THE EFFECT OF FINISH COATS

Of the 186 ceilings studied, 120 were finished with gypsum gauging-lime putty trowel finish, 60 with Keene's cement-lime putty sand float finish, 3 with prepared gypsum trowel finish and 3 with hard Keene's cement-lime putty trowel finish.

I KEENE'S CEMENT-LIME PUTTY SAND FLOAT FINISH

This finish, consisting of 100 pounds of Keene's cement, 150 pounds of dry hydrated lime and 600 pounds Ottawa silica sand, was applied to 60 ceilings over gypsum basecoat plasters aggregated with various proportions of sand, vermiculite and perlite (also wood fiber scratch coat) on both gypsum lath and metal lath; also to ceilings with restrained and unrestrained perimeter construction. In all cases, these ceilings developed an average of less than 5 inches of cracking per ceiling, with a rating of 10 points on the comparative scale.

This phase of the test program thus shows that ceilings finished with Keene's cement-lime putty sand float finish have uniformly excellent resistance to cracking, in conjunction with any or all of the various plastering systems included in this series of 60 ceilings.

II TROWEL FINISHES

Another 120 ceilings were finished with gypsum gauging-lime putty trowel finish. In addition, 3 ceilings were finished with prepared gypsum trowel finish and 3 with Keene's cement-lime putty trowel finish. The results obtained with the gypsum gauging-lime putty trowel finishes, in combination with each of the other principal variables, indicate a performance rating of 8.2 as compared to the rating of 10 for Keene's cement-lime putty sand float finishes.

THE REMAINDER OF THIS REPORT is devoted to ceilings having gypsum gauging-lime putty finish coats and to certain variables that affect performance of those ceilings. Composite ratings were calculated to show the over-all effect of certain variables as follows:

II-a Plaster Aggregate and Proportioning

The opposite table is a summary of strength test data from 310 2-inch cube specimens made on the various projects. A minimum of 5 cubes was taken at the mortar box at each sampling. The tabulated figures represent the average compressive strength in pounds per square inch of all of the cubes made for each of the various aggregates and proportions thereof.

Composite performance ratings have been calculated from the results obtained with different groups of ceilings (84 in all) in which the plaster aggregates and proportions are the only variables. That is, any one test group includes a number of ceilings in which the following types of plaster were applied over metal lath, and an approximately equal number of ceilings in which the same plasters were applied over gypsum lath. Here again, the composite figures represent a lumping of the results to show the over-all effect of a particular variable; in this case the aggregate and its proportioning:

The excellent rating obtained with the strongest plaster combination, neat wood fiber scratch coat and sanded brown coat, illustrates the important effect of plaster strength in improving crack resistance.

AVERAGE COMPRESSIVE STRENGTH (psi) OF PLASTERS USED

TYPE OF PLASTER	PROPORTIONS					
	NEAT	1:1	1:1½	1:2	1:2½	1:3
Gypsum-Wood Fiber	2173					
Gypsum-Sand				887		550
Gypsum-Perlite		901	716	679	521	448
Gypsum-Vermiculite		683		433	407	284

PERFORMANCE RATINGS

SCRATCH COAT	BROWN COAT	RATING
Neat Wood Fiber	1:2 or 1:3 Sand	10.0
1:2 Sand	1:3 Sand	8.9
1:2 Perlite	1:3 Perlite	8.1
1:2 Vermiculite	1:3 Vermiculite	6.3

In general, it can be concluded from these data that resistance to cracking is closely related to the strength of the basecoat plaster.

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II-b Metal Lath and Gypsum Lath

The relative performance characteristics of metal lath and gypsum lath are approximately equal when float finishes are used. However, when smooth trowel finishes are used their relative performance characteristics are indicated by the following composite ratings based on data from 75 ceilings. A trowel finish was used on all; but they included such variables as plaster aggregate and proportion, as well as unrestrained and restrained perimeter construction.

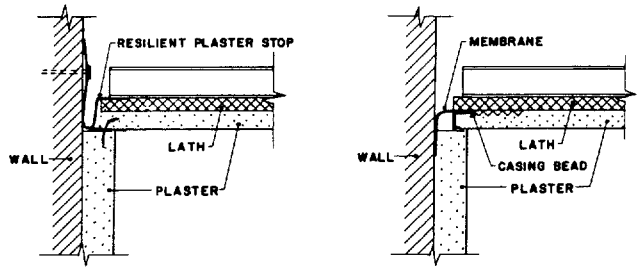
PERFORMANCE RATINGS

	RATING
Gypsum Lath	9.4
Metal Lath	6.8

A marked superiority is thus shown for gypsum lath in the constructions represented by these composite ratings, particularly when strengths of basecoat plasters were in the lower range.

II-c Restrained and Unrestrained Perimeter Construction

The term "restrained perimeter construction" indicates that concrete was placed in the perimeter angles of ceilings having gypsum lath. In the case of metal lath ceilings, it indicates that the ceiling lath was turned down at the wall, making the lath and plaster continuous in the angles. The term "unrestrained perimeter construction" means that continuity of both the lath and the plaster at the ceiling and wall intersection was broken by plaster stops or other mechanical devices. Thus, freedom of movement was provided between ceiling and wall surfaces to minimize transfer of stresses.



Methods Of Perimeter Unrestraint Used On Research Projects.

Composite ratings have been calculated to permit a direct comparison of 24 unrestrained ceilings with 24 restrained ceilings (all from the same project), each set comprising the same variables of plaster base and plaster aggregate. The superior performance of the unrestrained construction is shown by these over-all ratings:

PERFORMANCE RATINGS

	RATING
Unrestrained Perimeter	9.0
Restrained Perimeter	6.6

It must be concluded that ceilings with unrestrained perimeters are more resistant to cracking than those which are restrained. This is particularly evident where strengths of the basecoat plasters are in the lower range.

II-d Vermiculite Aggregated Basecoat Plaster

The series of 15 ceilings consisting of gypsum gauging-lime putty trowel finish, vermiculite aggregated basecoat plasters on metal lath and restrained perimeters, produced a composite performance rating of 1.8. The cracks were unusually wide and badly offset, beyond reasonable repair, and complete replacement of the ceilings was required.

Another series of ceilings, similar in all respects, except that gypsum lath was used, yielded a composite rating of 9.3. However, the rating was 3.8 for those ceilings where the plaster was applied by the two coat method, but similar in other respects. These two coat ceilings also were replaced.

From the data it must be concluded that ceilings with vermiculite aggregated basecoats applied to metal lath, or to gypsum lath by the two coat method, yield low performance ratings when gypsum gauging-lime putty trowel finishes are used; and that very good performance may be expected when such basecoats are applied by the three coat method to gypsum lath.

RECOMMENDATIONS FOR PLASTER PERFORMANCE

WITH RESPECT TO CRACK RESISTANCE

The Gypsum Association has prepared certain observations and recommendations intended to provide the designer with information that will permit him to predict ultimate performance of lathing and plastering systems with a much higher degree of accuracy. They are presented as guideposts and are based upon the data acquired from the Association's recently completed research project, and volumes of the industry's research and recorded field experience, all as related to crack resistance of plaster.

Important though it is, the proper selection of systems and materials must be supported by adequate construction details and definitive specifications. The contractor and mechanic must know precisely what is wanted. Further, competent field inspection is highly important to assure the designer of compliance with his expressed intentions.

These guideposts are not intended to be all inclusive. Nevertheless, the basic design principles that influence performance are quite clear. A knowledge of their relative contributions to performance will more accurately reflect the degree of integrity that is expected of the plaster surface. The important design principles and their interrelationship are here enumerated.

THE FINISH COAT OF PLASTER

As used in combination with various lath and plaster systems, the finish coats of plaster exhibit a wide range of performance. Hence, selection of the finish coat becomes very important.

Sand Float Finishes (Keene's cement or gypsum gauging with lime putty and sand) as compared to smooth trowel finishes provide a much higher factor of safety against cracking. They require a lesser degree of rigidity and strength in the lath and basecoat plaster, and we recommend the use of such finishes for maximum crack resistance. The description of the basic sand float finishes are found in paragraphs 7.40, 7.50, 7.60 of the American Standards Association Specification A42.1, 1955.

Acoustical Plasters and certain texture finishes are known to be highly resistant to cracking and are considered to be equal to sand float finishes in that respect.

When vermiculite basecoat plaster is used over metal lath, or over gypsum lath by the two coat method (double-up), only sand float finishes or acoustical plasters are recommended.

Smooth Trowel Finishes such as gypsum gauging-lime putty require a much higher degree of rigidity and strength in the lath and basecoat plaster for good visual performance. When the use of high strength basecoat plasters is impractical, consideration should be given to the elimination of restraint at the perimeter angles or the selection of a more rigid lath such as gypsum lath, or both, to the degree that is shown in the accompanying table (P. 8). They help to compensate for the lower strength of some basecoat plasters.

The resistance of gypsum gauging-lime putty trowel finishes to cracking, particularly to check cracking, can be increased by the addition of fine aggregate. The use of not less than ½ cubic foot of fine silica sand or perlite to each 100 pounds of gauging plaster or Keene's cement, increases the factor of safety in trowel finishes.

The Gypsum Association recommends the fine aggregate proportioning with gauging plaster or Keene's cement when gypsum-lime putty trowel finishes are applied over lightweight aggregate basecoats.

THE PLASTER BASE

The rigidity of the base to which the plaster is applied is an important factor in crack prevention. Under comparable circumstances gypsum lath usually provides a higher degree of resistance to cracking than does metal lath. Under certain conditions the selection of lath is not critical, but when the design calls for a plaster basecoat in the moderate to low range of strengths, a smooth trowel finish or restrained perimeters, the selection of the lath often becomes a determining factor in resistance to cracking. The relationship of these variables of design, as they affect visual performance, are shown in the accompanying table (P. 8).

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THE PLASTER BASECOAT

Under comparable circumstances crack resistance is closely related to the strength of basecoat plasters, the higher ranking basecoat strengths generally providing a higher degree of resistance. The strongest basecoat plaster is wood fiber scratch with sanded brown, followed in order by basecoats with sand, perlite and vermiculite aggregate, proportioned as indicated below. If good performance is to be expected of intermediate or low strength plasters, extreme care must be directed to selection of the finish coat and lath, and to the possible need for elimination of restraint at the perimeter angles. Experience and research prove the case for strong basecoat plasters where a high degree of surface integrity is to be realized.

For these reasons the Gypsum Association recommends the following proportioning of aggregate to plaster, regardless of whether it is aggregated on the job site or in the factory:

a. Not more than 2 cu. ft. of lightweight aggregate to 100 pounds of gypsum, *except over masonry where the proportioning should not exceed 3 cu. ft. of lightweight aggregate per 100 pounds of gypsum.* This proportioning is at variance with, and yields a stronger plaster than that permitted by Section 3.00 of American Standards Association Specification A42.1, 1955.

b. Not more than 2 cu. ft. of sand (12 shovels) for scratch coat and not more than 3 cu. ft. (18 shovels) for brown coat to 100 pounds of gypsum; except over masonry where proportioning should not exceed 4 cu. ft. of sand per 100 pounds of gypsum; and except over gypsum lath for two coat application where proportioning should not exceed 2½ cu. ft. of sand (15 shovels) per 100 pounds of gypsum.

CEILING PERIMETER CONSTRUCTION

Integration of walls and ceilings at the perimeter angles becomes very significant under some circumstances. Differential movement is always a factor, its extent being governed by the building's rigidity and the climatic changes. The performance of lath and plaster depends upon the extent of such movement and the ability of the wall and ceiling surfaces to move independently without transfer of undue stresses from one to the other, and other factors such as the finish coat, the lathing base and the strength of the plaster. It is believed, however, that restraint in the vertical angles of lath and plaster systems is less significant than in the perimeter angles of ceilings, and that performance in partitions is dependent primarily upon the other factors.

We recommend that serious consideration be given to the use of details that will help to eliminate restraint (continuity of lath and plaster) in perimeter ceiling angles where differential movement is anticipated, particularly where trowel finishes are indicated or the rigidity and strength of the lath and basecoat are in the moderate to lower range.

LARGE CEILINGS

In addition to perimeter consideration, large unbroken ceiling areas should be divided by relief joints. The maximum recommended distance between such joints is 60 feet with a maximum undivided area of 2400 sq. ft.

RELATIVE PERFORMANCE OF LATH AND PLASTER SYSTEMS

WITH RESPECT TO CRACK RESISTANCE

It must be recognized that performance of lath and plaster systems, like many other building constructions, cannot be predicted with complete accuracy. However, it is believed that a more accurate prediction can now be made, and that a knowledgeable and intelligent selection will more nearly provide the required visual characteristics of the plaster surface.

To assist the designer in this matter the accompanying table shows the anticipated relative performance of numerous lath and plaster constructions. It has been compiled from the recently acquired research data, volumes of other research, and the industry's long laboratory and field experience. Except as noted herein it is based upon full compliance with the provisions of American Standards Association Specification A42.1-4, 1955.

Obviously, plaster performance is affected by several factors, other than the basic variables considered in these recommendations, such as extreme weather conditions, lack of ventilation, thermal shock, unusual framing, etc. The standard precautions with respect to such factors should always be observed.

In compiling the table of Relative Performance, the absence of such unusual conditions is assumed. The table represents the Gypsum Association's best judgment of the relative resistance to cracking of the principal systems of lathing and plastering.

	RESTRAINED CONSTRUCTION			UNRESTRAINED CEILING CONSTRUCTION		
PERFORMANCE	LATH BASE	PLASTER BASECOAT	FINISH COAT	LATH BASE	PLASTER BASECOAT	FINISH COAT
EXCELLENT	G or M	WF	F	G or M	WF	F
	G or M	S	F	G	S or P	F
				G or M	WF	T
				G	S	T
				M	S	F
GOOD	G or M	WF	T	G2	S or P	F
	G	P	F	G	V	F
	G	S	T	M	P	F
	G2	S	F	G2 or M	S	T
	G	V	F	G	P or V	T
	G2 or M	P	F	M	V	F
	G2 or M	S	T			
	G	P	T			
ACCEPTABLE	G2 or M	V	F	G2	V	F
	G	V	T	G2 or M	P	T
	G2 or M	P	T			
NOT RECOMMENDED	G2 or M	V	T	G2 or M	V	T

G—Gypsum Lath - 3 Coat Plastering
G2—Gypsum Lath - 2 Coat Plastering
M—Metal Lath - 3 Coat Plastering
WF—Neat Wood Fiber Scratch and Gypsum Sanded Brown

S—Sanded Plaster
P—Perlited Plaster
V—Vermiculited Plaster
F—Sand Float Finish
T—Smooth Trowel Finish

NOTE: All proportioning of basecoat and finish coat plaster as recommended herein.

GYPSUM ASSOCIATION • 201 N. Wells Street • Chicago 6, Illinois

SGP 0003077



Recommended Practices for Construction of Ceilings With Gypsum Lath, Metal Lath and Plaster

GENERAL

For normal job conditions the Gypsum Association recommends that lath and plaster be applied in strict accordance with the following specifications:

A42.4 Standard Specifications for Interior Lathing and Furring

Gypsum Association's "Recommended Specifications—Gypsum Plastering."

These specifications reflect *minimum* requirements for normal job conditions and are inadequate for abnormal or unusual job conditions, such as:

1. Unventilated attic or plenum space.
2. Insulation supported by the lath prior to plastering.
3. Lath supported by edge clips only under high humidity conditions.
4. The wetting of gypsum lath before plastering or wetting the scratch coat over metal lath.
5. The use of excessive water in the plaster mix.
6. Excessive aggregate proportioning in the plaster mix.
7. Thin basecoat plasters.
8. The use of water in darbying plaster.
9. Slow setting plaster.
10. Application of acoustical plaster to wet basecoat plaster.

For these unusual conditions the Gypsum Association recommends that the minimum requirements of these specifications be supplemented by the following procedures:

VENTILATION

The space above the ceiling shall be ventilated so that the ratio of total net free ventilating area to the area of the ceiling shall not be less than 1 to 150. Location of vents shall provide positive ventilating action. If ventilation does not meet this requirement, plaster shall be applied by the three-coat method.

INSULATION

Where insulating batts, blankets, blown wool, or fill insulation is installed over the gypsum lath prior to the application of the basecoat plaster, the moisture evaporating from the plaster may condense within the insulation or on the underside of the vapor barrier. Therefore, wherever possible, insulation should be installed after the plaster has set and dried.

When insulation is installed before plastering, three-coat work is recommended and the scratch coat should be allowed to partially dry before applying the brown coat.

CLIPS

When the lath is attached to ceilings by clips providing edge support only, three-coat work is required; and, under conditions of high humidity, the scratch coat should be allowed to partially dry before applying the brown coat. Under high humidity conditions, the use of butt clips and center board clips to further reinforce the lath attachment is preferred.

WET LATH

Wetting of lath prior to plastering reduces suction of the lath and reduces plaster strength. The lath (or the scratch coat) shall never be wetted before plastering.

PLASTER—WATER RATIO

Basecoat plaster slump should not exceed 4 inches when tested in a 2" x 4" x 6" cone at the mixer. This slump standard is based on plaster mixes which should never exceed proportions recommended by the Gypsum Association.

AGGREGATE PROPORTIONING

The use of high aggregate ratios reduces plaster strength. Aggregate proportions shall meet the requirements of those recommended by the Gypsum Association.

Recommended Practices for Construction of Ceilings With Gypsum Lath, Metal Lath and Plaster

BASECOAT THICKNESS

Application of a thin basecoat plaster seriously reduces the strength of the ceiling. The basecoat plaster shall be applied to full thickness as required by "Recommended Specifications—Gypsum Plastering" especially where an acoustical plaster finish is used.

WATER DARBYING

Use of water in darbying plaster increases the water-plaster ratio and reduces plaster strengths. Water should never be used for darbying and only sparingly for floating.

SLOW SET PLASTER

The setting time of plaster shall not exceed 4 hours. Faster set can be obtained by adding small amounts of ground raw gypsum to the plaster mix. Or, a controlled fine spray of 5% aluminum sulfate solution can be applied to the plaster after application on the ceiling to obtain a faster set.

ACOUSTICAL PLASTER

Acoustical plaster should never be applied to a wet basecoat. The basecoat plaster shall be dry prior to application of acoustical plaster. If suction of the basecoat plaster must be adjusted to properly receive the acoustical plaster, care shall be exercised to avoid the use of excessive water.

BESTWALL GYPSUM COMPANY

For: ALL PLANT MANAGERS April 10, 1963 Paoli Laboratory

R.W. Brown-Acme

Subject: Recommended Practices for Construction of Ceiling with Gypsum Lath & Plaster

C. G. Shuttleworth/md

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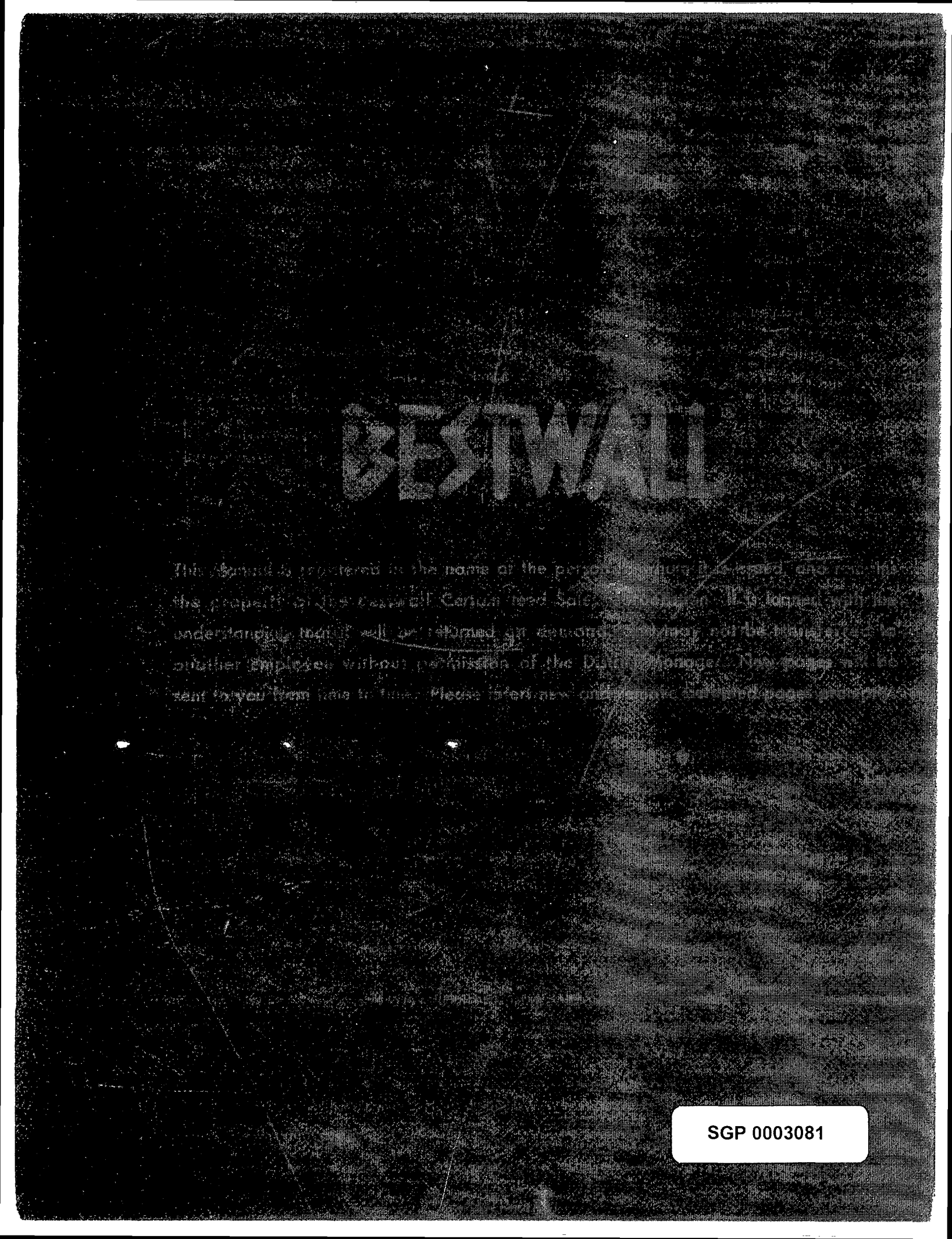
CGS

Attached please find two copies of the Gypsum Association bulletin, covering recommended practices for plastering on gypsum lath on ceilings.

Please keep one of these and give the other one to your Quality Supervisor.

Attachment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