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Description

[0001] The invention relates to a block-like, sound-absorbing paving element, to a paving comprising a number of such paving elements and to a method for arranging such paving elements on a ground surface.

[0002] Traffic noise of traffic on roads, railways and aviation is one of the most significant sources of noise nuisance. Noise nuisance may result in irritation or even health problems. Road traffic noise as a result of motor vehicles such as cars, trucks, motorbikes and the like generally comprises the following components: rolling noise resulting from wheels rolling over the road surface, engine noise resulting from operation of the engines of the passing vehicles, and noise resulting from the interaction between the moving vehicles and the air.

[0003] In order to reduce the sound levels caused by the road traffic for the surrounding area it is known to provide the road surface with sound-absorbing asphalt, such as very open asphalt concrete (ZOAB). The use of such sound-absorbing asphalt however has a number of drawbacks. Firstly, installation and maintenance of such asphalt is fairly expensive. This asphalt further has relatively poor resistance to cornering traffic. Such sound-absorbing asphalt is moreover less effective at lower speed and is therefore used less frequently in urban areas. A further drawback is that the monolithic character of an asphalt road impedes access to utilities situated under the road, such as cables, conduits and pipes. The density of such utilities under the road surface is particularly high in urban areas. For all these reasons it is usual in residential areas not to use a lot of asphalt, but to construct the road surface with paving elements. These paving elements are not sound-absorbing, and the drawback of using paving elements is therefore that they cause a relatively large amount of noise. Not only do the paving elements cause a relatively large amount of rolling noise because they are placed relatively far apart and the tyres can easily hit the edges of the paving elements and/or because the paving elements are made of acoustically hard material and therefore strongly reflect the rolling noise, the remaining traffic noise is also reflected by the hard surface of the paving elements and causes noise nuisance in the area.

[0004] It could optionally be possible to arrange a number of acoustic resonators in the upper surface of the paving elements (i.e. the surface over which the traffic travels), with the object of partially absorbing the sound incident on the upper surface. These resonators could at the very least reduce the noise which finds its way into the surrounding area from the engine, from the rolling noise and from the interaction with the air. A drawback of such a solution would however be that precipitation which has found its way into the resonators, for instance as a result of rain, wholly or partially eliminates the sound-absorbing effect of the resonators. The road surface will therefore absorb little or no sound during or immediately after a downpour of rain. Since precipitation will moreover

hardly evaporate from these resonators, certainly when these are relatively small, the water will remain in the resonators for a long time. In practice this would mean that the road surface would be non-absorbent or poorly absorbent a large part of the time.

[0005] It could also be possible to make the paving element of a water-permeable or porous material. Such material however tends to become soiled eventually, this reducing the water-draining effect. A water-permeable paving element is further less robust. Such paving elements can cause problems, certainly during frost and thaw. It is thus recommended to use a non-porous material. A drawback of using non-porous material is that it could only absorb sound if use is made of cavities (i.e. hollow portions) in which acoustic resonance occurs.

[0006] US 5 797 698 A describes a paving element for water-permeable reinforcement of surfaces, where one or more of the sides have vertical recesses extending from the top surface of the paving element to the bottom surface. The recesses are disposed asymmetrically about the mid points of the sides such that the recesses of the adjacent sides of neighbouring elements are offset from one another when the neighbouring elements are laid in alignment, thereby avoiding alignment of the recesses. Alternatively, an offset of the recesses on neighbouring stones is achieved by laying the elements in a displaced or staggered manner.

[0007] DE 20 2009 008 254 U1 describes a paving constructed from a pattern of partially hollow, block-like building blocks arranged on a ground surface, with a layer of air-permeable material on top of these building blocks. Each of the hollow building blocks comprises a hollow space forming a Helmholtz resonator. This known building block is complex, relatively expensive to manufacture and cannot be driven over directly (it is required that a layer of material is arranged on top). The absorbing effect of the building block will further eventually decrease due to precipitation seeping into the hollow spaces.

[0008] DE 10 2004 017 534 A1 describes a system of concrete block-like paving bricks which can be employed as paving of a verge adjacently of a road. The paving bricks can be mutually coupled via connecting means in the form of an upright protrusion and upright recesses. Each of the paving bricks comprises a number of openings arranged in a side surface and running all the way from the underside of the paving brick to the upper side thereof in order to enable plants to take root therein. These recesses are not dimensioned to absorb sound incident on the upper surface. All the openings are further of equal length, i.e. not suitable for absorbing the incident sound in different frequency ranges and thus in a relatively wide frequency range (for instance consisting of a number of overlapping frequency ranges).

[0009] The invention has for its object to provide a paving element wherein at least one of the stated and/or other drawbacks is at least partially obviated.

[0010] It is also an object to provide a sound-absorbing paving element with better practical applicability and/or

to provide a paving element which can absorb sound in various frequency ranges.

[0011] It is a further object of the invention to provide a paving of paving elements which can be arranged on a ground surface in simple manner and can realize a high sound absorption for a large part of the time.

[0012] It is another object of the invention to provide a paving element which enables incident sound to be absorbed and also precipitation to be discharged to the ground during use, so that the absorption is maintained over a longer period of time.

[0013] According to a first aspect of the invention, at least one of the stated objectives is achieved in a block-like sound-absorbing paving element according to claim 1.

[0014] The recesses are configured to be able to form resonators with which the incident sound can be absorbed. Because the resonators have different depths and/or shapes, the sound can be absorbed over a relatively wide frequency spectrum. Because the recesses are further arranged in one or more side surfaces, water which has found its way into a recess can flow out via the underside of the recess and the intermediate space between adjoining paving elements. This means that the recesses will empty quickly and the absorbing effect is not affected, or hardly so (and only for a very short period of time).

[0015] In embodiments of the invention the paving element comprises a first side and a second side (opposite side or adjoining side), wherein one or more recesses in the first side extend at peripheral positions differing from the peripheral positions at which the one or more recesses in the second side extend. The positioning of the recesses is such that when the first side of a first paving element and a second side of a second paving element are placed opposite each other during use, the recesses of the first paving element lie at different peripheral positions than the recesses in the second paving element. This achieves that two recesses of different paving elements will never connect (this is because the porosity is twice as great when two recesses of the same depth are placed opposite each other), so that the porosity always has the predetermined correct value. An optimal absorption is in this way achieved.

[0016] It is otherwise however possible to embody the paving elements such that the recesses of adjoining paving elements do lie precisely opposite each other. Each of the recesses must then be half the size of the recess in the above stated embodiments in order to together form a recess of the desired dimensions. In these embodiments the porosity can also have the predetermined correct value. It is important that the recesses of adjoining paving elements always lie at predetermined, fixed positions relative to each other when the paving elements are arranged on the ground, and that these fixed relative positions are taken into account in the dimensioning of the recesses.

[0017] The recess in a side surface is further preferably

wholly or partially open on the side. During use, i.e. when the paving elements are arranged on a ground surface in a determined laying pattern (i.e. the way in which the paving elements are laid relative to each other, for instance in each case with an end surface of the one paving element against a longitudinal side of the other paving element (herringbone pattern)), the side of an adjoining paving element lies opposite this open side of the recess. The recess in the one paving element and the side (optionally also at the position of a recess) of the other paving elements together form a resonator whereby the sound incident on the upper surface can be absorbed.

[0018] Said side of the other paving element preferably takes a flat form at the position of the recess in the original paving element. In this embodiment a resonator is constructed from the side of the recess, for instance a curved side in the case of a tubular or even cylindrical recess, in a side of the one paving element, and the flat side of the other paving element. As a result of the ever-present intermediate space between the two paving elements the resonator is however preferably open to some extent on the underside, or a water-permeable joint filler is applied, so that there is always the possibility of discharging water.

[0019] In other embodiments one or more side surfaces however take a form with a curved (for instance a sinusoidal), stepped or other form of profile. As long as the curved, stepped or other forms of profiles of the side surfaces of adjoining paving elements connect properly to each other, the resonators can be formed in similar manner as in the case of flat sides.

[0020] In determined embodiments the thus formed resonators are so-called $\frac{1}{4}$ -wavelength resonators. The walls and bottom of these resonators are manufactured from acoustically hard (non-absorbing) material, and absorption material is preferably not arranged in the space of the resonator either. In other embodiments the resonators are however partially or wholly provided with acoustically absorbing material. This material is moreover water-permeable so that precipitation which has found its way into the recess can be discharged quickly. In determined embodiments filling strips of water-permeable and acoustically absorbing material, for instance in the form of needle felt strips of PP and PE, are arranged in the intermediate spaces between the paving elements. These strips enable precipitation to be discharged to the ground, while "rattling" of the paving elements is reduced. These filling strips are located in the joint and generally also protrude into the recesses to some extent. In determined embodiments the recess extends substantially from the (upper) side to be driven over to the underside of the paving element to be placed on the ground. The recess can more particularly extend substantially parallel to the relevant side surface, for instance upright or obliquely in the plane of the element. A recess can particularly extend from the upper surface to a position between the upper surface and lower surface. The recess then thus has both a side wall and a bottom formed by the material from which the paving element is construct-

ed. The bottoms of different recesses can be situated at different distances relative to the upper surface in order to create resonators of different depths.

[0021] It is possible also to place resonators at positions other than in the sides of the paving elements, for instance somewhere in the upper surface at a distance from a side surface. In practice, such resonators would have few or no absorbing properties when filled, for instance with precipitation. It is however advantageous in some cases to arrange resonators which run through the whole of the paving element at a position other than on the sides. Such resonators then drain through the paving element, but resonate at a resonance frequency at which the corresponding wavelength is roughly equal to four times the overall thickness of the brick. In other embodiments resonators are however wholly absent at positions other than in the sides. In these embodiments the recesses are provided only in side surfaces.

[0022] Since the paving elements in many cases have to be embodied to support relatively heavy traffic travelling thereover, such as goods traffic, the mutual distance of the recesses should not be too small for reasons of structural strength. In embodiments of the invention at least one recess is in each case arranged in each of two opposite side surfaces, this preferably at different positions. When two paving elements are then placed adjacently of each other, there is no overlap of recesses. Depending on the minimum distances between recesses in a determined paving element, which are determined by the minimum structural requirements, a maximum number of recesses per unit area of paving elements can hereby be realized.

[0023] The paving element is preferably partially or wholly manufactured from acoustically hard material. This material is generally also structurally robust, so that relatively little wear occurs. Examples of acoustically and structurally hard material are concrete, brick, hard plastic and the like. A material can for instance be referred to as acoustically hard when the absorption coefficient of the material (without the resonators described herein) is smaller than 0.4, preferably smaller than 0.1 and still more preferably smaller than 0.05 in the relevant frequency ranges.

[0024] The block-like paving element can take different geometric forms. In a determined embodiment all side surfaces have a rectangular shape (rectangular block). In this embodiment the block forms a three-dimensional body whose angles are all right angles. Non-right angles also occur in other embodiments, such as an embodiment with more or fewer side surfaces than the four side surfaces of the rectangular block.

[0025] It is of further importance for a good absorbing effect that the porosity of the recesses, defined as the cumulative surface area of the upper outer ends of the recesses of equal form and equal volume (for instance equal depth of a cylindrical tube) divided by the overall surface area of the upper surface, is a maximum of 5%, preferably a maximum of 2% and still more preferably a

maximum of 1%. Said porosity values apply to recesses which are free of acoustically absorbing material. If acoustically absorbing material is arranged in the recesses, these values generally differ.

[0026] The number of recesses to be arranged in a paving element depends on, among other factors, the geometric dimensions of the recesses (i.e. the diameter and/or the depth), the structural requirements set for paving elements (for instance minimum wall thickness between two adjoining recesses in a determined paving element) and the geometry of the paving element itself. If the length/width ratio is for instance 4:1, the ratio of the number of recesses in the long sides and short sides can also be chosen as 4:1. If there are for instance two long sides and two short sides, $(2 \times 4 + 2 \times 1) = 10$ recesses, or an integer multiple thereof, can for instance be arranged in order to obtain a uniform number of recesses per cm. It is then possible to realize a placing of the recesses such that, irrespective of the pattern in which the paving elements are laid, the recess of the one paving element does not come to lie opposite a recess of another paving element.

[0027] When the paving element has for instance a so-called "Waal" format (paving brick, length 20 cm, width 5 cm, thickness 10 cm) the depth/height of the recesses preferably amounts to 52, 56, 60, 64, 69, 74, 80, 87, 94 and 100 mm in order to optimally absorb sound in a frequency range of 750 Hz to 1500 Hz.

[0028] When the length-width ratio however equals 3:1, the total number of recesses in the side surfaces is preferably eight ($= 2 \times 3 + 2 \times 1$) or a multiple thereof. In the case of eight recesses, the depths for the above stated frequency range preferably amount to 52, 56, 61, 66, 72, 79, 88 and 98 mm respectively, while in the case of sixteen recesses the depths preferably amount to 52, 54, 56, 59, 61, 64, 67, 71, 74, 78, 82, 86, 91, 95, 100 and 105 mm.

[0029] When the length-width ratio equals 2:1, the total number of recesses in the side surfaces is six or a multiple thereof, preferably twelve recesses. In the case of twelve recesses, the depths for the above stated frequency range of 750 Hz-1500 Hz are preferably 52, 54, 57, 61, 64, 68, 72, 77, 82, 88, 95 and 102 mm.

[0030] It has been indicated above that the recesses can be (semi-)tubular. More generally, the recesses can be (semi-)cylindrical (wherein a cylinder is defined as a form having a circular, oval or other form of base surface and having the same cross-section throughout parallel to the base surface, with all centres in a straight line) or, more particularly, be (semi-)prismatic (i.e. a form with an n-sided polygon as base, a translated copy of this base, and n side surfaces connecting these two planes to each other). Other embodiments have a first part (connecting to the inlet opening) with a relatively small cross-sectional diameter and a connecting second part (lying deeper) with a relatively large cross-sectional diameter, for instance a recess with a narrow neck and wider cavity. These embodiments are also referred to as Helmholtz

resonators. Figures 5A-5C show several possible embodiments of such Helmholtz resonators. In figure 5A the recess is embodied as a (semi-)truncated cone, wherein the (narrow) top of the cone has been removed. In this embodiment the base surface and top surface of the (imaginary) cone take a (semi-)circular (figure 5A) or (semi-)oval (figure 5C) form. Figure 5B shows a more classical form of a Helmholtz resonator, comprising a (semi-)cylindrical neck with a small diameter and connected directly thereto a (semi-)cylindrical cavity with a much larger diameter.

[0031] The transition between the first and second part can be fairly abrupt, although in other embodiments, such as in the case of conical recesses (with a circular or oval inlet opening), the transition is smoother. An advantage of the latter stated embodiments (wherein the second, deeper part is wider than the first part) is that sound with a lower frequency can be absorbed than would be possible with a cylindrical or prismatic recess with a length equal to the height of the paving element.

[0032] In determined embodiments the paving element can comprise spacers provided on one or more of the side surfaces in order to ensure that the side surfaces of adjoining paving elements have a mutual distance greater than a determined threshold value (for instance, though not limited to, at least 0.5 mm or more) during use. This enhances the water drainage capacity.

[0033] In embodiments of the invention the upper outer end of a recess has a straight edge. In other embodiments this edge (also referred to as the chamfer) is chamfered so as to reduce the rolling noise produced by the traffic travelling over the paving. Such a chamfered edge is moreover more robust than the straight edge.

[0034] The paving elements are preferably of a type which can be carried by a person, for instance having a maximum mass of 10 kg. The person can easily place the paving elements on a ground surface by hand.

[0035] In many embodiments the traffic will travel directly on the upper side of the paving element. The upper surface of the paving element is thus the driving surface here. In other embodiments a cover layer is arranged on top of the upper surface. This cover layer is for instance an acoustically absorbing layer. This layer, which can be arranged per element, preferably has a fine texture in order to minimize excitation of the tyre and/or to realize a high structural damping in combination with little lasting deformation. The layer is further preferably porous so that little sound is generated. An example of a suitable cover layer is a highly elastic layer, such as a rubber cover layer or a porous concrete.

[0036] The cover layer is preferably configured to absorb high-frequency sound, characteristically in the range of 2 kHz to 8 kHz. The cover layer has a limited layer thickness, characteristically 0.1-1.0 cm. Besides, and perhaps even more importantly than, absorbing high-frequency sound, the purpose of this cover layer is reduced excitation and thus reduced generation of sound. The reduced stiffness is important here. If the cover layer

is also arranged over the joints between the paving elements, for instance if the cover layer is arranged after the paving elements are placed on the ground, the recesses remain clean and the paving elements produce less rolling noise. This cover layer then does need to be a very open cover layer in order to preserve the desired resonance properties of the recesses. In other embodiments the cover layer is only or only partially arranged on the (upper) side of the paving element to be driven over, and no cover layer is thus present above the recesses and the joints.

[0037] According to a second aspect, a paving according to claim 13 is provided comprising a number of paving elements which are placed or can be placed adjacently of each other on a ground surface, wherein the paving elements are embodied to allow one or more recesses in a side surface of a first paving element together with a remaining part of the side surface of a second, opposite paving element to form one or more resonators for absorbing the sound incident on the upper surfaces, and are embodied to discharge precipitation from the resonators via the intermediate space between the paving elements.

[0038] As has been discussed above, the recesses are arranged at different (peripheral) positions along the periphery of the upper surfaces such that opposite a recess in a first paving element there is no recess in the paving element lying opposite. In this embodiment a resonator is thus formed by the recess in one of the two adjoining paving elements and the flat side of the paving element lying opposite.

[0039] According to a third aspect of the invention, a method according to claim 15 is provided for surfacing a ground surface with the paving elements described herein, the method comprising of:

- placing the paving elements on a ground surface;
- scattering joint material over the paving elements;
- removing the joint material only from the recesses.

[0040] The joint material removed from the recesses can serve as joint material between those positions in the joint where there are no recesses.

[0041] Further advantages, features and details of the present invention will be elucidated on the basis of the following description of several embodiments thereof. Reference is made in the description to the figures, in which:

Figure 1 shows a perspective view as seen at an angle from the upper side of an embodiment of a paving element according to the invention;

Figure 2 shows a perspective view as seen at an angle from the underside of the paving element of figure 1;

Figure 3 shows a perspective view of a paving comprising a number of bricks according to the embodiment of figures 1 and 2 placed adjacently of each

other;

Figure 4 shows a top view of the paving elements arranged on the ground, and a detail of the mutual connection of adjoining paving elements; and

Figures 5A-5C show outlines of alternative forms of a recess in the paving element.

[0042] Figures 1 and 2 show respectively the upper side and underside of a block-like paving element 1 according to an embodiment of the invention. Paving element 1 has an upper surface 2, a lower surface 3, two end side surfaces 5, 6 and two elongate side surfaces 4 and 7. Recesses 10, 10' are arranged distributed over the whole periphery of upper surface 2. These recesses extend in side surfaces 4-7, from upper surface 2 to positions at different heights or depths (h_1 , h_2 , wherein generally $h_1 \neq h_2$) relative to upper surface 2.

[0043] The reason for forming the resonators with different depths is that the incident sound field has to be absorbed over a relatively wide frequency spectrum (for instance from 750 Hz to 1500 Hz for road traffic) and the individual resonators realize only a narrow-band absorption, i.e. absorption in a small frequency range. Forming the resonators with two or more different depths enables two or more of such frequency ranges to be combined into a wider frequency range. A correct choice of the number of recesses and of the geometric dimensions (diameter and/or depth) of these recesses enables the sound to be absorbed over a frequency range of desired width, for instance from 750 Hz to 1500 Hz.

[0044] Since the sound absorption of a resonator depends on (among other factors) the resonator depth and the absorption takes place substantially in a relatively narrow frequency range, in the shown embodiment it has been chosen to form the resonators with different depths.

[0045] In the shown embodiment recesses 10, 10' extend in upward direction, perpendicularly of upper surface 2, although in the other embodiments the recesses can also be formed (slightly) obliquely relative to upper surface 2. Each recess 10 further has on the upper side an inlet mouth 13, into which the traffic noise incident on upper surface 2 can enter recess 10 from the upper side.

[0046] In the shown embodiment each recess 10 has a semi-cylindrical shape (with oval cross-section), i.e. the shape of a cylinder with a part of its wall removed. The recess is bounded by wall 11 and bottom 12.

[0047] Paving element 1 is preferably wholly manufactured from acoustically hard material. In other embodiments it is however also possible to manufacture the paving element only partially from acoustically hard material. In the embodiment shown in figures 1 and 2 upper surface 2 onto which the traffic noise is incident and wall 11 and/or bottom 12 of each of the recesses 10 is manufactured from acoustically hard (i.e. substantially non-sound-absorbing) material. The paving element can take a solid form, although hollow embodiments of the paving element (for instance in order to reduce mass and save material) are also possible.

[0048] Figures 1 and 2 show that edge 14 takes an acute form on the upper side of recess 10, i.e. at the position of inlet mouth 13. In other embodiments this edge 14 is however chamfered to some extent. This serves to reduce the rolling noise caused by wheels rolling over the upper surface 2 of the paving element.

[0049] Figures 3 and 4 shows the situation in which a number of paving elements 1, 1^{I-IV} is arranged on a ground surface (O). This figure clearly shows that opposite each of the recesses 10 of a determined paving element lies a flat side of an adjoining paving element. The recesses of adjoining paving elements are more particularly arranged alternately along the side surfaces so that on one occasion recess 10 is situated in the one paving element 1 and on the other occasion recess 25, 26 is situated in the other paving element 1^{III}, 1^V.

[0050] A recess 10 forms together with the side surface of an opposite paving element a resonator, for instance a $\frac{1}{4}$ -wavelength resonator. The walls of this resonator are acoustically hard, since both wall 11 and bottom 12 of the first paving element and the flat side of the second paving element are embodied in acoustically hard material. The resonator for absorbing the incident sound is in fact only formed at the moment that the paving elements are placed against each other.

[0051] Although the sides of the paving elements take a substantially wholly flat form in some embodiments, in other embodiments (as is shown in figures 1-3) depressions or indentations 17 are arranged at positions between the recesses. These depressions or indentations 17 extend over the whole height of the paving elements (although in other embodiments, which are not shown, the depressions extend only from the lower surface to a height just above the height of the bottom of the adjoining recess). In the shown embodiments recesses 10 are provided in flat parts 16 of the respective side surfaces, and the indentations/depressions are positioned between flat parts 16. In other embodiments the recesses can conversely be provided in the indentations, and the surfaces lying therebetween (protrusions) comprise no recesses. This arrangement is very robust.

[0052] When paving elements are placed against each other, a small intermediate space 30 (with an intermediate distance (a) of 0.5 mm or slightly more (a maximum of several mm)) will in practice always remain between the adjoining paving elements. These intermediate spaces 30 are shown schematically in figures 3 and 4. The intermediate spaces are filled with joint material in usual manner. This joint material is water-permeable so that the intermediate spaces can ensure that liquid, for instance precipitation, which may have entered the resonators from inlet opening 13 does not remain behind in the resonator but can be discharged via this intermediate space to the ground (in direction 28, figure 3). This for instance means that the water-filled resonators quickly empty again after a downpour of rain, and the resonators thereby once again fully regain their acoustically absorbing effect.

[0053] The different paving elements can preferably hook into each other such that the paving (surfacing) is laid more tightly. Where the elements lie against each other and there is no recess, the joint material keeps the elements apart so that no damage is done (bricks which are not filled do not form a whole and will rattle, which can result in damage). The intermediate space (which will be smaller than 1 mm in many cases) is as small as possible, and is preferably filled with material which is water-permeable. In other embodiments filling strips will be used, as further set forth below.

[0054] In the shown embodiments the presence of depressions 17 and contact surfaces 18 of flat parts 16 in fact results in an even greater intermediate space at the position of the recesses, so that the water in the resonator can be discharged still more easily.

[0055] The following method can be applied to arrange the paving on the ground surface. The paving elements are first placed adjacently of each other in known manner. A quantity of joint material, which finds its way into the intermediate spaces between the paving elements, is then scattered over the resulting road surface. Finally, the excess filler material is swept off upper surface 2 of the road surface and each of the resonators is also emptied. Joint material thus remains only at the positions where there are no recesses, and filling is thus also carried out under the recesses. The joint material can be a grouting mortar/sand, although filling is also possible with damping materials (for instance rubber granulate) so that vibrations of the paving elements are damped. As set forth above, the joint material forms a porous layer along which water can be discharged to the ground.

[0056] In a further embodiment of the invention an (optional) cover layer of very porous material 21 (figure 3) is arranged on top of the thus realized road surface. This material has to be wholly or almost wholly acoustically transparent in order to preserve the resonator effect of the recesses.

[0057] The cover layer is arranged over the whole surface area of the paving elements and over the intermediate space arranged between the paving elements. The layer is preferably formed from acoustically absorbing material, for instance very open asphalt concrete (ZO-AB), so that this layer per se already has some acoustically absorbing effect, for instance an absorption particularly in the high frequency spectrum. A drawback is of course that the presence of the layer can affect the absorbing effect of the resonators per se. An advantage is however that the inner side of the resonators remains clean at all times by arranging a layer on top of the paving elements. No solid parts, such as mud and dirt, will be able to find their way into the resonator. The cover layer further takes a porous form such that water which has come to lie on the cover layer will seep downward into the resonators, after which the water can flow away via the intermediate space between the paving elements in the above stated manner.

[0058] The recesses are preferably provided at asym-

metrical positions relative to an axis of symmetry 31 in the longitudinal direction (figure 4) and axis of symmetry 32 in the width direction. The paving element further preferably takes a point-symmetrical form in respect of the positioning of the recesses, more particularly the outlets of the recesses in the surface of the paving element on which it is possible to drive (so that the paving element coincides with itself after moving through a half rotation. This is of course not the case for the depths of the recesses). This achieves that use can be made of one type of paving element to realize a paving wherein two recesses never come to lie precisely opposite each other. Optimal use can hereby be made of the space available along the periphery of the paving elements. By distributing these recesses along the periphery of the paving elements in this way a repeating pattern of resonators can be created for the whole road surface (paving), so that the whole road surface can realize a uniform absorption of the incident sound.

[0059] The porosity of the resonators in a paving element, i.e. the ratio of the overall (cumulative) cross-sectional surface area of the upper side (inlet opening 13) of those resonators having an equal volume or equal depth (this being in many cases the surface area of only one resonator) divided by the overall surface area of upper surface 2 of the relevant paving element, is smaller than 5%, preferably a maximum of 2% and still more preferably a maximum of 1%.

[0060] It is apparent that the paving element can be used not only for road traffic. The paving elements can likewise be used as surfacing for parking garages, runways of airports, footpaths for pedestrians, floors for exhibition areas, music venues, concert halls, festivals and the like, or similar surfacings. It is also possible to arrange the absorbing paving elements between and/or laterally of the rails of a railway track. Although the resonators can realize a wide-band absorption, it is advisable to tune the resonators to the spectrum of the sound to be absorbed. Railway traffic for instance has a different characteristic frequency spectrum than road traffic, and so on. Rail traffic has slightly lower frequencies than the above stated road traffic (cars and the like) and the resonators therefore generally have a slightly greater depth so as to be able to also provide a high sound absorption at lower frequencies. Finally, it is also possible to use the paving elements as building blocks for upright structures, such as noise barriers and the like.

[0061] In determined embodiments (not shown in the figures) filling strips of water-permeable and acoustically absorbing material are arranged between the paving elements. These filling strips can for instance be formed by needle felt strips, for instance of PP and PE, and ensure that the paving elements remain placed more firmly on the ground surface, which reduces the chance of "rattling" of the paving elements. Use can for instance be made of a filling strip with a thickness of 4 mm with a water-permeability per running metre amounting to about 150 litres per hour (determined according to building di-

rective BRL-9040). These filling strips also extend partially into the recesses (resonators) so that acoustically absorbing material is in this case present in the recesses in order to increase the absorption of the resonators.

Claims

1. Block-like sound-absorbing paving element (1), comprising:

- an upper surface (2);
- a lower surface (3);
- a number of side surfaces (4-7) extending between the upper surface (2) and lower surface (3);
- a number of recesses (10) with different geometric dimensions which are free of acoustically absorbing material and arranged for absorbing sound incident on the upper surface (2) in different frequency ranges; whereby the porosity, defined as the cumulative surface area of the upper outer ends of the one or more recesses (10) having an equal form and volume, particularly an equal depth, divided by the overall surface area of the upper surface (2), amounts to a maximum of 5%, and that each of the recesses (10):

- is an elongate recess (10),
- is provided in one or more of the side surfaces (4-7), **characterized in that** each of the recesses (10)

extends from the upper surface (2) to a position between the upper surface (2) and lower surface (3) for the purpose of forming recesses (10) of different depths.

2. Block-like sound-absorbing paving element (1) as claimed in claim 1, wherein the recesses (10) are tubular.
3. Block-like sound-absorbing paving element (1) as claimed in claim 1 or 2, wherein the porosity amounts to a maximum of 2% and still more preferably a maximum of 1%.
4. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, wherein one or more of the recesses (10) are open on the side and wherein one or more of the recesses (10) extend substantially parallel to the relevant side surface or in upward direction.
5. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, comprising a first side and a second side, wherein one or more of

the recesses (10) in the first side extend at peripheral positions differing from the peripheral positions at which the one or more recesses (10) in the second side extend.

6. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, wherein at least two of the side surfaces (4-7) and preferably all side surfaces (4-7), take a form with a sinusoidal profile, except at the position of the recesses (10), or wherein at least two of the side surface and preferably all side surfaces take a substantially flat form, except at the position of the recesses (10).
7. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, wherein the paving element (1) is manufactured from acoustically hard material; or wherein the bottom (12) and walls (11) of the recesses (10) take an acoustically hard form.
8. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, wherein one or more of the recesses (10) have a form such that the diameter is smaller in an upper part than the diameter of a lower part or wherein the upper edge of a recess (10) is chamfered.
9. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claim, comprising spacers provided on one or more of the side surfaces (4-7).
10. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, which takes a portable form, or wherein the paving element (1) comprises a cover layer (21) arranged on top of the upper surface (2), more particularly an acoustically absorbing layer, preferably a highly elastic layer, such as a rubber layer.
11. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, wherein the outlets of the recesses (10) are distributed asymmetrically over the periphery, or wherein the paving element (1) takes a point-symmetrical form in respect of the outlets of the recesses (10).
12. Block-like sound-absorbing paving element (1) as claimed in any of the foregoing claims, wherein the paving element (1) takes a hollow form or wherein the upper surface is a driving surface.
13. Paving comprising a number of block-like sound-absorbing paving elements (1) as claimed in any of the foregoing claims which are placed or can be placed adjacently of each other on a ground surface (O), wherein the paving elements (1) are embodied to

allow one or more of the recesses (10) in a side surface (4-7) of a first of said paving elements (1) together with a remaining part of the side surface of a second of said paving elements (1), opposite to the first paving element to form one or more resonators, particularly $\frac{1}{4}$ -wavelength resonators, for absorbing the sound incident on the upper surfaces (2), and are embodied to discharge precipitation from the resonators via the intermediate space (30) between the paving elements (1), wherein the recesses (10) are preferably arranged at different positions along the periphery of the upper surfaces such that opposite a recess (10) in a first of said paving elements (1) there is no recess (10) in the second paving element lying opposite.

14. Paving as claimed in claim 13, wherein the intermediate space (30) between the block-like sound-absorbing paving elements (1) placed adjacently of each other is filled with a filling strip of at least one of water-permeable and acoustically absorbing material, wherein the water-permeability of the filling strip preferably amounts to at least 100 litres per hour, preferably 150 litres per hour or more, per running metre wherein the filling strip is preferably manufactured from needle felt.

15. Method for surfacing a ground surface (O) with block-like sound-absorbing paving elements (1) as claimed in any of the claims 1-14, the method comprising of:

- placing the paving elements (1) on a ground surface (O);
- scattering joint material over the paving elements (1);
- removing the joint material only from the recesses (10).

Patentansprüche

1. Blockartiges schallabsorbierendes Pflasterelement (1), das aufweist:

- eine obere Oberfläche (2);
- eine untere Oberfläche (3);
- eine Anzahl seitlicher Oberfläche (4 - 7), die sich zwischen der oberen Oberfläche (2) und der unteren Oberfläche (3) erstrecken;
- eine Anzahl von Vertiefungen (10) mit unterschiedlichen geometrischen Abmessungen, die frei von akustisch absorbierendem Material sind und eingerichtet sind, um Schall in unterschiedlichen Frequenzbereichen, der auf die obere Oberfläche (2) einfällt, zu absorbieren;

wobei die Porigkeit, die als die kumulative Oberfläche der oberen Außenenden der einen oder mehre-

ren Vertiefungen (10) mit gleicher Form und Volumen, insbesondere gleicher Tiefe, geteilt durch die Gesamtoberfläche der Oberfläche (2) definiert ist, maximal 5% beträgt und jede der Vertiefungen:

- eine längliche Vertiefung (10) ist;
- in einer oder mehreren Seitenoberflächen (4 - 7) bereitgestellt ist, **dadurch gekennzeichnet, dass** jede der Vertiefungen (10) sich zu dem Zweck, Vertiefungen (10) mit unterschiedlichen Tiefen auszubilden, von der oberen Oberfläche (2) zu einer Position zwischen der oberen Oberfläche (2) und der unteren Oberfläche (3) erstreckt.

2. Blockartiges schallabsorbierendes Pflasterelement (1) nach Anspruch 1, wobei die Vertiefungen (10) rohrförmig sind.

3. Blockartiges schallabsorbierendes Pflasterelement (1) nach Anspruch 1 oder 2, wobei die Porigkeit maximal 2% beträgt und bevorzugter maximal 1% beträgt.

4. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, wobei eine oder mehrere der Vertiefungen (10) auf der Seite offen sind und wobei eine oder mehrere der Vertiefungen (10) sich im Wesentlichen parallel zu der relevanten Seitenoberfläche oder in die Aufwärtsrichtung erstrecken.

5. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, das eine erste Seite und eine zweite Seite aufweist, wobei eine oder mehrere der Vertiefungen (10) in der ersten Seite sich an Umfangspositionen erstrecken, die verschieden zu den Umfangspositionen sind, an denen sich die eine oder mehreren Vertiefungen (10) in der zweiten Seite erstrecken.

6. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, wobei wenigstens zwei der Seitenoberflächen (4 - 7) und bevorzugt alle Seitenoberflächen (4 - 7), abgesehen von der Position der Vertiefungen (10), eine Form mit einem sinusförmigen Profil annehmen, oder wobei wenigstens zwei der Seitenoberflächen und bevorzugt alle Seitenoberflächen, abgesehen von der Position der Vertiefungen (10) eine flache Form annehmen.

7. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, wobei das Pflasterelement (1) aus akustisch hartem Material hergestellt ist; oder wobei die Unterseite (12) und Wände (11) der Vertiefungen (10) eine akustisch

harte Form annehmen.

8. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, wobei eine oder mehrere der Aussparungen (10) eine derartige Form haben, dass der Durchmesser in einem oberen Teil kleiner als der Durchmesser eines unteren Teils ist oder wobei der obere Rand einer Vertiefung (10) abgeschragt ist. 5
9. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, das Distanzstücke aufweist, die auf einer oder mehreren der Seitenoberflächen (4 - 7) bereitgestellt sind. 10
10. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, das eine tragbare Form annimmt, oder wobei das Pflasterelement (1) eine Deckschicht (21), insbesondere eine akustisch absorbierende Schicht, bevorzugt eine hoch elastische Schicht, wie etwa eine Gummischicht, aufweist, die oben auf der oberen Oberfläche (2) angeordnet ist. 15
11. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, wobei die Auslässe der Vertiefungen (10) asymmetrisch über den Umfang verteilt sind, oder wobei das Pflasterelement (1) eine punktsymmetrische Form in Bezug auf die Auslässe der Vertiefungen (10) annimmt. 20
12. Blockartiges schallabsorbierendes Pflasterelement (1) nach einem der vorhergehenden Ansprüche, wobei das Pflasterelement (1) eine hohle Form annimmt, oder wobei die obere Oberfläche eine Fahrbahnoberfläche ist. 25
13. Pflaster, das eine Anzahl blockartiger schallabsorbierender Pflasterelemente (1) nach einem der vorhergehenden Ansprüche aufweist, die benachbart zueinander auf einer Bodenoberfläche (O) angeordnet werden oder angeordnet werden können, wobei die Pflasterelemente (1) derart ausgeführt sind, dass sie zulassen, dass eine oder mehrere der Vertiefungen (10) in einer Seitenoberfläche (4 - 7) erster der Pflasterelemente (1) zusammen mit einem restlichen Teil der Seitenoberfläche eines zweiten der Pflasterelemente (1) gegenüber dem ersten Pflasterelement einen oder mehrere Resonatoren, insbesondere 1/4-Wellenlängen-Resonatoren, bilden, um den auf die oberen Oberflächen (2) einfallenden Schall zu absorbieren, und ausgeführt sind, um Niederschläge von den Resonatoren über den Zwischenraum (30) zwischen den Pflasterelementen (1) abzugeben, wobei die Vertiefungen (10) bevorzugt an unterschiedlichen Positionen entlang des Umfangs der oberen Oberflächen angeordnet sind, so 30

dass gegenüber einer Vertiefung (10) in einem ersten der Pflasterelemente (1) keine Vertiefung (10) in dem zweiten gegenüberliegenden Pflasterelement (10) ist.

14. Pflaster nach Anspruch 13, wobei die Zwischenräume (30) zwischen den blockartigen schallabsorbierenden Pflasterelementen (1), die benachbart zueinander angeordnet sind, mit einem Füllstreifen aus einem wasserdurchlässigen und/oder akustisch absorbierenden Material gefüllt sind, wobei die Wasserdurchlässigkeit des Füllstreifens bevorzugt wenigstens 100 Liter pro Stunde, bevorzugt 150 Liter pro Stunde oder mehr, pro laufendem Meter beträgt, wobei der Füllstreifen bevorzugt aus Nadelfilz hergestellt ist.
15. Verfahren zur Beschichtung einer Bodenoberfläche (O) mit blockartigen schallabsorbierenden Pflasterelementen (1) nach einem der Ansprüche 1 - 14, wobei das Verfahren aufweist:

- Anordnen der Pflasterelemente (1) auf einer Bodenoberfläche (O);
- Streuen von Verbindungsmaterial über die Pflasterelemente (1);
- Entfernen des Verbindungsmaterials nur aus den Vertiefungen (10).

Revendications

1. Élément de pavage (1) insonorisant en forme de bloc, comprenant :
 - une surface supérieure (2) ;
 - une surface inférieure (3) ;
 - un certain nombre de surfaces latérales (4-7) s'étendant entre la surface supérieure (2) et la surface inférieure (3) ;
 - un certain nombre d'évidements (10) de dimensions géométriques différentes qui sont exempts de matériau acoustiquement absorbant et agencés pour absorber le son incident sur la surface supérieure (2) dans différentes plages de fréquences ; moyennant quoi

la porosité, définie comme étant la superficie cumulative des extrémités extérieures supérieures des un ou plusieurs évidements (10) ayant des formes et des volumes identiques, en particulier des profondeurs identiques, divisée par la superficie totale de la surface supérieure (2), s'élève à un maximum de 5 %, et chacun des évidements (10) :

- est un évidement allongé (10),
- est prévu dans une ou plusieurs des surfaces latérales (4-7), **caractérisé en ce que** chacun

- des évidements (10) s'étend de la surface supérieure (2) à une position entre la surface supérieure (2) et la surface inférieure (3) afin de former des évidements (10) de différentes profondeurs.
2. Élément de pavage (1) insonorisant en forme de bloc selon la revendication 1, dans lequel les évidements (10) sont tubulaires. 5
 3. Élément de pavage (1) insonorisant en forme de bloc selon la revendication 1 ou 2, dans lequel la porosité s'élève à un maximum de 2 % et encore plus préférentiellement à un maximum de 1 %. 10
 4. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, dans lequel un ou plusieurs des évidements (10) sont ouverts sur le côté et dans lequel un ou plusieurs des évidements (10) s'étendent sensiblement parallèlement à la surface latérale concernée ou dans une direction vers le haut. 15 20
 5. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, comprenant un premier côté et un second côté, dans lequel un ou plusieurs des évidements (10) dans le premier côté s'étendent à des positions périphériques qui diffèrent des positions périphériques auxquelles s'étendent les un ou plusieurs évidements (10) dans le second côté. 25 30
 6. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, dans lequel au moins deux des surfaces latérales (4-7) et de préférence toutes les surfaces latérales (4-7), prennent une forme ayant un profil sinusoïdal, sauf à la position des évidements (10), ou dans lequel au moins deux des surfaces latérales et de préférence toutes les surfaces latérales prennent une forme sensiblement plate, sauf à la position des évidements (10). 35 40
 7. Élément de pavage (1) insonorisant en forme de bloc selon l'une des revendications précédentes, dans lequel l'élément de pavage (1) est fabriqué à partir d'un matériau acoustiquement dur ; ou dans lequel le fond (12) et les parois (11) des évidements (10) prennent une forme acoustiquement dure. 45 50
 8. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, dans lequel un ou plusieurs des évidements (10) ont une forme telle que le diamètre est plus petit dans une partie supérieure que le diamètre d'une partie inférieure ou dans lequel le bord supérieur d'un évidement (10) est chanfreiné. 55
 9. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, comprenant des séparateurs prévus sur une ou plusieurs des surfaces latérales (4-7). 5
 10. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, qui prend une forme portable, ou lequel élément de pavage (1) comprend une couche de couverture (21) agencée au-dessus de la surface supérieure (2), plus particulièrement une couche acoustiquement absorbante, de préférence une couche hautement élastique, telle qu'une couche en caoutchouc. 10
 11. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, dans lequel les sorties des évidements (10) sont réparties de manière asymétrique sur la périphérie, ou dans lequel l'élément de pavage (1) prend une forme à symétrie ponctuelle par rapport aux sorties des évidements (10). 15
 12. Élément de pavage (1) insonorisant en forme de bloc selon l'une quelconque des revendications précédentes, dans lequel l'élément de pavage (1) prend une forme creuse ou dans lequel la surface supérieure est une surface de fongage. 20
 13. Pavage comprenant un certain nombre d'éléments de pavage (1) insonorisants en forme de blocs selon l'une quelconque des revendications précédentes qui sont placés ou peuvent être placés les uns à côté des autres sur une surface du sol (O), dans lequel les éléments de pavage (1) sont réalisés pour permettre à un ou plusieurs des évidements (10) dans une surface latérale (4-7) d'un premier desdits éléments de pavage (1) conjointement avec une partie restante de la surface latérale d'un deuxième desdits éléments de pavage (1), en face du premier élément de pavage, à former un ou plusieurs résonateurs, en particulier des résonateurs quart d'onde, pour absorber le son incident sur les surfaces supérieures (2), et sont réalisés pour décharger une précipitation des résonateurs via l'espace intermédiaire (30) entre les éléments de pavage (1), dans lequel les évidements (10) sont de préférence agencés à des positions différentes le long de la périphérie des surfaces supérieures de sorte qu'en face d'un évidement (10) dans un premier desdits éléments de pavage (1), il n'y a aucun évidement (10) dans le deuxième élément de pavage situé en face. 25 30 35 40 45 50
 14. Pavage selon la revendication 13, dans lequel l'espace intermédiaire (30) entre les éléments de pavage (1) insonorisants en forme de blocs placés les uns à côté des autres est rempli d'une bande de remplissage d'au moins un parmi un matériau acous-

tiquement absorbant et perméable à l'eau, dans lequel la perméabilité à l'eau de la bande de remplissage s'élève de préférence à au moins 100 litres par heure, de préférence 150 litres par heure ou plus, par mètre linéaire, dans lequel la bande de remplissage est de préférence fabriquée à partir de feutre aiguilleté. 5

15. Procédé de surfaçage d'une surface au sol (O) avec des éléments de pavage (1) insonorisants en forme de blocs selon l'une quelconque des revendications 1 à 14, le procédé comprenant : 10

- la mise en place des éléments de pavage (1) sur une surface au sol (O) ; 15
- la dispersion du matériau de jointure sur les éléments de pavage (1) ;
- le retrait du matériau de jointure uniquement des évidements (10). 20

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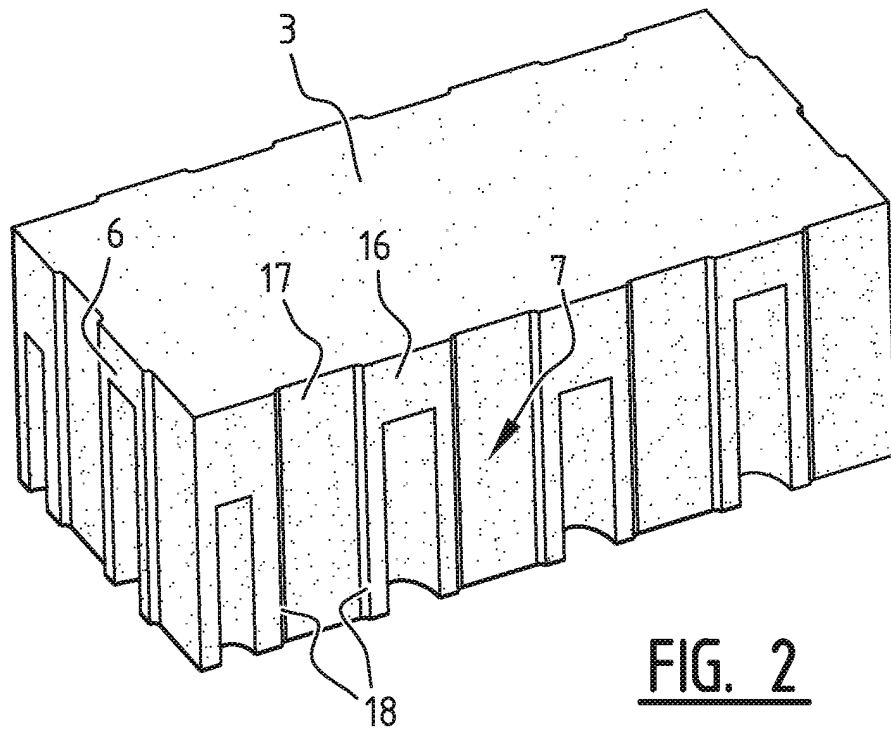
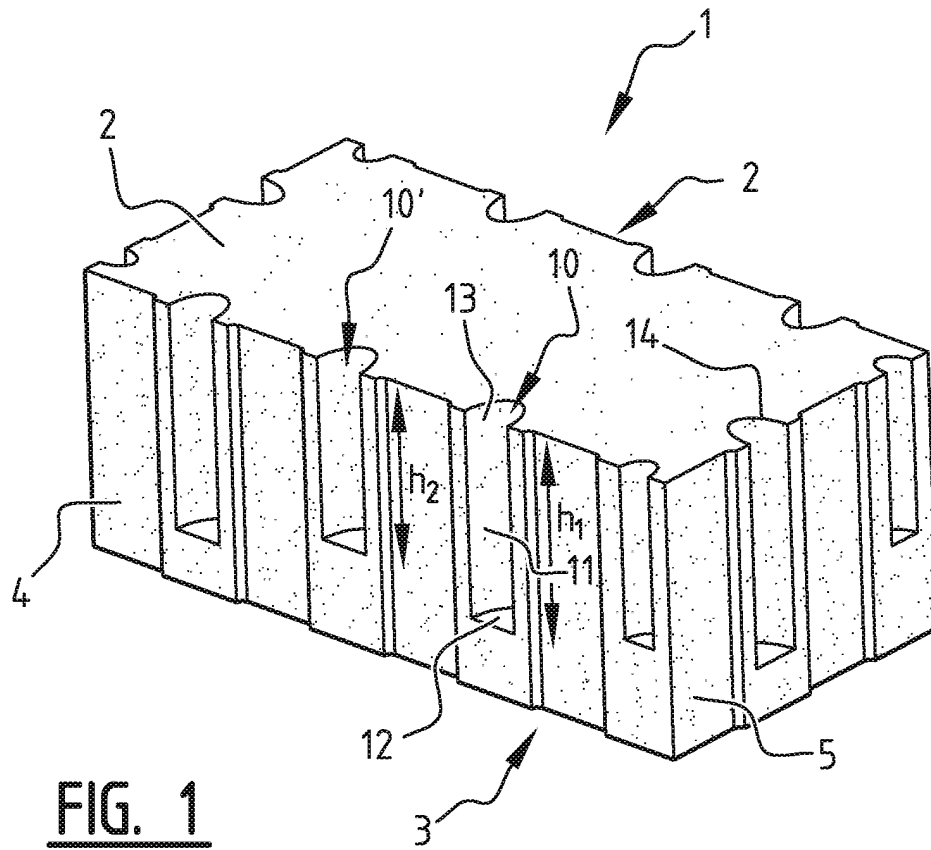
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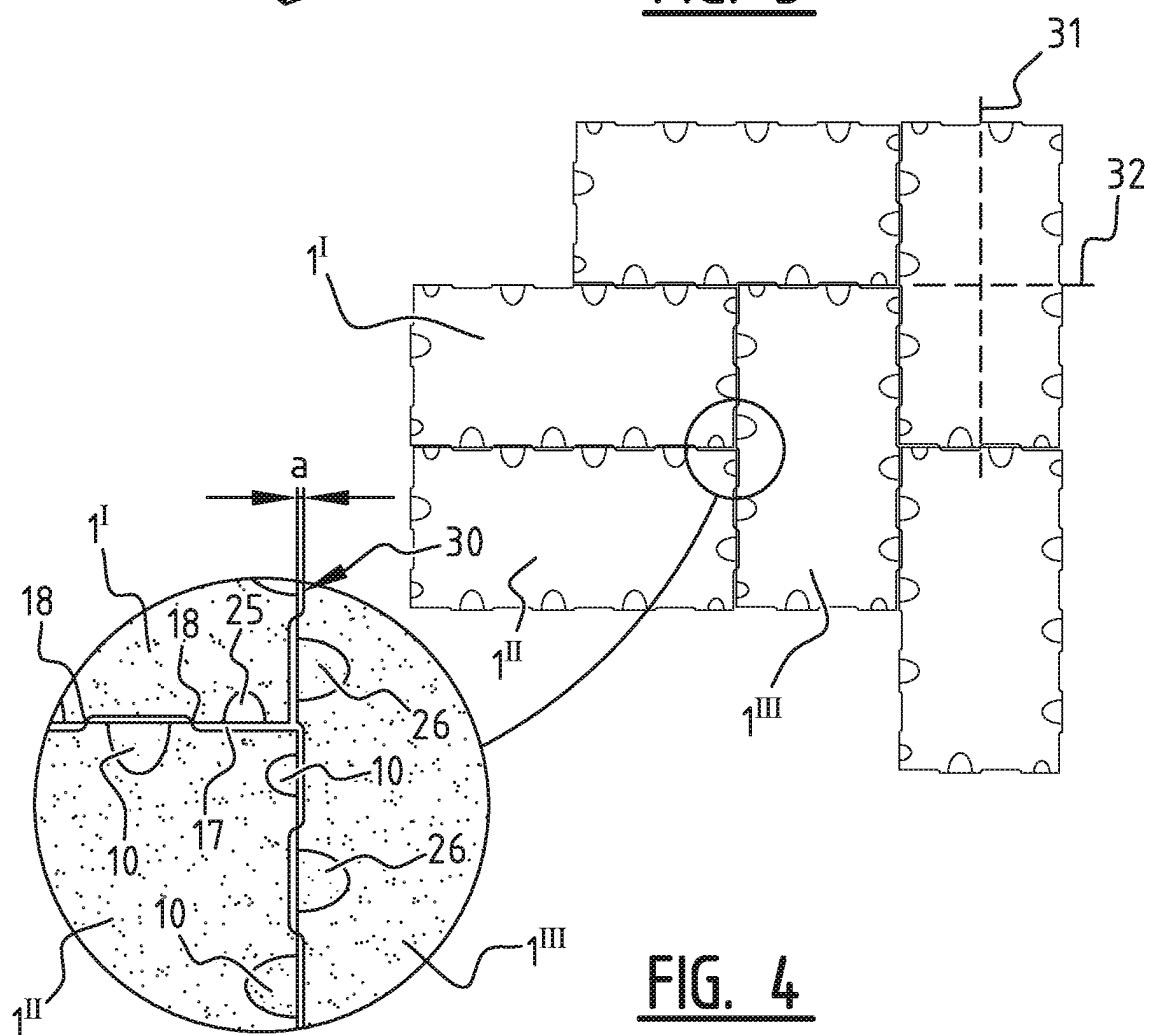
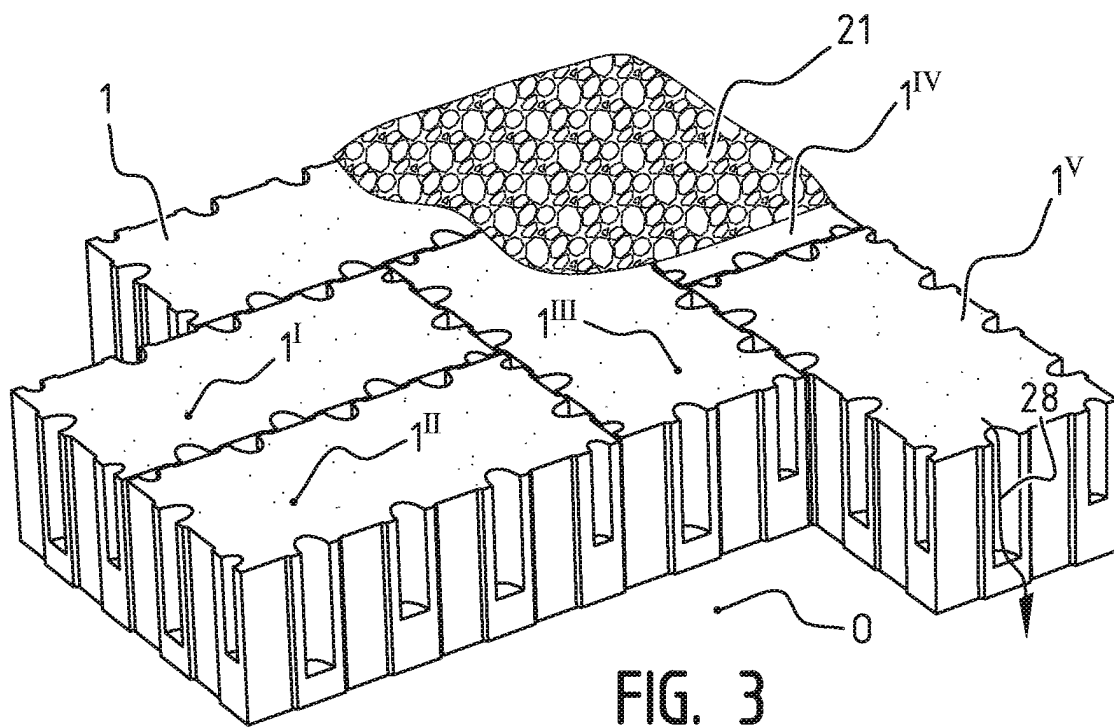
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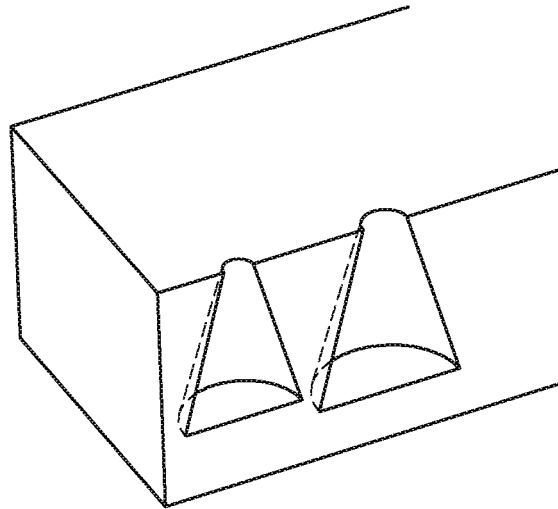


FIG. 5A

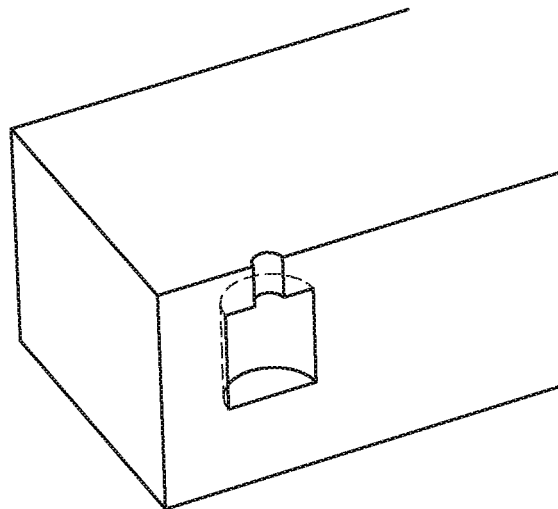


FIG. 5B

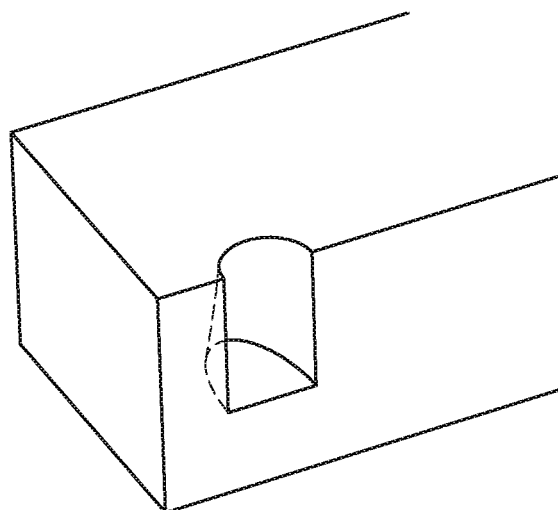


FIG. 5C

REFERENCES CITED IN THE DESCRIPTION

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