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## (54) LIGHTWEIGHT PLASTERBOARD WITH FIBROUS COVERING AND METHOD OF PRODUCING SAME

(71) We, CENTRAL GLASS CO., LTD., OHBAYASHI-GUMI LTD. and NAIGAI MOKUZAI KOGYO CO., LTD., corporations organized under the laws of Japan, of No. 5253, Oaza Okiube, Ube City, Yamaguchi Prefecture; of No. 3-37, Kyobashi, Higashi-ku, Osaka and of No. 2-100, Tanigawa, Daito City, Osaka, Japan, respectively, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to a lightweight plasterboard with a fibrous covering and a method of producing the same so as to realize an intimate contact of the covering with the core of the board even at the edges of the board.

Recently there is an increasing demand for fireproof building materials with increase in multi-storied buildings and decrease in open-spaces in urban and surburban territories. A variety of materials, for example air-entrained concrete such as autoclaved lightweight concrete, gypsum and calcium silicate, have been used as fireproof building materials. However, panels or boards of these materials are not yet fully satisfactory in some respects, because such fireproof boards are required also to exhibit a good surface finish and high physical strength represented by bending strength and resistance to mechanical shocks but can hardly meet all the requirements completely.

The present invention provides a fireproof board for constructive use, which board is superior to conventional boards of gypsum or calcium silicate both in fire-resistance and in physical strength, particularly in shock resistance, and exhibits a better surface finish than air-entrained lightweight concrete boards. The plasterboard of the invention is relatively low in bulk density but sufficient in physical strength and further features the presence of an intimately and exactly fitting fibrous covering.

The invention accordingly provides a lightweight plasterboard comprising:

a rectangular core plate of an air-entrained plaster containing short strands of glass fiber dispersed therein; and

a covering of a fibrous sheet material securely and intimately laid on said core plate so as to cover front and back faces and two parallel sides of said core plate including edges formed by the intersection of said front and back faces with said two parallel sides.

Preferably the core plate is made to have a bulk density of 0.55-0.65g/cm$^3$, and the glass fiber amounts to 1-3 Wt% of the plaster.

It is preferable to use either woven or nonwoven cloth of a synthetic fiber as the material of the covering.

A method of producing a lightweight plasterboard according to the invention comprises the following steps. (a) laying a generally rectangular sheet of a fibrous material on the inside of a mold of a rectangular box shape, (b) bending and creasing the sheet so as to make four right-angled and lasting creases in parallel arrangement such that two of these creases extend along the two parallel borders of the bottom of the mold and the remaining two creases extend respectively above the former two creases at a vertical distance corresponding to the thickness of the plasterboard and leave a gap between the two borders of the bent sheet in a horizontal plane containing the upper two creases, (c) preparing a plaster slurry comprising an air-entraining agent and short strands of glass fiber, (d) pouring the plaster slurry into the mold until the slurry surface in the mold reaches the level of the upper two creases, and (e) placing another rectangular sheet of the fibrous material on the surface of the slurry in the mold.

Preferably a synthetic fiber cloth is used as the fibrous material and the creasing is performed by applying heat to the sheet along the crease line.

The plaster slurry is prepared fundamentally from hemihydrous gypsum and water as is usual. To afford a relatively low bulk density and a good physical strength to the product, the proportioning of the ingredients is preferably such that the air-entraining agent and the glass fiber respectively amount to 0.01-0.5 Wt% and 1-3 Wt% of the gypsum, and additionally a water soluble polymer may be incorporated as an air-entraining assistant. Optionally a lightweight aggregate may be added to the plaster slurry in an amount of 1-3 Wt% of the gypsum.

The invention will fully be understood from the following detailed description with reference to the accompanying drawing, wherein:

the single Figure is a perspective view of a plaster board according to the invention.

As shown in the Figure, a lightweight plaster board 10 according to the invention consists of a rectangular plate 12 of air-entraining plaster and a fibrous sheet material 14 which intimately covers the rectangular plaster plate 12 except its two parallel sides 12*c*, usually shorter sides. (The thickness of the sheet material 14 is shown in exaggeration. The sheet material 14 is impregnated with plaster and hence united with the plate 12 as will be understood from the hereinafter presented description of the production method.) To avoid confusion, the plaster plate 12 itself will hereinafter be referred to as core plate.

The core plate 12 is made of a lightweight or air-entrained plaster containing chopped strands of glass fiber dispersed therein. Optionally the plaster may be mixed with a small amount of a lightweight aggregate. The fundamental material of the lightweight plaster is plaster of Paris, i.e. hemihydrate of calcium sulfate ($CaSO_4.1/2\ H_2O$) which sets by hydration. The hemihydrous gypsum is obtained as α -gypsum and/or β -gypsum from calcium sulfate dihydrate (gypsum) either by calcination or dehydration under pressure in the presence of steam. Both α -gypsum and β -gypsum are useful for producing the core plate 12. Nowadays the dihydrate is produced in large quantities, for example, as a by-product of the preparation of phosphoric acid by wet process and as the result of sulfur removal processes performed in various fields as an antipollution measure. It is therefore greatly profitable industrially to make use of gypsum for building materials such as plaster boards which are in large and probably increasing demand.

The core plate 12 is produced by a casting method in which a plaster slurry is poured into a mold of a rectangular box shape (in this case the sheet material 14 is laid in the inside of the mold as will later be described and allowed to set in the mold. To give an air-entrained plaster, the plaster slurry contains an air-entraining agent and, preferably, an air-entraining assistant other than the fundamental components, hemihydrous gypsum and water. Various air-entraining agents such as anion surface active agents and resin type agents which are commonly called vinsol and used as an aqueous alkalline solution (pH 8-12) are known for the production of lightweight concrete. These agents are useful also in the present invention. Water soluble polymers such as polyvinyl alcohol, carboxymethylcellulose, methylcellulose, ethylcellulose and hydroxyethylcellulose are useful, either singularly or in combinations, as an air-entraining assistant. In the present invention, it is desired that the plaster slurry involves air as uniformly distributed bubbles of 0.1-0.5 mm diameter and that the core plate 12 has a bulk density of 0.55-0.65 g/cm$^3$. To meet these requirements the air-entraining agent in the plaster slurry can be used in an amount of 0.01-0.5 Wt% of the gypsum, and an air-entraining assistant is used in such a quantity that its concentration in the water for preparing the slurry ranges from 1 to 5% by weight.

A suitable plaster slurry is obtained by first preparing an aqueous solution (which involves stable and almost uniformly distributed air bubbles of 0.1 to 0.5 mm diameter) of an air-entraning agent and a water soluble polymer as an assistant (introduced in the form of an aqueous solution) through a vigorous agitation at temperatures between 0 and 40°C, more preferably between 20 and 30°C, and then adding hemihydrous gypsum to this solution, followed by kneading. The concentration of the plaster slurry is preferably such that the fluidity of slurry is expressed by a flow value of 110-300 mm, more preferably 140-200 mm, according to JIS (Japanese Industrial Standard) R-5201 (in this text a truncated cone of plaster (base diameter 100 mm, upper diameter 70 mm, height 60 mm) is reciprocated vertically through 10 mm once a second for 15 seconds and then an average diameter of the cone is determined to give a flow value).

The short strands of glass fiber are added to the plaster slurry for the enhancement of the shock resistance of the core plate 12. A suitable amount of the glass fiber in the slurry is 1-3 Wt% of the gypsum. The use of about 1/2 to 2 inch long strands of glass fiber (which may be an alkali-resistant glass fiber comprising $ZrO_2$) is preferable. To prevent breakage and aggregation of the fiber strands, the glass fiber is introduced into the plaster slurry at a last stage of the kneading.

Optionally a lightweight aggregate such as a perlite or vermiculite may be added to the plaster slurry in an amount of about 1-3 Wt % of the gypsum with the purpose of augmenting the physical strength of the core plate 12.

The covering material 14 in the plasterboard 10 can be selected from a wide variety of fibrous sheet materials. However, cloth of synthetic fiber, either woven cloth of nonwoven cloth, is the most suitable covering material in due consideration of the affinity for plaster slurry and capability of giving lasting creases. In the case of nonwoven cloth, there is no particular restriction on the structure of the cloth. Either continuous or discontinuous fiber filaments may be formed into nonwoven cloth by the employment of a suitable method such as knitting, gluing or fusion. Examples of suitable synthetic fibers are those of polyester, polyamide, polypropylene, polyethylene, cellulose acetate, polyvinyl chloride and acrylic polymers. Cloth of a certain natural fiber such as silk also is useful. Further, it is possible to use board paper or any other suitable type of paper instead of cloth. In the case of using paper as the covering material, a silicofluoride such as $CaSiF_6$, $MgSiF_6$, $K_2SiF_6$ or $Na_2SiF_6$ is preferably added to the above described plaster slurry in an amount of 0.2-6 Wt% of the gypsum for promoting cohesion of the plaster to the paper.

As seen in Figure, the covering 14 consists of two portions: a larger portion 14*a* which covers the lower face 12*a* (this face 12*a* may be either a front or a rear face of the plasterboard 10) and two sides of the core plate 12 and a smaller portion 14 *b* covering the upper face 12*b* . Before pouring of the above described slurry into a mold for shaping the core plate 12, the larger portion 14*a* (which is a rectangular sheet) of the covering 14 is laid on the inside of the mold and creased in the following manner. The sheet 14*a* is bent at right angle along the two parallel borders of the bottom of the mold so as to make two linear creases 16 and then the portions stood on both sides are inwardly bent at right angle to give two linear creases 18 which extend horizontally at a vertical distance corresponding to the intended thickness of the core plate 12 from the creases 16. The width of the sheet 14*a* is slightly larger than the sum of the width of the core plate 12 and twice the thickness of the core plate 12, so that two barrow areas 20 each defined between a border 22 of the bent sheet 14*a* and one of the creases 18 lie parallel to the bottom of the mold. However, a sufficiently wide gap is left between the borders 22 of the bent sheet 14*a*. The creases 16 and 18 must be sharp and lasting. When the sheet 14*a* is cloth, it is impossible to make a sharp and lasting crease by bending the sheet 14*a* merely by hand. The creases 16 and 18, therefore, are made by applying heat to the sheet 14*a* along the lines of crease. In practice, such a manner of heating can be accompalished by sliding a heated spatula or iron which has such a thin tip as leaves an about 0.5-1 mm wide trace on the sheet 14*a*. In general the heating temperature is above about 50°C but below a substantial melting point of the material of the sheet 14*a*. Preferably the heating temperature is made as high as possible so far as rupture of the sheet 14*a* by melting can be avoided.

Thereafter the plaster slurry is poured into the mold which contains the shaped and creased sheet 14*a* until the slurry surface reaches the level of the horizontally lying marginal portions 20 of the sheet 14*a*. After the slurry surface is made even, the smaller portion 14*b* of the covering 14, a rectangular sheet with the same width and length as the core plate 12, is placed on the slurry surface and smoothed by means of, for example, a roller. In this state the plaster slurry in the mold is left still in the mold until it sets completely.

In the case of continuously performing a production method according to the invention, the larger portion 14*a* of the covering 14 is continuously transferred by means of, for example, a belt conveyer so as to make a sliding contact with appropriately and stationarily positioned creasing irons. Following the pouring of the plaster slurry, the smaller portion 14*b* of the covering 14 also is continuously placed on the slurry surface.

The light weight plaster board 10 produced by the above described method has primarily the advantage, in addition to a close fitting and even surface finish of the covering 14 over flat faces of the core plate 12, that all the edges covered with the covering 14 are quite sharp and exactly right-angled. This is very favorable for placing the plasterboards 10 in exact abutment against each other.

The core plate 12 in the plasterboard 10 has a bulk density of 0.55-0.65 $g/cm^3$ and can be made as thick as about 60 mm. By the joint effect of the well fitted covering 14 and glass fiber strands in the core plate 12, the lightweight plasterboard 10 exhibits an excellent resistance to shock. An experiment was carried out to examine the effect of the length and quantity of the glass fiber strands on the shock resistance of the core plate 12 itself and the covered plasterboard 10. In this experient the core plate 12 was 600 mm in width, 2400 mm in length and 60 mm in thickness. A spun-bonded nonwoven cloth of polyester was used as the covering 14. Each specimen of the core plate 12 or the plasterboard 10 was subjected to an impact testing according to JIS A-1414. In this test, the core plate 12 (or the plasterboard 10) was set vertically and supported along two lines each drawn at a distance of 300 mm from the upper or lower side of the plate 12. A 5 m long pendulum having a sand bag which weighed 30 kg at its one end was supported at the other end 5 m above the center of the plate 12. The test was performed by allowing this pendulum to swing down through a certain angle so that the sand bag can hit against the plate 12 at its middle region. The magnitude of the impact was varied by varying the angle of the pendulum movement, expressed by the fall of the sand bag. When the plate 12 was not broken by a single impact, the test was repeated with the same fall. The result of this experiment is presented in the following table.

| Sample | Bulk Density (g/cm$^3$) | Fall of Sand Bag (mm) | Destruction 1st hit | 2nd hit | 3rd hit |
|---|---|---|---|---|---|
| No Covering No Glass Fiber | 0.60 | 250 | yes | - | - |
| No Covering 1/2 inch long Glass Fiber Strands, 2 Wt% | 0.61 | 250 | yes | - | - |
| No Covering 1/2 inch Strands, 3Wt% | 0.60 | 250 | no | no | no |
| | | 500 | yes | - | - |
| No Covering 1 inch Strands, 1Wt% | 0.59 | 250 | no | yes | - |
| | | 500 | no | yes | - |
| No Covering 1 inch Strands, 2Wt% | 0.60 | 250 | no | no | no |
| | | 500 | no | no | no |
| | | 750 | yes | - | - |
| with Covering No Glass Fiber | 0.61 | 250 | no | yes | - |
| with Covering 1/2 inch Strands, 3Wt% | 0.58 | 250 | no | no | no |
| | | 500 | no | no | no |
| | | 750 | no | no | no |
| | | 1000 | no | no | no |
| | | 1250 | yes | - | - |
| with Covering 1 inch Strands, 2Wt% | 0.60 | 250 | no | no | no |
| | | 500 | no | no | no |
| | | 750 | no | no | no |
| | | 1000 | no | no | no |
| | | 1250 | no | no | yes |

The invention will further be illustrated by the following Examples.

*EXAMPLE 1*

At first a 2.4% (by weight) aqueous solution of polyvinyl alcohol was prepared in a quantity of 35 kg, and 17.5 g of an air-entraining agent (which was an anion surface active agent) was added to this solution. Then the solution was vigorously agitated by means of a high speed stirrer operated at 1000 rpm to obtain a finely bubbling solution. To this solution was added 50 kg of α-type hemihydrous gypsum, followed by kneading. At least stage of the kneading, 1 kg of 1 inch long strands of glass fiber was added and thoroughly mixed with the gypsum. A resultant plaster slurry exhibited a flow value (JIS R-5201) of 180 mm.

A spun-bonded nonwoven cloth of polyester which had a thickness of 0.5 mm and a density of 70 g/m$^2$ was used as the material of the covering 14. As the larger portion 14*a*, this cloth was cut into a 760 mm wide and 2400 mm long rectangular piece. This sheet 14*a* was creased along the longer sides by means of slender electric iron heated to 280°C so as to make two linear creases 16, which were individually about 1 mm in width, respectively at a distance of 80 mm from the longer sides. In addition, two linear creases 18 were made in the same manner each to extend at a distance of 20 mm from each of the longer sides of the sheet 14*a*. Then the sheet 14*a* was bent at right angle along the creases 16, and the vertically stood portions were bent inwardly at right angle along the respective creases 18, so that the sheet 14*a* was formed into the shape of a cross-sectionally rectangular (600 mm wide and 60 mm deep) trough. The marginal portions 20 of the sheet 14*a* were individually 20 mm wide, so that the upper opening of the trough was 560 mm wide. The thus shaped sheet 14*a* was placed in a mold which was 600 mm wide, 2400 mm long and 60 mm deep in the inside.

The above described plaster slurry was poured into the shaped sheet 14*a* in the mold until the slurry surface reached the level of the horizontally lying marginal portions 20 of the sheet 14*a*. The slurry surface was made even, and a 600 × 2400 mm sheet 14*b* of the polyester nonwoven cloth was placed on the slurry surface, followed by rollering for smoothing. The plaster slurry was allowed to set in the mold to give a covered plasterboard 10, which was dried after removal from the mold. The product 10 was a lightweight plasterboard having a bulk density of 0.61 g/cm$^3$ (for the core plate 12). The edges of this plasterboard 10 were quite sharp and exactly right-angled.

This plasterboard 10 was subjected to the above described impact test. The plasterboard 10 endured without breaking three times of impact at a fall of 1000 mm but was broken when the fall was increased to 1250 mm.

*EXAMPLE 2*

This example illustrates a continuous production method. Polyvinyl alcohol and an air-entraining agent of resin type (vinsol) were dissolved in water respectively in such concentrations as amounted to 3 Wt% and 0.05 Wt% of gypsum when a plaster slurry was prepared using this solution. This solution was maintained at a temperature of 5°C and continuously supplied at a rate of 1 liter per minute to a mixer whose blades revolved at 1000 rpm. With the continued stirring, α-type hemihydrous gypsum was continuously introduced into the solution at a rate of 1500 g/min so as to continuously prepared a plaster slurry of which flow value was 140-150 mm.

A 760 mm wide and 0.5 mm thick nonwoven cloth of polyester (the same cloth as was used in Example 1) was fed to a belt conveyer which was running at a speed of 5 m/min. The cloth on the conveyor was caused to make a sliding contact with stationarily arranged irons, which were heated to 260°C, so as to continuously be creased along each of its longer sides at a distance of 20 mm and additionally at another distance of 80 mm from each side. The creased sheet was bent in the same manner as in Example 1 (but continuously in this case), and the plaster slurry was poured into the shaped sheet on the moving belt conveyer. At the same time, chopped strands of glass fiber, which were 1 inch long, were uniformly introduced into the slurry at a feed rate of 30 g/min. Thereafter, a 600 mm wide sheet of the same polyester nonwoven cloth was laid on the slurry surface at a rate of 5 m/min and smoothed by means of a pair of rollers arranged with an interval of 60 mm. A resultant long strip was cut into 3000 mm long pieces to obtain a covered plasterboard which was 600 mm in width, 3000 mm in length of 60 mm in thickness.

The lightweight plasterboard produced in this exaple had a bulk density of 0.60 g/cm$^3$ (for the core plate) and exhibited a bending strength of 25 kg/cm$^2$. The bending rupture load on this plasterboard was 520 kg/m$^2$. When the plasterboard was subjected to the above described impact test, three times of impact at a fall of 1000 mm did not cause any breakage. When the fall was increased to 1250 mm, the plasterboard endured two times of impact but was broken by the third impact.

Further, this plasterboard was subjected to a two hour fire resistance test according to JIS A-1304, resulting in that the maximum temperature on the opposite side of the plasterboard was 120°C. Accordingly this plasterboard serves as the material of fire resistant walls according to the Japanese Building Standard Law.

WHAT WE CLAIM IS:

1. A lightweight plasterboard comprising:

a rectangular core plate of an air-entrained plaster containing short strands of glass fiber dispersed therein; and

a covering of a fibrous sheet material securely and intimately laid on said core plate so as to cover front and back faces and two parallel sides of said core plate including edges formed by the intersection of said front and back faces with said two parallel sides.

2. A lightweight plasterboard as claimed in claim 1, wherein said core plate has a bulk density of 0.55-0.65 g/cm$^3$, the amount of said strands of glass fiber being 1 to 3% by weight of said plaster.

3. A lightweight plasterboard according to claim 1 or 2, wheren said strands of glass fiber are from 1/2 to 2 inch long.

4. A lightweight plasterboard according to claim 1, 2 or 3, wheren said fibrous sheet material is a cloth of a synthetic fiber selected from polyester fiber, polyamide fiber, polypropylene fiber, cellulose acetate fiber, polyvinyl chloride fiber and acrylic fiber.

5. A lightweight plasterboard according to claim 4, wherein said cloth is a nonwoven cloth.

6. A lightweight plasterboard according to claim 1, 2, or 3, wheren said fibrous sheet material is a silk cloth.

7. A lightweight plasterboard according to claim 1, 2 or 3, wherein said fibrous sheet material is a sheet of paper.

8. A lightweight plasterboard according to claim 7, wherein said core plate additionally contains a silicofluoride in an amount of 0.2 to 6% by weight of said plaster.

9. A lightweight plasterboard according to any one of the preceding claims wherein said covering is creased at said edges by application of heat.

10. A lightweight plasterboard according to any one of the preceding claims, wherein said core plate additionally contains a lightweight aggregate selected from perlite and vermiculite in an amount of 1 to 3% by weight of said plaster.

11. A method of producing a lightweight plasterboard comprising the steps of:

(a) laying a generally rectangular sheet of a fibrous material on the inside of a mold of generally a rectangular box shape;

(b) bending and creasing said sheet so as to make four right-hangled and lasting creases in a parallel arrangement such that two of said four creases in a parallal arrangement such that two of said four creases extend along two parallel borders of the bottom of said mold and the remaining two creases extend respectively above the former two creases at a vertical distance corresponding to the thickness of the plasterboard and leave a gap between two borders of the bent sheet in a horizontal plane containing the upper two creases;

(c) preparing a plaster slurry comprising an air-entraining agent and short strands of glass fiber;

(d) pouring said plaster slurry into said mold until the slurry surface reaches the level of the upper two creases; and

(e) placing another generally rectangular sheet of said fibrous material on the surface of said plaster slurry in said mold.

12. A method according to claim 11, wherein said plaster slurry is prepared by the steps of dissolving said air-entraining agent and a water soluble polymer as an air-entraining assistant in water, adding hemihydrous gypsum to a resultant aqueous solution, and adding said strands of glass fiber to a resultant slurry, the amount of said air-entraining agent being 0.01 to 0.5% by weight of said gypsum, the amount of said polymer being such that the concentration of said polymer in said aqueous solution is 1 to 5% by weight.

13. A method according to claim 12, wherein said water soluble polymer is selected from polyvinyl alcohol, carboxymethylcellulose, methylcellulose, ethylcellulose and hydroxyethylcellulose.

14. A method according to claim 11, 12 or 13 wherein said fibrous material is a cloth of a synthetic fiber selected from polyester fibers, polyamide fiber, polypropylene fiber, polyethylene fiber, cellulose acetate fiber, polyvinyl chloride fiber and acrylic fiber.

15. A method according to claim 14, wherein said sheet is creased by application of heat so as to soften said fibrous material.

16. A method according to claim 14 or 15, wherein said cloth is a nonwoven cloth.

17. A method according to claim 11, 12 or 13 wherein said fibrous material is a silk cloth.

18. A method according to claim 11, 12 or 13 wherein said fibrous material is paper.

19. A method according to claim 18 wherein a silicofluoride is added to said plaster slurry in an amount of 0.2 to 6% by weight of said gypsum.

20. A method according to any one of claims 11 to 19 wherein said plaster slurry is prepared such that said plaster slurry contains air bubbles of 0.1- 0.5 mm. diameter.

21. A method according to any one of claims 11 to 20 wherein a lightweight aggregate selected from perlite and vermiuculite is added to said plaster slurry in an amount of 1 to 3% by weight of said gypsum.

22. A lightweight plasterboard according to claim 1, substantially as hereinbefore described with referece to the accompanying drawing.

23. A method of producing a lightweight plasterboard according to claim 11, substantially as hereinbefore described in Example 1 or Example 2.

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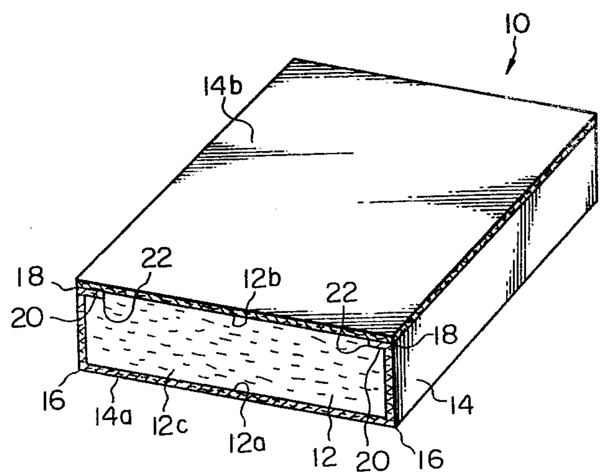
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