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- (73) Patenthaver: **Fliesenmarkt Herberhold GmbH, Erwitter Strasse 107, 59557 Lippstadt, Tyskland**
- (72) Opfinder: **GEUKING, Hans-Dieter, Lintelers Kamp 10, 59556 Lippstadt-Cappel, Tyskland**
DICKOPF, Michael, Am Wald 1, 56244 Maxsain, Tyskland
LAHR, Johannes, Kutscheider Weg 7, 56237 Deesen, Tyskland
OGBAZGHI, Tekie, Görresstr. 30a, 59557 Lippstadt, Tyskland
THOMAS, Christian, Chorherrenweg 20, 59494 Soest, Tyskland
- (74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**
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DONDI MICHELE ET AL: "Clays and bodies for ceramic tiles: Reappraisal and technological classification", APPLIED CLAY SCIENCE, ELSEVIER, AMSTERDAM, NL, Bd. 96, 18. Februar 2014 (2014-02-18), Seiten 91-109, XP028876075, ISSN: 0169-1317, DOI: 10.1016/J.CLAY.2014.01.013

Description

5 [0001] The present invention relates to a stoneware tile, in particular a stoneware tile that can be used as a facade panel. Thermally insulated facade systems are becoming more and more important in construction technology. A special significance within the thermal insulation composite systems is given to the facades, which are protected against environmental influences with ceramic facade panels.

10 [0002] The following requirements apply to ceramic facade panels:
- high resistance to mechanical stress and surface wear
- high breaking strength
- pore distribution according to DIN 18515
- pore volume according to DIN 18515
- Water absorption < 3 %
- frost resistance according to EN 14411.

15 [0003] The production of ceramic facade panels includes a complex and multi-stage process of preparing, assembling and processing raw materials, shaping blanks as well as drying, firing and post-processing the ceramic facade panels. An overview of the process steps is given by Dondi Michele et al. in the technical article entitled "Clays and bodies for ceramic tiles: reappraisal and technological classification", for example in
20 section 3.2 "Ceramic tile production" (DONDI MICHELE ET AL: "Clays and bodies for ceramic tiles: Reappraisal and technological classification", Applied clay science, Elsevier, Amsterdam, NL, vol. 96, 18, February 2014, pages 91-109, XP028876075, ISSN: 0169-1317, DOI: 10.1016/J.CLAY.2014.01.013).

25 [0004] The main raw materials for ceramic facade panels are clays. In addition, there is feldspar, kaolin, possibly
Fireclay, if necessary colorants (dyes and/or pigments) and water.

30 [0005] The various clays used often consist of assembled clay mixtures that are delivered in a pre-broken form (piece size max. 5 cm). In a first processing step, the clays are dried in a dryer from the pit moisture content (approx. 10 to 14% depending on quality and weather) to approx. 5% Residual moisture pre-dried. The clayey raw materials are then dried in a mill to a fineness of < 100 µm and a moisture content of < 1%. The clays thus processed are then stored in separate storage silos and subjected to a defined maceration period in order to achieve a uniform moisture content of the clays.

35 [0006] After the mauk period, the clays and other raw materials such as feldspars, chamotte, kaolins and/or colorants are first mixed dry according to a recipe and then wet mixed with the addition of water.

[0007] The raw mass produced in this way is further processed in a vacuum extrusion press.

40 [0008] Extrusion, also known as sintering, is the actual shaping step in the production of ceramic facade panels. The raw mass is highly compressed in the extrusion press via screw shafts and pressed out through a mouthpiece of the press. In addition, the mass is evacuated to avoid voids (air inclusions). The shape of the mouthpiece determines the contour, height and width of the resulting endless tape. The blanks are cut to the desired length using cutting equipment.

45 [0009] The extruded blanks contain approximately 15% to 17% water, which was required to keep the raw material recipe plastically deformable for extrusion. For the next process steps, the water is removed from the plates. For this purpose, the blanks are placed in a continuous dryer for a certain period of time, in which the panels are dried at a temperature of approx. 80 - 110°C the residual process water is removed until a residual moisture content of < 1% is reached.

50 [0010] During this drying process, the blanks shrink in all dimensions by approximately 5% to 6% of their original size. This must be taken into account, among other things, for the dimensioning of the extrusion mold (mouthpiece).

55 [0011] In order to avoid drying cracks, the raw material recipe, the drying temperature/humidity over time and the residual water content must be strictly adhered to in accordance with the strict development specifications for ceramic facade panels.

60 [0012] Once the blanks have reached a residual moisture content of < 1%, they are unloaded from the dryer and processed further. For the further process steps, a distinction is made between glazed and unglazed panels.

[0013] Unglazed plates consist exclusively of the original, now dried raw mass recipe, which is fired without any further coatings. The surface colour corresponds to the natural colour of the body.

[0014] After drying, glazed tiles are given a coat of paint (glazed) and coated with a durable top glaze. The glaze consists of finely ground glaze components, which are fired in the kiln at approx. 1200 degrees Celsius and develop their color brilliance.

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[0015] The color application can be carried out as a decorative print (stone structure, wood structure, etc.) or in plain colors (red, black, blue, white, etc.).

[0016] After drying and if necessary the blanks are then glazed and fired into tiles.

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[0017] Through these process steps, ceramic facade panels as well as other ceramic products can be produced.

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[0018] If ceramic facade panels are attached to a building, it can happen - especially in the case of highly thermally insulated facades - that moisture collects in the facade, directly behind the facade panels. This could, for example, be moisture that enters the wall with the facade from inside the building. This moisture migrates from the inside to the outside of the building's wall through the wall and, since it cannot penetrate through the facade panels, collects behind the facade panels. If the facade cools down, the moisture can condense in the wall. If the condensed moisture freezes, the expansion of the freezing water can lead to frost heaves, which means that at least some of the ceramic facade panels will become completely or partially detached from the wall or at least become damaged.

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[0019] However, moisture can accumulate behind the facade panels not only due to condensation. It is also possible that rainwater penetrates through the joints into the adhesive bed of the facade panels and leads to frost damage in the event of frost.

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[0020] Ceramic facade panels are therefore currently only used to a limited extent in areas at risk of frost.

[0021] The invention is based on the object of eliminating this limitation.

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[0022] The object is achieved according to the invention in that the recipe of a tile according to the invention contains various clay mixtures, feldspars and kaolin according to the following composition (mass fraction):

Sound mix "T2761"	50 %
Sound mix "T1571"	7,73 %
Feldspar "HP-1"	9,54 %
Feldspar "Silver Mine"	12,27 %
Feldspar "FS-700"	12,73 %
Kaolin "KDG"	7,73 %

[0023] 1.100 kg of a dry mix prepared according to this recipe can be wet mixed with 188 l of water to produce the raw material for a tile according to the invention.

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[0024] The clay mixture T2761 contains the following components (mass fraction):

SiO ₂	66 up to 73%, preferably approx. 69 to 70%
TiO ₂	1,4 up to 1.9%
Al ₂ O ₃	22 up to 25%, preferably approx. 23 to 24%
Fe ₂ O ₃	1 up to 2%, preferably 1.4 to 2%
CaO	0,2 up to 0.3%
MgO	0,3 up to 0.5%
K ₂ O	2,1 up to 3.0%
Na ₂ O	0,15 up to 0.3%

[0025] The clay mixture T1571 contains the following components (mass fraction):

SiO ₂	68 up to 75%, preferably approx. 71.5 to 73%
TiO ₂	1,4 up to 1.9%
Al ₂ O ₃	20 up to 24%, preferably approximately 21.5 to 23%
Fe ₂ O ₃	1 up to 2%, preferably 1.0 to 1.2%
K ₂ O	2,1 up to 3.0%
Na ₂ O	0,01 up to 0.03%

40

[0026] Feldspar HP-1 contains the following components (mass fraction):

SiO ₂	71,63 up to 75.63%
Al ₂ O ₃	13,05 up to 14.65%
Fe ₂ O ₃	0,18 up to 0.24%
MgO	Max. 0,08%
CaO	Max. 0,15%
Na ₂ O	0,38 up to 0.46%
K ₂ O	9,96 up to 10.96%
TiO ₂	max.0.1%

5 **[0027]** The feldspar Silbergrube contains the following components (mass fraction):

SiO ₂	73 up to 75%
Al ₂ O ₃	15 up to 16%
Fe ₂ O ₃	0,5 up to 0.55%
TiO ₂	max.0.1%
CaO	max. 0,5%
MgO	max. 0,03%
K ₂ O	3,0 up to 4.0%
Na ₂ O	4 until 5%

[0028] The feldspar FS-700 contains the following components (mass fraction):

SiO ₂	66 up to 68%
Al ₂ O ₃	16,5 up to 18.5%
Fe ₂ O ₃	max. 0,17 %
TiO ₂	max.0.6%
CaO	max. 0,05%
MgO	max. 0,05%
K ₂ O	11,0 up to 13.0%
Na ₂ O	max. 0,7%

[0029] Kaolin KDG contains the following components (mass fraction):

SiO ₂	59 up to 62%
Al ₂ O ₃	35,5 up to 36.9%
Fe ₂ O ₃	max. 0,75 %
MgO	max. 0,5%
K ₂ O	0,9 up to 1.4%
Na ₂ O	max. 0,5%

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[0030] The manufacturing process can also play a role. Basically, a tile according to the invention can be manufactured according to the method described above.

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[0031] However, it has proven to be particularly advantageous if a layer is removed from the back of the dried blanks before firing. In this layer, which is also called the press skin, the pressed raw mass is highly compacted so that it contains few pores or capillaries compared to the interior of the blank. If this press skin is removed, more pores and capillaries are in contact with the back of the blank, which facilitates the transport of water from the back of the fired tile to its edges. The pressed skin can be removed over the entire surface or only in parts of the back of the tile. The latter is particularly useful if the back of the tile is not flat, but grooved or ribbed. In this case, only the pressed skin can be removed from the raised webs between the grooves. The removal can be done by grinding. By removing material, 0.5 to 2.5%, preferably 1 to 2%, of the thickness of the blank can be removed from the back side of the dried blank.

20

25 **[0032]** After drying and before firing, the blank can be decorated. For this purpose, the blank can be provided with a glaze, especially with a cover glaze. The glaze can be used to apply a pattern to the blank.

[0033] Decorating is preferably done after sanding the back of the blank.

[0034] After removing the press skin, the blank can be heated for 80 minutes at max. 1200°C fired.

[0035] The edges of the blanks or the fired tiles can also be finished by grinding. This also allows a more open-pored structure to be achieved at the edges than with untreated edges, which facilitates the transport of water from the tiles into the joints between the tiles.

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[0036] The pore distribution and pore volume of a stoneware tile according to the invention meet the requirements of the DIN 18515 standard in its currently valid version.

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[0037] The machine used to produce the blanks could also be a determining factor for the properties of the tile. For example, an extrusion mold or the mouthpiece of the extrusion press can promote the capillary alignment of the ceramic raw mass. An inventive mouthpiece, which is adapted to the tile geometry, achieves optimal compaction and homogenization of the pressed mass strand. The mouthpiece is designed in such a way that an isokinetic passage of the masses occurs during the production of the strand from which the blanks are cut. But the design of a compression unit of an extrusion machine and the guidance of the mass in the extrusion machine can also influence the desired homogeneity and the desired degree of compaction, which is advantageous for the creation of the capillaries and their alignment in the blanks or tiles.

15

[0038] Another contributing factor for the formation of the capillary could be a special design of a tile according to the invention. For example, the blank may contain fibers, yarns, twines or threads, preferably parallel to the back of the blank. These fibers, yarns, twines or threads in a blank of a tile according to the invention preferably burn without residue during the firing process and can thus create capillaries in the tile which facilitate liquid transport from the back of the tile to the edges of the tile.

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[0039] The fibres, yarns, twines or threads can be made of synthetic fibres, for example nylon, carbon fibres or combustible natural fibres.

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[0040] As an alternative to fibres, yarns, twists or threads, linear traces of powders can also be introduced into the blanks during production, particularly during extrusion, which preferably burn without residue during firing and thus form capillaries in the tiles. These powders can be made from plastics, such as nylon, from coal or other combustible natural materials.

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[0041] It is also possible that powder and fibers, yarns, twines or threads are used in combination to form capillaries.

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[0042] The tile to be used as a facade panel has an average water penetration depth of 200 to 1500 μm , in particular 300 to 1500 μm , in a 2-hour vacuum test dye penetration test at 200 mbar. The average penetration depth can advantageously be 500 to 1300 μm .

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[0043] In comparison, the penetration depth of a porcelain stoneware tile, for example, is less than 100 μm and only at specific points.

[0044] The relative mass increase in the 2h vacuum test can be 1.5% to 2%, in particular 1.7% to 1.95%.

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[0045] A dye penetration test at normal pressure also shows that water or moisture can penetrate a tile according to the invention better than a conventional tile. In a 10-hour immersion test at normal pressure, a penetration depth of 100 to 500 μm was determined. The relative mass increase can be 0.4% to 0.5%.

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[0046] Alternatively or additionally, the invention can be described in such a way that water or water vapor in the tile has a capillary-direction-related penetration rate that is significantly higher than the penetration rate in conventional tiles used as facade panels. Thus, according to the invention, the tile can have a penetration rate in a direction perpendicular to the back of the tile of approximately 30 $\mu\text{m}/\text{h}$ to 50 $\mu\text{m}/\text{h}$ and/or in a direction parallel to the back of the tile of approximately 150 $\mu\text{m}/\text{h}$ to 200 $\mu\text{m}/\text{h}$ in an area adjacent to a back in an immersion test at normal pressure. Immersion test means that the penetration rate is determined when a tile is completely immersed in water.

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[0047] A facade panel with these properties has capillaries that allow water to penetrate deeper into the facade panel than conventional facade panels. In contrast, conventional facade panels lack such capillaries. Water cannot penetrate the facade panels.

60

[0048] However, the capillaries do not only allow water to penetrate the facade panel. It is also possible that water can escape from the facade panel through the capillaries.

[0049] This makes it possible for water that collects in the facade behind the facade panels according to the invention to pass through the back of the facade panels into the capillaries in the facade panels. From there, the water can be transported through the capillaries in the facade panels to the edges of the facade panels.

There, water can escape from the facade panels and enter the joints between the facade panels. The water can then escape from the facade through the joints. This means that there is no collection of water in the facade behind the facade panels. Frost cracking cannot occur with facade panels according to the invention. [0050] Thus, capillaries are preferably present in tiles according to the invention which extend parallel to the back of the tile and form a connection, e.g. B. have additional capillaries that lead to the back of the tile.

[0051] The possibility that moisture can be transported through the facade panels according to the invention, which can be quantified by the penetration depth in the dye penetration test, is due to capillaries that are created in the facade panels during manufacture.

[0052] At the same time, it is advantageous if the tile has a water absorption of 1% to 2%, preferably around 1.5%. Despite the possibility that water can be absorbed comparatively quickly and deeply into a tile according to the invention, the tile advantageously has only a comparatively small possibility of absorbing water, i.e. it can only hold a small amount of water. This means that the water that accumulates on the back of the tile is transported through the tile to its edges and from there can be drained away via the joints between the tiles.

[0053] Like any stoneware tile, tiles according to the invention contain pores. An advantage of a tile according to the invention is that the pores of a tile according to the invention are interconnected by channels or are formed into channels and the channels are aligned substantially parallel to an underside of the tile. These channels can be parts of the capillaries that allow water to transport through the tile.

[0054] Various factors can be causal or at least co-determining for the capillaries in the facade panels according to the invention.

[0055] A firing process for a tile according to the invention is explained below with reference to a figure. It shows the

Fig. 1

a temperature distribution in a roller kiln used for the firing process.

[0056] The figure shows the temperature distribution in the oven with which tiles according to the invention can be produced. The oven can advantageously be a roller oven. The tiles are fired continuously in the kiln.

[0057] The measuring points for which the temperatures are given in Figure 1 are not equidistantly distributed over the length of the oven or the path of the tiles through the oven. The length of the furnace is 80 m. The firing time, i.e. the residence time of the blank/tiles, is approx. 80 minutes. The blanks/tiles are transported through the kiln at an almost constant speed. The speed of the blanks/tiles can be set in different areas of the oven as follows:

Furnace meters 37 to 43	Transport speed 1100 mm/minute
Furnace meters 43 to 49	Transport speed 1100 mm/minute
Furnace meters 49 to 55	Transport speed 1100 mm/minute
Furnace meters 55 to 63	Transport speed 1035 mm/minute
Furnace meters 63 to 69	Transport speed 1075 mm/minute
Furnace meters 69 to 77	Transport speed 1075 mm/minute
Furnace meters 77 to 80	Transport speed 1070 mm/minute

[0058] The oven meter refers to the distance of the blank/tile to the entrance of the oven.

[0059] In the furnace, a heating zone, a first firing zone, a high-temperature zone (second firing zone), a first direct cooling zone, a first indirect cooling zone, a second direct cooling zone, a second indirect cooling zone and final cooling can be distinguished. In the heating zone temperatures of up to approx. 800°C is reached. At 800°C the blank begins to sinter and becomes a tile. The burning curve peaks at approx. 1200 C in the high temperature zone, followed by the drop cooling zone in which the tiles are directly cooled (furnace meters 54.5 to 63). This is followed by an indirect cooling zone (furnace meters 63 to 71.5) and a final cooling zone (furnace meters 71.5 to 80). In the drop cooling zone, the temperature is reduced, for example with the help of fans.

Patentkrav

1. Råstofblanding til fremstilling af en stentøjsflise, **kendetegnet ved, at** råstofblandingen har følgende sammensætning i masseprocent:

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Lerblanding "T2761"	50 %
Lerblanding "T1571"	7,73 %
Feldspat "HP-1"	9,54 %
Feldspat "Silbergrube"	12,27 %
Feldspat "FS-700"	12,73 %
Kaolin "KDG"	7,73 %

2. Råmasse til fremstilling af en stentøjsflise med en råstofblanding ifølge krav 1, **kendetegnet ved, at** der til 1100 kg af en råstofblanding med
10 sammensætningen ifølge krav 1 sættes 188 l vand.

3. Fremgangsmåde til fremstilling af en stentøjsflise, **kendetegnet ved** følgende trin:

- bearbejdning af råstofblandingen ifølge krav 1 ved formaling til en finhed, dvs.
15 kornstørrelse på $< 100 \mu\text{m}$, tørring til en fugtighed på $< 1 \%$ og mæskning til frembringelse af en ensartet fugtighed,
- tørblanding af råstofferne,
- vådblanding af råstofferne og vandet til en råmasse ifølge krav 2,
- ekstrusion af råmassen,
20 - skæring af den til et lerbånd pressede råmasse til fliseemner,
- tørring af fliseemnerne og
- brænding af fliseemnerne, hvorved stentøjsflisen har en gennemsnitlig indtrængningsdybde for vand, der i et 2h-vakuumsforsøg farveindtrængningsforsøg ved 200 mbar udgør 200 til 1500 μm , især 300 til 1500 μm , og/eller at en
25 gennemtrængningshastighed i en retning vinkelret på flisens bagside i et nedsænkingsforsøg ved normalt tryk ligger på ca. 30 $\mu\text{m}/\text{h}$ til 50 $\mu\text{m}/\text{h}$ og/eller i en retning parallel med bagsiden på ca. 150 $\mu\text{m}/\text{h}$ til 200 $\mu\text{m}/\text{h}$ i et til en bagside tilstødende område af flisen.

4. Fremgangsmåde ifølge krav 3, **kendetegnet ved, at** en underside af flisen slibes før brændingen.

5. Fremgangsmåde ifølge krav 3 eller 4, **kendetegnet ved, at** emnerne evt. efter 5 slibningen af undersiden og før brændingen forsynes med en suspension til fremstilling af en glasur.

6. Fremgangsmåde ifølge krav 3 til 5, **kendetegnet ved, at** rande på flisen slibes efter brændingen.

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7. Fremgangsmåde ifølge et af kravene 3 til 6, **kendetegnet ved, at** en overfladefilm fjernes fra en underside af emnet mellem presningen og brændingen.

15 **8.** Fremgangsmåde ifølge et af kravene 3 til 7, **kendetegnet ved, at** der ved ekstrusionen indarbejdes fibre, garner, tvindegarner eller tråde i emnet.

9. Fremgangsmåde ifølge krav 8, **kendetegnet ved, at** fibre, garnerne, tvindegarnerne eller trådene er orienteret i en retning, der er parallel med flisens 20 underside.

10. Fremgangsmåde ifølge krav 8 eller 9, **kendetegnet ved, at** fibre, garnerne, tvindegarnerne eller trådene forbrænder under brændingen.

25 **11.** Stentøjsflise, der kan fås ved fremgangsmåden ifølge et af kravene 3 til 10, **kendetegnet ved, at** flisen har en gennemsnitlig indtrængningsdybde for vand, der i et 2h-vakuumsforsøg farveindtrængningsforsøg ved 200 mbar udgør 200 til 1500 μm , især 300 til 1500 μm , og/eller at en gennemtrængningshastighed i en retning vinkelret på flisens bagside i et nedsænkingsforsøg ved normalt tryk 30 ligger på ca. 30 $\mu\text{m}/\text{h}$ til 50 $\mu\text{m}/\text{h}$ og/eller i en retning parallel med bagsiden på ca. 150 $\mu\text{m}/\text{h}$ til 200 $\mu\text{m}/\text{h}$ i et til en bagside tilstødende område af flisen.

12. Stentøjsflise ifølge krav 11, **kendetegnet ved, at** den gennemsnitlige indtrængningsdybde for vand udgør 500 til 1300 μm .

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13. Stentøjsflise ifølge krav 11 eller 12, **kendetegnet ved, at** flisen har en vandoptagelse på 1 til 2 %, fortrinsvis omtrent 1,5 %.

14. Stentøjsflise ifølge et af kravene 11 til 13, **kendetegnet ved, at** flisens porer er forbundet med hinanden gennem kanaler eller er formede til kanaler, og kanalerne i det væsentlige er orienteret parallelt med en flisens underside.

15. Stentøjsflise ifølge et af kravene 11 til 14, **kendetegnet ved, at** flisens underside eller dele af flisens underside er bearbejdet ved slibning.

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16. Stentøjsflise ifølge et af kravene 11 til 15, **kendetegnet ved, at** rande på flisen er bearbejdet ved slibning.

17. Stentøjsflise ifølge et af kravene 11 til 16, **kendetegnet ved, at** undersiden og/eller randene har en åbenporet struktur.

15

Fig. 1

