

May 28, 1974

W. A. KINKADE ET AL
PROCESS FOR MAKING GYPSUM BOARD

3,813,312

Original Filed Oct. 5, 1970



FIG. 1



FIG. 2

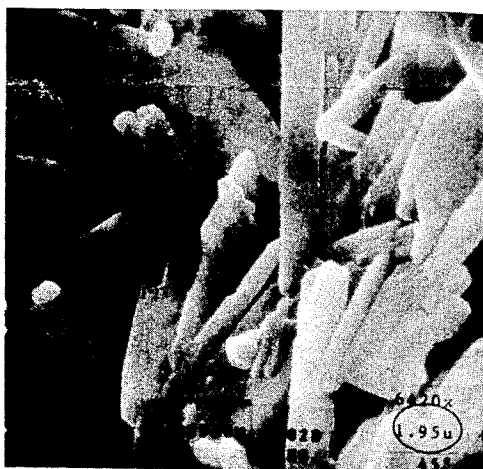


FIG. 3

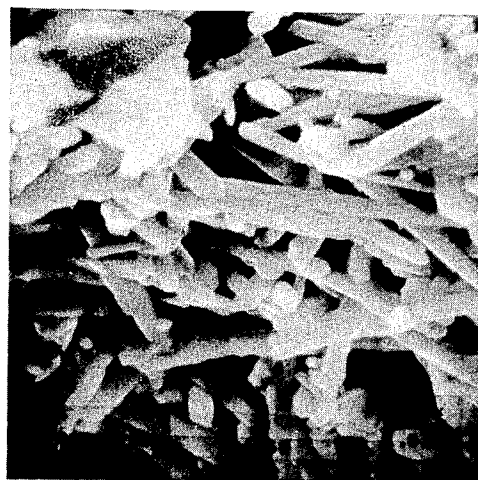


FIG. 4

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PROCESS FOR MAKING GYPSUM BOARD

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Original application Oct. 5, 1970, Ser. No. 78,067, now
abandoned. Divided and this application Jan. 25, 1972,
Ser. No. 220,721

Int. Cl. B32b 13/00; C04b 11/00

U.S. Cl. 156—39

20 Claims

ABSTRACT OF THE DISCLOSURE

A process of producing gypsum board of enhanced strength and resistance to humidified bond failure at any particular density through the use of a delayed action accelerator. The accelerator is preferably formed by grinding landplaster and a sugar.

The present invention relates to gypsum board, sometimes called plaster board, which consists of a gypsum core encased in paper cover sheets. The invention is particular directed to the production of such board of reduced weight or density without sacrifice in strength and also to the production of such board without loss of bond between the paper cover sheets and the core on exposure to high humidities, particularly for short periods of time. In general, the invention is an improvement over the post acceleration disclosed in Lane *et al.* U.S. Pat. 3,359,146, which patent, in general, seeks to accomplish at least the former of these desirable objectives. Additionally, the invention is intended for application, not only to the primary-secondary mixer combination discussed by Lane *et al.*, but also to the more modern multi-pass mixers of the sort described in Camp U.S. Pat. 2,660,416.

This is a divisional of application Ser. No. 78,067, filed Oct. 5, 1970, now abandoned.

BACKGROUND OF THE INVENTION

Gypsum board or plaster board has long been a large volume commercial article of commerce. In addition to the Lane *et al.* and Camp patents hereinabove referred to, the manufacture of gypsum board is discussed in Roos Pats. Nos. 2,017,022 and 2,080,009. In general terms gypsum board is manufactured by dispersing calcined gypsum in water and adding thereto a light weight pre-generated foam to control the finished density of the slurry. Additives conventionally used in minor amounts include accelerators, bond protecting agents, fibrous reinforcements, and consistency reducers. Typical of accelerators are calcium sulfate dihydrate, potassium sulfate, ammonium sulfate, and aluminum sulfate. Bond protecting agents are unusually cereal flours or starches. The fibrous reinforcements may be either cellulosic or glass. Consistency reducing agents are typified by the ligno-sulfonates, of which ammonium lignosulfonate is particularly advantageous. These additives are used in minor quantities in relation to the total weight of the board core, and represent, in total, less than 5%, usually less than 2%, of the weight of the finished core.

The slurry containing the desired ingredients is prepared in continuous mixers, such as the primary-secondary mixer combination described by Lane *et al.* or the multi-pass mixer described in the above mentioned Camp patent. The mixed slurry is continuously deposited on a paper cover sheet moving beneath the mixer. A second paper cover sheet is applied thereover and the board is passed under a roll or rolls to adjust the thickness. The continuous strip thus formed is conveyed on a belt until the calcined gypsum has set, whereafter the strip is cut

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to form boards of desired length and the boards are conveyed through a drying kiln to remove excess moisture.

The Lane *et al.* solution to some of the problems to which the present invention is addressed involves, in general, a post-acceleration process, in which the calcined gypsum feed is dispersed in water to a high degree of fineness, whereafter the accelerator is added to the slurry and the product is then cast. It is clear from the Lane *et al.* disclosure that a high degree of dispersion (i.e. fineness) of the calcined gypsum is highly advantageous in producing a board of maximum strength. The Lane *et al.* process, insofar as commercial gypsum board operations are concerned, is directed to a primary-secondary mixer and foam and accelerator are added to in the secondary mixer. Although this operation works quite well in that mixer combination, it is not conveniently adapted to the more modern multi-pass mixer described by Camp. In the latter, the peripheral velocity increases as the material moves toward the outer rim of the mixer, thus making the final mixing more intense, rather than less intense, as is the case with the primary-secondary combination.

In considering the strength, as measured by compressive breaking load of gypsum board or gypsum board core in relation to the density thereof, the "standard" or "normal" strength concept described by Lane *et al.* has been found highly useful. Lane *et al.* point out that the strength-density relationship is not a linear one, but instead corresponds to the equation $S=A+10^0.0297D$, wherein S is the compressive strength in pounds per square inch, A is a constant amounting to 29.02 and D is the density in pounds per cubic foot.

Another characteristic of gypsum board important in the present invention is what is known as humidified bond. Brief exposure to high humidities, such as a test condition involving one hour's exposure at 90° F. and 90% relative humidity, causes a weakening at or near the paper-core interface, as a result of which the paper may be partially or completely stripped from the core with a relatively gentle pull.

On failure, a little of the core, perhaps up to a few thousands of an inch in thickness, is often removed with the paper. This is perhaps due to strains set up by partial penetration of high moisture content air into the board, well short of equilibrium. This condition also occurs in storage and use of the board when it is exposed to varying ambient temperature and humidity conditions. In general, the lower density boards exhibit greater humidified bond failure than do the high density boards.

OBJECTS OF THE INVENTION

It is a primary object of the present invention to provide a process for making gypsum board of lower density and lighter weight than heretofore commercially achieved without sacrifice in strength of the board or its resistance to bond failure on humidification.

It is a further object of the invention to accomplish these desirable results in board manufactured on conventional gypsum board producing machinery.

It is a still further object of this invention to accomplish the aforesaid desirable results in board made on commercial machinery without sacrificing production speed.

It is a still further object of this invention to accomplish the aforesaid advantageous results by the use of a delayed action accelerator.

It is a still further object of this invention to control the hydration of the calcined gypsum in a fashion which provides relatively slow temperature rise during the early portions of the hydration period, followed by a rapid temperature rise toward the end of the temperature rise-measured hydration period.

A still further object of the invention is to provide a process for hydrating the calcined gypsum forming the bulk of the core of gypsum board in a fashion which produces a multitude of slender rod-like crystals to enhance the strength of the finished board.

A still further object of the invention is to provide a gypsum board whose core is made up predominantly of slender rod-like crystals whose diameters are generally below about $\frac{3}{4}$ micron.

GENERAL DESCRIPTION OF THE INVENTION

We have found that the foregoing and other desirable objects are achieved by incorporating into the calcined gypsum slurry as the sole accelerator of the set thereof an accelerator whose accelerative effect is a delayed one. Such accelerators are preferably sugar coated landplaster (calcium sulfate dihydrate) of the sort disclosed, for other purposes, in King U.S. Pat. 2,078,199.

GENERAL DESCRIPTION OF THE DRAWINGS

FIG. 1 is a scanning electron microscope photograph of a laboratory-made set gypsum cast prepared using the set stabilization composition taught in King Pat. 2,078,199.

FIG. 2 is a scanning electron microscope photograph of a laboratory-made set gypsum cast using the delayed action accelerator disclosed in this invention, without the retarder called for by King.

FIG. 3 is a scanning electron microscope photograph of the core of a commercial gypsum board manufactured using "Microfloc" as an accelerator (see McCleary and Kinkade Pats. Nos. 3,262,799 and 3,307,919).

FIG. 4 is a scanning electron microscope photograph of the core of a commercial gypsum board made in accordance with this invention.

DETAILED DESCRIPTION OF THE DRAWINGS

The insight into the micro-structure of the crystals in a gypsum cast provided by FIGS. 1-4 has only recently been possible. The instrumental development which has made this insight possible is referred to as scanning electron microscopy. The technique is described generally in the following quotation from an article titled, "Morphology of Dental Surfaces and Adhesion of Polymeric Filling Materials: Primer Studies With Scanning Electron Microscopy," by Henry Lee, Michael L. Swartz, and D. G. Stoffey which appeared at page 243 of the preprint booklet of the Division of Organic Coatings and Plastics Chemistry of the American Chemical Society, volume 30, No. 1 (references to citations and figures omitted from the quotation):

"Inasmuch as there are only a limited number of these new instruments available, it would seem desirable to digress for a few minutes to review the scanning electron microscope for those readers who have not had the occasion to work with one personally.

"The scanning electron microscope differs from the transmission instrument in that it uses reflected (backscatter) electrons or more preferably, secondary emission electrons, emitted from the incident surface.

"The secondary emission electrons are preferred to the backscatter electron as they provide higher contrast due to their enhanced emission in the case of rough surface.

"In addition, the incident beam of electrons in a scanning microscope is not stationary but is scanning the specimen surface in a TV raster pattern. A directly synchronized raster pattern is displayed on a cathode ray tube, and is modulated by the signal from the secondary electron detector.

"The result is a picture displayed on the cathode ray tube which provides magnifications of $50\times$ to $140,000\times$, on a resolution of about 300-400 angstroms, and a depth of focus 300-500 times greater than a light microscope or a transmission electron microscope.

"... The sequence of operations for use of the microscope are straightforward. The specimens are examined in

most cases by use of a transmission or reflected-light microscope to determine the area of probable interest. Then the specimen is mounted on a specimen holder, usually a small brass cylinder, using a conducting (silver-containing) paint or adhesive. The specimen cylinders are then mounted on a plastic tray, using double backed adhesive tape, and placed in a vacuum evaporator. A coating of gold, copper, or aluminum about 200 angstroms thick is deposited on the specimen. The specimen is rotating during coating so that a uniform conducting coating is obtained. Generally, no attempt is made to "shadow" the specimen as in transmission microscopy, as the purpose is not to create a shadow, but to provide a conductive surface so that electrons will not build up a charge in a given area and distort the picture. The thickness of coating is less than that of the resolution and does not alter the picture but actually increases the sharpness of the image.

"A specimen cylinder is then mounted in a specimen boat and inserted in the forechamber of the instrument and then into the operating chamber. The position of the specimen is adjusted by means of dials which permit X or Y horizontal motion, as well as rotation or tilting. The image is viewed on two cathode ray tubes, located on the control console. A 35 mm. camera or Polaroid camera is swung into place to record desirable pictures."

In all of the figures the gypsum cast surface is depicted in magnification of $6420\times$, and the scanning angle in each case was 45° . The ellipse shown in the lower right-hand corner of each figure indicates a 1.95 microns dimension, the major and minor axes of the ellipse corresponding to directions parallel and transverse to the mounting angle.

Examination of FIG. 1 reveals that the King composition is made up of a multitude of squat, stubby crystals. In contrast, the composition of this invention, shown in FIG. 2, consists almost exclusively of very slender, long, rod-like crystals of diameters less than about $\frac{3}{4}$ micron, with almost complete absence of the squat, stubby crystals found in the King composition.

That this crystal formation is responsible for the improved characteristics of the board of the present invention is illustrated by a comparison of FIGS. 3 and 4. In FIG. 3, which shows a prior art board composition, it will be seen that at least half the crystals visible are squat, stubby crystals of the sort shown in FIG. 1. There are only a few long rod-shaped crystals visible, and these are of quite large diameter, on the order of one micron or more. In contrast, the board core composition of this invention, shown in FIG. 4, exhibits the slender, rod-like crystals also shown in FIG. 2. Stubby, squat crystals are almost completely absent. It will be observed that a substantial majority of the crystals of FIG. 4 have a diameter of less than about $\frac{3}{4}$ micron. This dramatic difference in crystal formation and ultimate crystal size and shape is believed to be responsible for the improved characteristics of the board produced according to the present invention. The accelerator of this invention should be present in an amount equal to between about five and about twenty pounds per ton of calcined gypsum.

SPECIFIC EMBODIMENTS OF THE INVENTION

Example I

Parallel runs were made on a commercial gypsum board machine in which the control board was made with "Microfloc" accelerator in comparison to the delayed action accelerator of the present invention. The so called "Microfloc" accelerator is a dilute aqueous suspension of calcium sulfate dihydrate. Its production is described in McCleary and Kinkade Pats. Nos. 3,262,799 and 3,307,919. The delayed action accelerator of the present invention was prepared by grinding landplaster in a continuous rod mill in the presence of about 5% of its weight of sucrose to a Blaine fineness of approximately 8,000 to 12,000 square

centimeters per gram (see ASTM method C-204). The difference in the setting behavior is shown in the data in the subjoined table.

TABLE I-A

Test units	Microfloc accelerator 1/2" wallboard	Delayed action accelerator 1/2" wallboard
Usage rate.....	Lbs./m sq. ft. 11.7	8.0
Final set.....	Minutes 7.89	7.94
Maximum rate of hydration.....	° F./minute 9.05	9.86
Temperature rise during 3d minute.....	° F. 4.81	3.39
Ratio of maximum rate to rise during 3d minute.....	2.10	2.81

It will be observed that the temperature rise during the early stages of set with the accelerator of the present invention is much less than was observed in the control run and that the rate of temperature rise toward the end of the setting period was substantially greater in the case of the delayed action accelerator used in the present invention. The tests recounted in this example further show that the normal weight of the control board was about 1,900 lbs./m. sq. ft. (45.7 lb./cu. ft. core density) and that equivalent strengths and humidified bond performance were achieved with the delayed action accelerator of the present invention at weights as low as 1,675 lbs./m. sq. ft. (39.9 lbs./cu. ft. core density).

A further advantage disclosed in the trials described in this example lay in the edge hardness of the board. It is well known that the edges of gypsum board are especially subject to calcination and therefore excessive softness in passing through the drying kiln. In the foregoing tests it was found that the average edge hardness went up about 5 points (out of approximately 15-20) at the same board weight when using the delayed action accelerator of the present invention. Further data collected in the test recounted in this example are shown in the two subjoined tables, the first of which recounts the core quality of the boards and the second of which sets forth the results on the humidified bond test after one hour's humidification at 90° F. 90% RH.

TABLE I-B

	Dry density, lbs./cubic ft.	P.s.i. strength	Percent normal strength
Control, microfloc accelerator.....	47.5	658	83.0
Test, delayed action accelerator "normal" weight board.....	46.8	641	105.0
Test, delayed action accelerator reduced weight board.....	45.4	674	105.0
Do.....	42.6	520	98.0
Test, delayed action accelerator "normal" weight board.....	46.7	769	110.0

TABLE I-C

	Number of boards in average	1/2" board weight, lbs./m.	Core density, lbs./cu. ft.	Percent bond failure	
				Face	Back
Control, microfloc acceleration.....	6	1,868	45.0	28	69
Delayed action accelerator.....	8	1,892	45.6	2	3
Do.....	6	1,797	43.0	7	12
Do.....	4	1,815	43.6	6	30
Do.....	5	1,720	41.0	35	81

Example II

The tests reported in this example were conducted at a commercial gypsum board producing facility different from that of Example I and indicate the same sort of

range of improvement. The data is given in the subjoined table.

TABLE II

Test units	Block and potassium sulfate accelerator	Delayed action accelerator
Usage.....	Lb./m. sq. ft. 10+1.5	7
Final set temperature rise.....	Minutes 6.5	6.8
Maximum rate of hydration.....	° F./minute 7.6	8.45
Temperature rise during 3d minute.....	° F. 5.2	4.8
Ratio of maximum rate to rise during 3d minute.....	1.46	1.76

The above Table shows that by the use of the delayed action accelerator of this invention in the process for forming gypsum wallboard of this invention, the maximum rate of temperature rise during set of the core in the manufacture of gypsum wallboard is at least about 1.5 times the temperature rise occurring during the third minute, and the maximum rate of temperature rise occurs subsequent to the third minute.

Example III

A series of gypsum boards was prepared in the laboratory to compare the performance of conventional ground block accelerator with the delayed action accelerator of this invention. The latter was the previously described landplaster which had been ground with 5% of sucrose. The boards were prepared at a series of core densities from an upper value of 50 lbs. per cubic foot to a lower value of 38 lbs. per cubic foot. Quite in contrast to commercial plant experience, ground block, carefully prepared under laboratory conditions, performs quite effectively as an accelerator. The boards at corresponding densities were found to be substantially equal in core compressive strength and in resistance to passage of air, the latter as measured on a Gurley densometer. However, the test for humidified bond failure clearly shows, even under these nearly ideal conditions, the significant advantages of the present invention, particularly when it is desired to make lower weight boards. The boards were conditioned for 24 hours at 90° F. and 90% RH and then tested in the usual bond failure test. The density and the percent bond failures are shown in the subjoined table.

TABLE III

Core density, lbs./ft. ³	Percent bond failure	
	Block accelerator	This invention
50.....	0	0
45.....	9	12
39.5-40.....	57	20
38-39.....	97	53

It will be observed that at high core densities the humidified bond is substantially equal as between ground block accelerated board and board accelerated with the delayed action accelerator of this invention. However, very marked and important differences begin to occur as the density of the core is reduced. The results at the lower density ranges are especially significant. Note that at 39.5-40 lbs. density the accelerator of this invention produced a board showing only 20% bond failure and that the percent failure increased only to 53% when the density was further reduced to 38-39 lbs. In contrast, the board prepared with ground block accelerator showed 57% bond failure at 39.5-40 lbs. density and 97% bond failure at 38-39 lbs. density. This illustrates the extreme criticality of this phenomenon as efforts are made to reduce the board weight.

The data in this example, from boards made under controlled laboratory conditions, also illustrates, when compared to the bond failure data recorded in Example I, the differences expectable on translation of laboratory experi-

ence to full scale production machinery. The data clearly shows the highly advantageous results of the delayed action accelerator of the present invention in the manufacture of lightweight board.

We claim:

1. In a process of producing paper covered plasterboard characterized by enhanced strength at any particular density and by improved bond of core to paper the improvement which comprises admixing calcined gypsum, water, and pregenerated foam together in the presence of a delayed action accelerator, said accelerator being the uncalcined product of grinding landplaster with up to about 5% of its weight of sugar and being present in an amount sufficient to produce a temperature rise set of said calcined gypsum in not more than about 15 minutes.

2. The process of claim 1 wherein said accelerator has a Blaine fineness of at least about 8,000 sq. cm./g.

3. The process of claim 1 wherein the maximum rate of temperature rise during set is at least about 1.5 times the temperature rise occurring during the 3rd minute, and said maximum rate of rise occurs subsequent to said 3rd minute.

4. The process of claim 1 wherein said delayed action accelerator comprises an intimate dispersion of finely ground landplaster and a sugar.

5. The process of claim 1 wherein said accelerator is present in an amount equal to between about 5 and about 20 pounds thereof per ton of calcined gypsum.

6. The process claimed in claim 5 wherein said accelerator is present in an amount equal to at least about ten pounds thereof per ton of calcined gypsum.

7. The process claimed in claim 1 wherein the said accelerator is present in an amount equal to between about 5 and about 20 pounds thereof per ton of calcined gypsum.

8. A method for increasing the strength at any particular density of the gypsum core of a wallboard formed from stucco, the method comprising the steps of incorporating a delayed action accelerator comprising a finely ground uncalcined mixture of landplaster and a sugar in the stucco, said sugar being present in an amount up to about 5% of the weight of said landplaster, and thereafter casting the stucco between paper cover sheets and permitting it to set to form gypsum wallboard.

9. In a process of producing paper covered plasterboard, wherein calcined gypsum, water, and a pregenerated foam are admixed together to form a slurry, and said slurry is disposed between paper sheets and allowed to set, the improvement comprising

admixing a delayed action accelerator with said calcined gypsum, water and pregenerated foam to form said slurry, said delayed action accelerator comprising a finely ground uncalcined mixture of landplaster and sugar, said sugar being present in an amount up to about 5% by weight of said landplaster, the amount of said delayed action accelerator being sufficient to produce a temperature rise set of said calcined gypsum in not more than about 15 minutes, whereby said plasterboard has enhanced strength at any particular density.

10. The improvement in a process according to claim 9, wherein said delayed action accelerator has a Blaine fineness of at least about 8000 sq. cm./g.

11. The improvement in a process according to claim 9, wherein the maximum rate of temperature rise during

set is at least about 1.5 times the temperature rise occurring during the third minute, and said maximum rate of rise occurs subsequent to said third minute.

12. The improvement in a process according to claim 9, wherein the amount of said delayed action accelerator admixed with said calcined gypsum, water and pregenerated foam is equal to between about 5 and about 20 pounds per ton of calcined gypsum.

13. The improvement in a process according to claim 12, wherein the amount of said delayed action accelerator which is admixed with said calcined gypsum, water and pregenerated foam is equal to at least about 10 pounds per ton of calcined gypsum.

14. The improvement in a process according to claim 9, wherein said sugar is sucrose.

15. In a process of producing plasterboard, wherein calcined gypsum, water, and a pregenerated foam are admixed together to form a slurry, and said slurry is formed into a sheet and allowed to set, the improvement comprising

admixing a delayed action accelerator with said calcined gypsum, water and pregenerated foam to form said slurry, said delayed action accelerator comprising a finely ground uncalcined mixture of landplaster and sugar, said sugar being present in an amount up to about 5% by weight of said landplaster, the amount of said delayed action accelerator being sufficient to produce a temperature rise set of said calcined gypsum is not more than about 15 minutes, whereby said plasterboard had enhanced strength at any particular density.

16. The improvement in a process according to claim 15, wherein said delayed action accelerator has a Blaine fineness of at least about 8000 sq. cm./g.

17. The improvement in a process according to claim 15, wherein the maximum rate of temperature rise during set is at least about 1.5 times the temperature rise occurring during the third minute, and said maximum rate of rise occurs subsequent to said third minute.

18. The improvement in a process according to claim 15, wherein the amount of said delayed action accelerator admixed with said calcined gypsum, water and pregenerated foam is equal to between about 5 and about 20 pounds per ton of calcined gypsum.

19. The improvement in a process according to claim 18, wherein the amount of said delayed action accelerator which is admixed with said calcined gypsum, water and pregenerated foam is equal to at least about 10 pounds per ton of calcined gypsum.

20. The improvement in a process according to claim 15, wherein said sugar is sucrose.

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U.S. Cl. X.R.

106—114