

Grid Block Material

This Sheet Has Been Replaced

Background of the Invention

- 05 The present invention is based on a US Patent Application of serial number 08/033,111, filed on 18th March 1993, and also on a continuation-in-part application filed with respect thereto.

10 The invention relates to building materials or structural components and a method for their manufacture. More precisely, the invention relates to a structured material or building material which has a multidimensional grid structure, and a method for its manufacture.

Description of the Prior Art

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In the field of materials science, the search for lighter and more solid materials has been a main aim for many years. Currently, research in this field has been concentrated primarily on the use of metals, plastics and ceramics. This research has led to the improvement of existing technologies. In addition, it has brought
20 about new materials and methods, in order to fulfil the changing engineering and economic requirements of modern society.

A slightly more recent activity in the field of materials science, in so far as it relates to better characteristics in the strength to weight ratio, has been
25 concentrated primarily on polymers based on hydrocarbon and the corresponding chemical processes. Even if the materials and methods developed on the basis of this research under the selected conditions are both expedient and useful or effective, typically they are not concerned with the problem of improving structures of higher order. Furthermore, the repetition or reproducibility of the
30 metallic, mechanical characteristics using chemical formulation techniques based on carbon remains the aim of many of these materials and methods. As a result,



many of these materials only show a nominal improvement compared with the more readily available metallic building materials or structural elements.

Summary of the Invention

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It is an object of the present invention to make available a high-strength, low-weight building material.

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The building material according to the present invention is characterised by a wire grid. Typically, the wire grid is constructed in the form of uniformly stacked pyramids in a three-dimensional arrangement. Each pyramid generally consists of eight wire segments which are connected with each other at their intersection- or crossing points. The wire segments are part of a continuous wire. Even if the construction of the material is such that it looks solid or strong to the naked eye,

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in fact it consists of a three-dimensional network of fine wires. These wires typically consist of brass or stainless steel. Preferably the material is composed of structural parts which are approximately 0.005 inch to 0.1 inch [0.1 mm - 2.5 mm] in diameter and are 0.03 inch - 0.09 inch long. The material according to the invention is not, however, restricted to the above-mentioned materials and wire diameters. In particular, the term "wire" in the sense of the present invention is not intended to refer only to metal wires, but to encompass all types of elongated filaments, irrespective of the material of which they consist, with only the actual purpose of use placing limits on the selection of material. Also for mechanically weaker materials than the above-mentioned metallic wires, however, the structure

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according to the invention brings a distinct improvement to the mechanical strength of the grid structure material in relation to the weight, when the material is compared with other known structures, for example in the form of homogeneous solid material. Also the indicated preferred diameter range for the wires can be readily exceeded or fallen below by a factor of 10. Even with very thin wires in the range of 10 μm to 250 μm diameter, possibly interesting fields of application are produced for the manufacture of extremely stable and

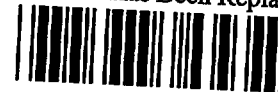
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nevertheless light and thin-walled components.

A material produced from steel wire according to the present invention has approximately one fifth of the density of solid steel, but is nevertheless of comparable strength. These characteristics are due to a variety of factors. For example, forces acting on the material are transferred in the same manner as forces in a framework or supporting structure with conventional dimensions. Furthermore, the small cross-sectional area of the wires leads to a large surface : volume ratio. In addition, the isolation of elements reduces the progression of cracks or other defects through the material and also contributes likewise to the uniform distribution or transfer of loads. Finally, the small cross-sectional dimension of the wires which are used to produce the material, preferably with less than 0.01 inch [0.25 mm] in diameter, leads to superior strength characteristics because the small grain size of the wires prevents a progression of cracks.

In the most general form, the material can be characterised in that it is composed of a three-dimensional grid structure, the concern being initially not so much with the chemical/physical characteristics of the material which is used. The invention proceeds from the consideration as to which structure of a building material provides as favourable as possible a ratio of rigidity or bending strength to the weight of the structure material. The components, i.e. the wires from which the structure material is composed, should of course have a good compression- and tensile strength. Here, the "wires" however do not necessarily have to consist of a metallic material, but rather they can also consist of a plastic or of natural fibres which are accordingly welded or glued to each other. In fact, one will generally achieve higher strengths with metallic wires, on the other hand however with the use of other building materials such as plastics or natural fibres, possibly an extremely low weight can be achieved with a still sufficient strength, a correspondingly low weight possibly not being able to be achieved with metallic materials.



The method according to the invention makes provision that at least three groups of wires or filaments (non-metallic materials being included) are arranged in parallel in each group and are placed one over the other, aligned relative to each other at an angle between 10° and 90° , these groups of wires or other filaments being connected with each other at their points of intersection preferably by welding or glueing. With a flat or even material produced in this way, the three groups of parallel wires or filaments form a structure of triangles which are contiguous in a manner covering the area. These can be folded along parallel lines running at identical intervals, with the wires of one of the groups of parallel wires preferably defining the fold lines. Without intending to restrict and merely to simplify the description, only wires will be referred to hereinbelow, this term also being intended to include non-metallic materials or to mean non-metallic materials in an analogous manner.

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In the preferred embodiment, the triangular grid produced from the three groups of parallel wires is folded alternately along adjacent wires from one of the groups in the manner of a concertina. The thus folded grid appears in a side view in a zigzag shape with two parallel planes of fold lines which are to be designated here as upper and lower planes for better differentiation.

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Depending on the structure of the triangular grid, quite specific fold angles are preferred. The fold angle here designates the angle between two planes which intersect in one of the fold lines of a plane and run through the two fold lines of the other plane adjacent hereto.

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Particularly preferred here is a variant of the invention in which the fold angle is selected so that the spacing of adjacent fold lines in the upper plane and also the spacing of adjacent fold lines in the lower plane is exactly equal to the internodal distance of the node- or intersection points of the wires along the fold lines, or that at least these distances between folds and nodes are in the relationship of

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small whole numbers with respect to each other. This makes it possible in particular that two such folded grids can be placed one over another, rotated through 90° with respect to each other, all the node points or in any case a plurality of node points of the lower plane of one grid being able to be brought
05 to coincide with the node points of the upper plane of the other grid, a connection between these adjacent grids also to take place in these node points. This leads to a particularly stable three-dimensional structure.

10 In a particularly preferred embodiment of the invention, the flat grids are composed of equilateral triangles, i.e. the three groups of wires intersect each other reciprocally at angles of 60° , the arrangement preferably taking place so that the third group of parallel wires runs precisely along the intersection points of the other two groups, which, however, otherwise does not imperatively have to be the case.

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In such an embodiment, the preferred fold angle at which the spacings of adjacent fold lines of one plane are equal to the spacings of the node points along the fold lines, amounts to approximately 51.3° .

20 Another embodiment, deviating from this, which can be preferred for particular conditions of use, is composed of three groups of wires which are aligned relative to each other so that non-equilateral, but isosceles triangles are formed, in which the sides are distinctly longer than the base. This means that two groups of wires intersect each other at a more acute angle than 60° , whereas the third group of
25 wires forms an angle of more than 60° with the first two and runs through the intersection points of the first two groups. In so doing, the latter third group of wires also forms the fold lines, wherein through the folding, just as in the previously described embodiment, a three-dimensional structure of pyramids is produced, from which only two opposing base sides are missing. In the latter
30 embodiment with the preferred fold angle, the resulting pyramids are higher and more acute and the upper and lower planes are spaced further apart than in the



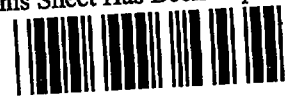
previously mentioned embodiment which is composed of equilateral triangles. Also in this case, two grids, rotated perpendicularly with respect to each other, can be placed one on another and brought to coincide with their node points and connected, when the above-mentioned, preferred fold angle is maintained which
05 depends on the precise form of the triangles from which the respective flat grid is composed. Through the connection of two such folded grid structures placed one over another crosswise, the desired pyramids are also produced with base edges running completely around. Irrespective of the folded grids which are to be placed one on another, however, flat grids can also be welded with the folded
10 grids, with these flat grids intended to have precisely the structure of the node points of the upper or lower plane of the folded grids. In the triangular grids described above, through the folding in the upper and lower plane in each case rectangular grid structures are produced and with the preferred fold angle, the structure of a square grid. In particular, according to the present invention also a
15 structure can be produced from several layers of folded grids, in which optionally also matching layers of flat grids, e.g. rectangular grids, can be joined therebetween. If a flat grid is placed between two folded grids, the rotation of the folded grids through 90° with respect to each other can be eliminated and in this case one is also not instructed to maintain the preferred fold angle.

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An embodiment of the present invention relates to a particular production of the initial elements, namely of the flat grids, which are then possibly folded and connected with each other in several layers, in order to form the final grid block material.

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To simplify the production of flat grids, according to this embodiment a flat or even web material is used such as, for example, a sheet metal, from which a portion of the material is removed by punching, etching, drilling or other methods, so that the remaining parts of the web material form a cohesive network
30 or grid, the remaining parts of the web material being considered as "wires", forming a grid and connected with each other in one piece, in the sense of the



embodiments previously described.

Compared with the previously described embodiments, the latter has especially the following advantages:

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1. The resulting flat grid is equally thick throughout, i.e. also at the "intersection points" of "wires" the material is just as thick as between these intersection points or nodes.

10 2. In manufacture, the step of placing several groups of parallel wires in layers over each other intersecting each other and connecting them with each other at their intersection points is eliminated. The connection exists from the outset through the cohesive web material.

15 3. The "wires" or the individual cross-pieces of the web material which remain after the punching out or etching out of corresponding holes in the web material do not necessarily have to run along continuous straight lines, but rather they can already be angled relative to each other in the web plane at the individual node points. Hence, the node points also do not necessarily have to be arranged on
20 three groups of parallel lines, in which the three groups intersect each other but, rather, more complex structures are also conceivable, in which in fact in turn the individual nodes are arranged along parallel straight lines, in which however possibly more than three groups of parallel lines are necessary, in order to describe the position of all node points or in which the spacings of the node lines
25 compared with materials which are produced from three groups of parallel wires, are smaller or greater. A correspondingly more complex structure is produced for example when one considers that, proceeding from a wire grid consisting of equilateral triangles, two of the groups of wires intersecting each other do not run exactly straight but rather along slight zigzag lines, with angling in each case
30 at the node points and in which adjacent wires of the same group in each case are angled in precisely the opposite direction, so that to a given wire of one group



only every other wire runs parallel along the same zigzag line. The triangular grid resulting therefrom is then no longer composed of equilateral triangles, but rather from oblique-angled triangles, the angle points of which, however, on a greater scale can still have the symmetry of a grid of equilateral triangles.

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4. The "wires" or filaments, from which a grid produced from web material is composed, do not necessarily have to have a constant cross-section over their entire length, but rather can be wider and hence reinforced for example at the node points.

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Furthermore, there are a number of further development possibilities in the structure of flat grid structures or networks which, however, nevertheless are to be developed as far as possible so that they have parallel node lines, along which the web material can be folded, so that after folding, these node lines define two parallel planes and so that in these planes the connection can take place with other grids which have a compatible node structure in the connection plane. A grid structure which either has the same symmetry and the same distance between the node points is regarded as "compatible" here, so that the node points of adjacent grid planes of the two grids which are to be connected can be brought to coincide with each other, or which at least has such a symmetry and such a node distance that a considerable proportion of the nodes of the adjacent grids, i.e. for example at least 10 % can be brought to coincide and thus be connected with each other. This of course applies in an analogous manner also when it is not the nodes of adjacent grids which are connected with each other, but rather in each case one node of one grid with a connecting cross-piece between two adjacent nodes of the other grid. Particular conditions of symmetry and spacing must also be fulfilled here, so that the connection points are distributed as uniformly as possible over the connection plane, so that the forces acting on the material during subsequent use are uniformly distributed and diverted.

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Two methods are additionally described hereinbelow for the production of flat



grids, composed of equilateral triangles, and corresponding folded grids.

According to a first method, the method according to the invention includes the making available of an apparatus which is able to receive a series of sliding
05 pulleys and a loom frame in which the sliding pulleys can be arranged. Next, fine wires are secured to the loom frame and are then woven. Following the weaving, the wires are welded together. The webs resulting therefrom or the web material can then be used in the desired manner or shaped as necessary in order to produce a corrugated material. In an alternative embodiment of the method
10 according to the invention, the material according to the invention can be produced in elongated sections and with the use of matching securing- and welding superstructures. These elongated sections can then be corrugated or shaped as desired. The individual steps of these methods according to the invention are discussed in detail further below.

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Reference will now be made to a first method according to the invention, in which in a first step a frame or tentering frame and various sliding pulleys are mounted. These devices serve to keep the wires under tension and in the correct arrangement before welding. The tentering frame is a substantially flat ring which
20 has three sets of opposing webs with T-shaped slits which are arranged at intervals of 120°. The sliding pulley superstructures which are measured and shaped so that they fit into the webs or rails or the tentering frame, have rows of parallel grooves, in order to catch the wires and keep them exactly in position. In the next step the loom frame, which consists of three grooved stands on a
25 rotating triangular platform, is prepared. More precisely, the loom frame is prepared such that it includes three columns or stands which have positioning surfaces on which the sliding pulley superstructures are locked, before the wire is withdrawn from the spool. Whilst the spool frame or loom frame and hence also the stands rotate, the wire continues to run downward through the grooves of the
30 sliding pulleys so that after one revolution, the wire runs into the next deep groove.



As soon as the wire is arranged on the loom- or spool frame, the wire is separated alongside the sliding pulleys. Then the sliding pulleys are mounted on the previously prepared frame, so that a wire network or matrix forms. The node
05 points of the wire matrix, i.e. the points at which the wires overlap each other or lie on each other, are then connected with each other using a forging press. The forging press supplies heat and pressure uniformly to all connections, in order to achieve a welding at each node point. As soon as all node points are connected with each other, the material can be removed from the sliding pulleys and the
10 tentering frame. The flat material thus produced using the method of the invention can be used in isolation as building material. As an alternative, the resulting material can be bent or kinked using a press, a press ram and die, or by passing through a set of sawtooth rollers, in order to form corrugated webs or webs folded in the manner of a concertina. This latter material can be stacked
15 alternately with flat webs of the material and connected therewith, in order to form a thicker three-dimensional material.

At the start of an alternative method according to the invention, a set of wires is positioned on a second holding frame. Next, a wire is arranged on a first holding
20 frame. The first and second holding frames are then moved lying opposite each other so that the wires of the second holding frame are arranged at a relative angle of approximately 60° to the wire on the first frame. At the intersection points, the wires of the second frame are welded with the wire on the first frame. The welding can be carried out wire by wire or in groups, as desired. When the
25 welding is completed, the wires are drawn forward in the second frame, so that the wire in the first frame can be moved into an adjacent groove. Then a second wire is arranged in the first frame and the welding process is repeated. This process is continued until a substructure with desired dimensions is produced from two sets of welded wires.

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In the next phase of this method of the invention, a third set of wires is welded to



the substructure of two wires, described above. In turn, a wire is arranged in the first holding frame. The first and second holding frames are then moved into a position lying opposite each other, so that all the wires are aligned at relative angles of approximately 60° . This therefore means that a series of equilateral triangles is formed. At the intersection points, the wires are in turn welded with each other. As mentioned above, the welding can be carried out wire by wire or in groups, entirely as is desired. When the welding of the wires is completed, the finished material is released from the holding frame.

- 10 The material produced using the alternative method of the invention can also be used in isolation by itself as a structural material or building- and construction material. Optionally, the thus produced material can also be bent or kinked using a press, a press ram and a die or by passing through a set of sawtooth rollers, so that corrugated or toothed or serrated webs are formed. This latter material can be stacked alternately with flat webs of the material and connected therewith, in order to form a thicker three-dimensional material.

In another method for the production of the grid material, which is not restricted to a 60° angle between the groups of wires, a series of parallel wires is clamped, which can be advanced through a welding device in parallel in their longitudinal direction. The corresponding device additionally contains guide- and/or clamping devices in order to keep the first group of wires parallel and contains further guide- and clamping devices for a second group of parallel wires which extend at an angle with respect to the first-mentioned group of wires, in which this angle can lie between 10° and 90° . Finally, the corresponding device also has a third group of guide elements or clamping devices, by means of which a third group of parallel wires is aligned so that it extends to the two first-mentioned groups at an angle between 10° and 90° , preferably at the same angle to the first group, which the second group also forms with the first group. Here, the guiding- and clamping devices are arranged so that the three groups of wires in each case have common intersection- or overlapping points. A welding can take place in succession, i.e.



firstly between wires of the first and second group and then between wires of the third and second group, however, it can also be carried out simultaneously at all three groups or individual wires. Then the wires are lifted out from corresponding guides and moved on by a distance which corresponds to the working range of
05 the welding device.

In so doing, the groups of wires can be arranged simply in layers one over another, if required, however, they can also be woven with each other, which, of course, makes the manufacturing process more complicated.

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On the basis of the principles according to the invention, however, not only can flat structure materials be produced, but also objects which are curved three-dimensionally, such as, for example, tubes or the like. For this, for example, one of the folded grids described above can be produced and then bent into a
15 tube or tube section. In this case, however, the connection with a further folded grid or else with one or two flat grids takes place on the inner and/or outer face of the folded grid bent into a tube only after bending. In particular in this case, care is to be taken that owing to the curvature the spacing of the node points on the inner face of the bent folded grid is different from on the outer face.
20 Expediently, therefore, flat grids and folded grids are produced with different grating measurements, which for a given tube diameter can be brought to coincide exactly with the node points of a bent folded grid. Therefore, the production of particular, fixed tube diameters is preferred, for which correspondingly large numbers of matching folded grids and flat grids can be
25 produced.

Other general and specific aims of the invention are in part obvious and will in part become clear hereinbelow.

30 The invention accordingly has a method and a device which have steps, construction features, combinations of elements and arrangements of parts which



are designed to bring about such steps, as described by way of example in the following detailed disclosure, the scope of protection of the invention being indicated by the claims.

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Brief Description of the Figures

For a more complete understanding of the nature and of the objects of the invention, reference is made to the following exact description and to the associated drawings, of which:

10 Figure 1 is a perspective view of an embodiment of the construction material of the invention,

Figure 2 is an enlarged top view from above onto a cut-out of the construction- or structure material according to Figure 1,

15 Figure 3 is a perspective view of a further embodiment of the structure material of the invention, which has a corrugated or grooved cross-sectional structure,

Figure 4 is a perspective exploded illustration of a further embodiment of the structure material of the invention, which has alternating layers of the embodiments of the invention illustrated in Figures 1 - 3,

20 Figure 5 is a perspective view of the embodiment of the structure material of the invention illustrated in Figure 4, in assembled state,

25 Figure 6 is a perspective view of the frame or tentering frame, which is used for the production of the structure material of the invention, a first method of the invention being used, in which the sliding pulleys and wire filaments are to be forged in one position,

Figure 7 is a perspective view of the loom or spool frame, which is used for the production of the structure material of the invention, a first method according to the invention being used, the wire being woven onto a section of the sliding pulleys,

30 Figures 8A and 8B

are top views from above onto first and second holding frames



which are used to produce the structure material of the invention, with the alternative method according to the invention being used,

Figure 9 is a flat grid which is composed of isosceles triangles with a small acute angle,

05 Figure 10 shows diagrammatically the structure change connected with a folding process,

Figure 11 is a top view onto a folded grid with preferred fold angle, so that the node points of one plane form a square grid,

Figure 12 is a cutout from Figure 11 in perspective representation, and

10 Figure 13 shows a grid produced from a web material.

Description of the Preferred Embodiments

Reference will first be made to Figures 1-8, in which the same reference numbers
15 refer to the same parts, and in which a structure material 10 is shown which is realized by the present invention. The structure material 10 is produced from a grid or network of fine wire segments 12 which are connected with each other at their node points 14. The fine wire segments 12 are sections of a continuous wire 16.

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As is illustrated in Figures 1 - 5, the structure material 10 is characterised by a grid of fine wire segments 12. As is illustrated in Figures 1 - 3, the structure material 10 can be flat or corrugated or serrated in cross-section, depending on the planned technical application. In larger, more complex embodiments of the
25 invention, as are illustrated in Figures 4 and 5, the structure material 10 has a multilayered construction which consists of uniformly stacked pyramids 18 in a three-dimensional arrangement. Each pyramid 18 consists of eight wire sections 12 which are connected with each other at their node points 14. In all these embodiments, the wire segments 12 typically consist of brass, stainless steel or of
30 EDM wire. Preferably, the fine wires 12 have a diameter between 0.005 inch and 0.01 inch [0.125-0.254 mm]. In addition, the wire sections 12 are typically between



0.02 inch and 0.1 inch [0.5-2.5 mm] long. A currently preferred wire material has a diameter of 0.08 inch [approximately 0.2 mm] and is produced from stainless steel.

- 05 The invention also takes into consideration alternative methods for the production of the structure material 10. A first method uses frame- or tentering frame superstructures 22 and loom superstructures 26 which are described in detail further below. An alternative method uses holding frames 70 and 72 which are illustrated in Figures 8A and 8B, in order to produce the material according to the invention.

At the start of a first method for the production of the material of the invention, a frame 22 is provided, which is designed to receive a series of sliding pulleys 24. In addition, a loom 26 is prepared, in which the sliding pulleys 24 can be arranged during the initial weaving. In the next step of the method of the invention, a continuous wire 16 is mounted for weaving. The wire 16 is then drawn into the loom 26 and woven according to requirements. Following the weaving, the wire or wires 16 are positioned in the frame 22 and connected with each other, typically welded, at the node points or intersection points 14 of the wire segments 12. The webs or sheets resulting therefrom can then be used as desired or shaped as required, in order to produce a multilayered material. The individual steps of the procedure according to the invention are discussed in more detail further below.

- 25 In the first step of the method according to the invention, the frame 22 and the sliding pulleys 24 are mounted. As illustrated in Figures 6 and 7, these devices serve to keep the wires or wire filaments 16 under tension and in the correct orientation before welding. Generally, the frame 22 is a flat ring 28 which has three sets of opposing rails or guides 30, which have T-shaped slits 35. The rails 30 are arranged at angular distances or intervals of 120°. This angle is therefore selected so that when the three sets of sliding pulleys 24, which have wires or wire



filaments 16, which extend therefrom, are arranged in the frame 22, the wire segments 12 overlapping each other form a plurality of equilateral triangles.

05 The sliding pulleys 24 have in each case a first section 32 with a surface 33 which has a series of parallel grooves 34 to receive the wires 16 and hold them precisely in their place. A second surface 37, which is arranged on the visible side of each of the sliding pulleys 24, is constructed so that it is able to be mounted on the stands 38 of the loom 26, which is described more precisely hereinbelow. Each sliding pulley 24 also has a second section 36, which is constructed so that it fits
10 the first section 32. The second section 36 is dimensioned and shaped so that it engages into the wires, when the weaving described below is completed. The first and second sections 32 and 36 can be connected for example with the use of machine screws, bolts and other securing means with which specialists are familiar.

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Next, the loom 26, which is illustrated in Figure 7 and which consists of three stands 38 on a rotating triangular platform 40, is prepared or produced. Each upright 38 has a positioning surface 42 on which the first sections 32 of the sliding pulleys 24 are secured, before the wire 16 is drawn into the loom 26. The
20 positioning surfaces 42 on the stands 38 are constructed so that they secure the sliding pulleys 24, their surfaces 33, which are provided with grooves, being turned outwards. In operation, each of the second surfaces 37 of the first sections 32 on the sliding pulleys 24 are arranged in contact with a surface of one of the stands 38, in order to prepare the loom 26 for weaving. The sliding pulleys 24 can
25 be secured to the stands 38 for example using machine screws, bolts or other securing means with which the specialists are familiar.

In the next step of the method of the invention, the weaving frame 26 and hence also the stands 38 are turned in order to thus draw the wire 16 over the grooves
30 34 of the sliding pulleys 24. In particular, the frame 26 is turned so that after a revolution, the wire 16 runs into the next deeper groove 34 of each sliding pulley



24. This procedure is continued until all the grooves 34 of the sliding pulleys 24 contain a section of the wire 16. During the weaving, the wire filament 16 is preferably kept at a tensile stress of between 0.05 and 0.2 ounces [1.4 - 6 g]. When this method is carried out, a parallel field of the wire or of the wires 16 is thus formed between all stands 38. When the wire is arranged on the loom 26 or on the spool frame in the parallel arrangement, then the second section 36 of each of the sliding pulleys 24 is arranged over each of the first sections 32. The wire 16 is then fixed in its position for further processing. Following on therefrom, the wire 16 is separated through. More precisely, the wire 16 is severed along the stands 38, with a welding torch being used, for example. This procedure produces three independent sections 46 with a sliding pulley 24 at each end of a wire section 48. The sliding pulleys 24 are then released from the positioning surfaces 42 and transported to the frame 22.

15 In the next step of the method according to the invention, the sliding pulleys 24 and the wire sections 48 are mounted on the frame 22 and the wire sections 48 are connected with each other using a forging press. In particular, the sliding pulleys 24 are positioned in the T-slits 35 of the rails 30. Similar T-slits 35, sliding pulleys 24 and wire sections 48 are mounted on the frame 22 at relative angles of 120°. An arrangement in this manner produces a trigonal grid of wire segments 12, which have the form of a plurality of equilateral triangles 50. Each triangle 50 has three node points 14 in common with its adjacent triangles 50. When all wire segments 12 are correctly or properly oriented, a forging press is used, with which the specialists in this field are familiar, in order to apply heat and pressure to all node points 14 simultaneously. Preferably, the press provides a pressure of approximately 50 pounds per square inch and a temperature of 1250° Fahrenheit. The welding of the wire segments 12 takes place preferably under vacuum. As soon as all node points 14 are connected with each other, the structure material 10 originating therefrom can be removed from the frame 22 and possibly from the side blocks 24.



Figures 8A and 8B show holding frames 70 and 72 which can be used for an alternative method of the invention, in order to produce the material of the invention. According to Figure 8A the holding frame 70 has an approximately rectangular shape. A series of grooves 74 are cut into the surface 76 of the frame 70. It is clear to specialists in the art that the dimension of the grooves 74 is determined by the dimension of the wire used for the construction of the material and of the grid according to the invention. The grooves 74 are distributed uniformly on the surface 76, spaced apart from each other. Generally, the separating distance between the grooves 74 is determined by the desired characteristics of the produced material and grid. Typically, the grooves 74 are separated approximately 0.03 inch and 0.07 inch from each other [0.75 mm - 1.8 mm]. Preferably, the grooves 74 are separated by approximately 0.05 inch from each other [approximately 1.27 mm]. The grooves 74 run parallel. A slit 78 is cut into an edge 80 of the frame 70, in order to ensure access for a welding electrode (not illustrated).

According to Figure 8, the holding frame 72 has a polygonal shape with at least two sides 82 and 84, which are arranged an angle in relation to each other. The angle between the sides 82 and 84 of the holding frame 72 is selected here such that the wires, when they are arranged on the frame 72, are aligned at approximately 60° relative to a wire arranged on the holding frame 70. The frame 72 likewise has a series of grooves 86, which are cut into one of its surfaces 88. Here, also, the specialists in the art recognize in turn that the dimension of the grooves 86 is determined by the dimension of the wire used for the construction of the material and grid according to the present invention. The grooves 86 are spaced uniformly apart from each other on the surface 88. The distance between the grooves 86 is determined by the desired characteristics of the produced material and grid. Typically, the grooves are spaced apart from each other by approximately 0.03 inch to approximately 0.07 inch [approximately 0.75 mm - 1.8 mm]. Preferably the grooves 86 are spaced apart from each other by approximately 0.05 inch [approximately 1.27 mm]. The grooves 86 are parallel. A



flange 90, which is held in its position by a screw 92, extends over a portion of the surface 88 of the holding frame 72. In use, flange 90 and screw 92 cooperate with each other so that they secure or fasten the wires arranged on the frame 70.

05 At the start of an alternative method according to the invention, a first set of wires is arranged in the grooves 86 of the frame 72. As soon as these are arranged, the flange 90 is arranged over the wires and secured using the screw 92. Next, a wire is arranged in the groove 74, which lies closest to the edge 80 of the frame 70. The first and second frames 70 and 72 are then brought into a contact
10 position adjacent to each other, so that the wires overlap and are aligned at a relative angle of approximately 60° to each other. Preferably, the wires which are held in the frame 72 overlap the wire which is held in the frame 70. The wires are then welded together at the intersection points. The welding can be carried out wire by wire or in groups, depending on how it is desired.

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When the welding of the wires which are held in the frames 70 and 72 is completed, the partial- or sub-structure is moved, so that the wire in the frame 70 now rests in the groove further out from the edge 80 or next-but-one groove. Then a new wire is arranged in the groove 74, which lies closest to the edge 80
20 and the welding process begins again. In this way, successive wires which are held in the first frame 70 are arranged on the wires held in the second frame 72. In the next phase of the method according to the invention, a third set of wires is arranged on the substructure of wires, which was produced according to the method described above. To carry out this composition procedure, a wire is again
25 arranged in the groove 74, which lies closest to the edge 80 of the frame 70. The first and second frames 70, 72 are moved lying adjacent to each other in contact again, so that all wires overlap each other and are arranged at relative angles of approximately 60° . The wires are then welded together again at the intersection points. The welding can be carried out as required, wire by wire or in groups.

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When the welding of the wires is completed, the material 10 of the invention is



removed from the frames. The material 10 can then be further processed according to requirements.

05 The structure material 10, which is produced using the methods according to the invention, can be used in isolation, as is illustrated in Figure 1. Optionally, the structure material can also be corrugated or folded, as is illustrated in Figure 3, for example using a press, a press ram and a die, or by allowing it to run through a set of sawtooth rollers, in order to form webs which are corrugated or provided with folds. Preferably, the folded or corrugated embodiment of the structure
10 material 10, which is illustrated in Figure 3, is produced in that the flat structure material which is illustrated in Figure 1 is passed through a roll press. The roll press has a substantially flat protruding part and a curved returning part. The curved, returning part touches the flat protruding part tangentially along a single line. In operation, the structure material 10 is bent along the contact line between
15 the projecting and the returning part of the press. This construction is preferred, because it makes it possible that the structure material 10 draws together whilst it is bent or kinked.

The structure material produced using the method according to the invention can
20 also be used in order to form a larger, multi-layered construction, as illustrated in Figures 4 and 5. In this embodiment, alternating layers of the flat structure material 10 according to Figure 1 are connected with the corrugated or folded structure material 10 according to Figure 3. To form this material, the layers are firstly stacked on each other, as illustrated in Figure 4. Next, the loose material 10
25 is arranged in the forging press and is welded according to the method which was described above in connection with the method for the formation of an individual sheet of the structure material 10.

The following is an illustrative, non-restrictive example of the procedure for
30 producing a material according to the invention.

Example 1

At the start of the manufacturing process, a section of a wire was in each case inserted into the grooves which were cut into the surface of a second holding
05 frame (Figure 8B). A single wire was arranged in the first groove of a first holding frame (Figure 8A). The wires arranged in both frames were produced from stainless steel, had a diameter of 0.008 inch [0.2 mm] and were produced by All Stainless Co. in Hingham, Massachusetts. Next, using a straight edge, the ends of the wires arranged in the second frame were aligned such that each wire
10 extended by approximately 0.01 inch beyond the edge of the frame. The wires arranged in the second frame were then brought into contact with the single wire arranged in the first frame. In particular, the wires were oriented so that the wires in the second frame ran at a relative angle of 60° to the wire in the first frame.

15 In the next step of the process, an electrode was brought into contact with the wires in the second frame and the single wire in the first frame. More precisely, at each intersection point an electrode was arranged such that it exerted a pressure of five (5) pounds on each wire transition. The electrode was connected with a current source which was able to make available a regulated percentage of
20 a nominal current in the range from one (1) to ninety (90) percent in 1% stages, and namely for a regulated number of sixty (60) Hertz cycles (in which each cycle amounted to approximately 16.7 ms), in the range from one (1) to seventy (70) cycles in stages of one (1) cycle. Using the current supply, a current of 55% of the standard nominal current was supplied at the intersection point during one
25 (1) cycle. This process was repeated until all intersection points were welded with each other. In the concluding phase of the composition process, the partial construction of the first and second wires was arranged again in the second frame and then a third frame was arranged in the first frame. At each intersection point in turn an electrode was arranged in contact with the wires, so that they exerted a
30 pressure of five (5) pounds on each wire transition. A current of approximately sixty-five (65) percent of the standard nominal current was supplied to the



intersection point during one cycle, using the current supply described above. This process was repeated until all intersection points were welded with each other. One can therefore see that the invention achieves in an efficient manner the aims described above, among all the others which are obvious from the above
05 description. In particular, the present invention represents a high-strength structure material having low weight and also an efficient method for its manufacture.

It is understood that alterations can be made to the above construction and in the
10 above operating or manufacturing sequences, without departing from the framework of the invention. Accordingly, it is intended that everything which is contained in the above description or is illustrated in the associated drawings, is only by way of example and is not understood in a restrictive sense.

15 It is also understood that the following claims are all inherent in the invention described here and are intended to cover specific features and likewise also all statements of the framework or scope of protection of the invention, which could lie therebetween on the basis of the mode of expression.

20 Figure 13 shows diagrammatically as an example a cutout from a flat web material which through punching out or etching has been given the structure of a regular triangular grid. The removed areas have in top view approximately the form of equilateral triangles rounded at the corners, so that node points or node surfaces are produced, which are reinforced with respect to the filaments forming the
25 nodes. Possible kink lines on folding such a grid are indicated by dot-and-dash lines.

It is understood that the recesses in the web material can have basically any desired form and arrangement, so that not only all structures are able to be
30 produced, which one can also produce with groups of parallel wires, but rather in addition also further more complicated grid- and network structures. Proceeding



from such a flat grid or network, this can in turn be folded and connected similar grids or else with other folded or flat grids and stacked in layers, in order to produce the block material therefrom.

- 05 In Figure 9 a cutout from a flat grid is illustrated, in which three groups of wires 1, 2 and 3 are aligned respectively parallel to each other, the groups 2 and 3 intersecting each other at an angle of approximately 40° and both forming with the third group 1 in each case an angle of approximately 70° .
- 10 If a folded grid is produced from this group, the fold lines preferably run along the first group 1 of wires, with the second and third groups 2, 3 of wires then forming a pyramid structure.

15 In Figure 10, the effect is shown of the folding process on the structure in the upper and lower planes 4, 4' of a folded grid.

Firstly Figure 10 shows at the bottom left a flat grid which is constructed from equilateral triangles.

- 20 The wires 1, 1' from one of the groups of parallel wires are selected as fold lines. The folding can be carried out by means of rolls, bending devices or presses. At the top left in Figure 10, a side view of the folded grid is illustrated diagrammatically. The wires 1 define an upper grid plane 4 and the wires 1' define a lower grid plane 4'. Also drawn in Figure 10 at the top left is the fold
- 25 angle α which is defined as the angle of two intersecting planes, with the planes intersecting in one of the fold lines and running through each of the next adjacent fold lines of the other plane.

- To the right in Figure 10, the folded grid is illustrated in a top view from above.
- 30 For a better comparison with the flat grid, four grid points on wires 1 which define the upper plane 4 are emphasized in the flat grid by circling. The same



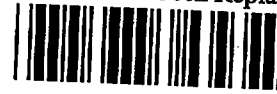
circled grid points are also seen on the right in the folded grid, in which their distance in the direction of the fold lines 1 has not changed, however the distance perpendicular to the fold lines 1,1' has. Actually, this horizontal distance in the folded grid only depends on the fold angle α . With a flat grid which is composed of equilateral triangles and which has a hexagonal structure, one can achieve with a fold angle α of approximately 51.3° a situation in which the horizontal spacing of the grid points, designated in Figure 1 by a , i.e. the spacing of adjacent fold lines of the same plane 4 or 4', becomes equal to the spacing b of the grid points along the fold lines 1,1'. Such a case is illustrated in Figure 11.

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In Figure 11 one can see that after folding around the preferred angle, the node points of the upper grid plane form a square grid and that also the node points of the lower grid plane marked at some points by circles form an identical square grid. For better clarification of the three-dimensional structure, the fold lines of the lower grid plane are only drawn in dotted lines and the fold lines of the upper grid plane, like the side edges of the forming pyramids, are drawn with continuous lines.

The region drawn by 5 in Figure 11 is illustrated again in perspective representation in Figure 12. In Figure 12, twelve pyramids can be seen in total, the points of which are connected with each other by the wires 1, whilst the wires 1' of the lower plane 4' in each case define parallel side edges of the lower planes of the pyramids. In this form, the structure is only resistant to bending in one direction and has a high resistance to a bending about an axis which runs in the plane 4 or 4' perpendicular to the fold lines. Initially, however, such a grid still offers little resistance to a bending about an axis parallel to the fold lines, because on the pyramids the lower edges of these pyramids running horizontally in Figure 12 are still missing. However, if one takes an identical folded grid, turns it through 90° with respect to the one illustrated in Figure 11 and 12 and then places it onto the first grid, then its fold lines run precisely perpendicular to the fold lines 1, 1' of the illustrated grid and the two grids can be arranged relative to

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each other so that the node points which form the points or lower corners of the pyramids coincide precisely. If the grids are welded together in this form, then the points or base points of the pyramids are also connected with each other in horizontal direction and then form a structure which is very resistant to torsion.

- 05 Here, several such layers can be welded on each other, staggered alternately through 90° with respect to each other. On the respectively lowest layer, either a simple flat square grid having the same grating dimension as the pyramid base points can be welded on, or only a simple group of parallel tensioned wires, which run perpendicular to the fold lines 1' and have the same spacing from each
- 10 other as the hold lines 1' (and hence also like the lower corner points of the pyramids) can be welded onto the lower plane 4' in the node points.

- The same also takes place of course with the pyramid points of the uppermost layer of such a block grid, which is composed of several layers, with the points of
- 15 the pyramids already connected with each other in one direction via the wires 1 also being connected with each other horizontally by a square grid or a corresponding group of parallel wires. In addition, it is to be pointed out that the lower corner points of each of the pyramids at the same time also form points of inverted pyramids, as can also be easily subsequently effected with the aid of
- 20 Figure 12. The connecting of the pyramid points is accordingly a fully equivalent process to the connecting of the lower corner points of the pyramids.

- When several layers of such folded grids are connected with each other, of course an exact alignment of all grid points is involved, so that the node points in the
- 25 adjoining planes 4, 4' of adjacent folded grids lie exactly against each other. The folding of the grids must take place previously in a correspondingly accurate manner. When the two grids are aligned exactly with each other, in the case of only two grids the welding can take place only by a forging press, which engages respectively from one side of the grids into the pyramid points. In superstructures
- 30 of several layers, however, such a mode of operation is not readily possible. If, however, the grids are produced very exactly and lie on each other in a precisely

fitting manner, the welding can also take place in that electrodes having a large area are placed onto the two outer sides of the grids, through which then a suitable current surge is passed, so that the two grids are welded with each other at their transition points which define a greater electrical resistance than the
05 remaining material.

Of course, mechanical connection techniques, such as are known for example from the contacting of semiconductor chips, e.g. with gold wires, are also used.

10 Instead of one or more flat grids or in addition to these, of course plates or foils can also be welded or glued onto the pyramid points and base points of the folded grids. This applies in particular to the outermost layers or single- or multi-layered grids. The structure material according to the invention can then also be used for gas-tight and fluid-tight dividing walls or containers.

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Likewise, the intermediate spaces of the grid can also be filled, independently of or in addition to the surface coverage, e.g. with a synthetic resin or other flowable, preferably hardenable substances.

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Claims

1. A grid structure of wires, in particular of thin wires which has a first, a second and a third group of continuous wire sections, the wire sections being
05 welded with each other at their intersection points, at least two of the first, second or third group of wire segments being arranged at an angle of approximately 60° relative to the other series, the first, second and third groups of wire segments being secured or fixed with each other so that they form a continuous field of trigonal structures, the trigonal structures being present in the
10 form of a series of equilateral triangles.
2. A wire grid according to Claim 1, the first, second and third series of wire segments being formed from a material which is selected from the group which consists of brass, stainless steel and EDM wire.
15
3. A wire grid according to Claim 2, the material which forms the first, second and third series of wire segments having a diameter between approximately 0.005 inch and approximately 0.01 inch [0.125mm - 2.5 mm].
- 20 4. A wire grid according to Claim 3, the material which forms the first, second and third series of wire segments having a diameter of approximately 0.008 inch [0.2 mm].
5. A wire grid according to Claim 1, the spacing between the intersection
25 points of the first, second and third series of wire segments lying between approximately 0.01 inch and 0.1 inch [between 0.25 mm and 2.5 mm].
6. A method for the production of a grid of wires, in particular of thin wires, the method having the steps:
30 a) Preparation of a frame, the frame having an annular shape and at least three sets of opposing rails, each of these rails being dimensioned and shaped so



that it can receive a sliding pulley, the sets and the opposing rails being arranged at relative angles to each other of 120° ,

b) Preparation of the sliding pulleys, the sliding pulleys having a first section which has a series of parallel grooves on a first surface, and a second section
05 which is constructed so that it can enter into engagement with the first surface of the first section.

c) Preparation of a loom, the loom having at least three stands provided with grooves on a rotating trigonal platform, the stands having positioning surfaces which are constructed so that they receive one of the respective first sections of
10 the side blocks in a firmly secured manner,

d) Drawing of a fine wire filament into the loom and into the grooves in the surface of the first section of the sliding pulleys,

e) Securing of the wire in the sliding pulleys by arranging the second section of the sliding pulleys in engagement with the first surfaces of the first sections of
15 the sliding pulleys and separating of the wires adjacent to the sliding pulleys,

f) Securing of the sliding pulleys on the opposing sets of rails on the frame, in order to thus form a wire matrix from the wire filaments, the sliding pulleys being mounted on the frame such that the wires which are secured on the frame intersect each other at angles of approximately 120° , the wires forming a field of
20 equilateral trigonal superstructures, and

g) Welding together the wires, in order to thus form the wire grid which has a flat construction.

7. A method according to Claim 6, which additionally has the step that the
25 wire grid is bent in order to form a wire grid which has a corrugated construction or a construction placed in folds.

8. A method according to Claim 7, which additionally has the step that a first section of a wire grid which has the flat construction is welded onto one side of a
30 wire grid, which has the corrugated or folded construction.

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9. A method according to Claim 8, which additionally has the step that a second section of the wire grid which has the flat construction is welded onto a second side of the wire grid, which has the corrugated or folded construction, the second side of the wire grid which has the corrugated construction lying opposite
05 the first side of the wire grid which has the corrugated construction.
10. A method for the production of a wire grid, the method having the steps:
- a) Preparation of a first frame, the first frame having a series of grooves for receiving a first group of fine wires,
 - 10 b) Preparation of a second frame, the second frame having a series of grooves for receiving a second group of fine wires,
 - c) Arrangement of a group of wires in the grooves of the second frame and securing of this group of wires in their position,
 - d) Arrangement of a wire segment in a groove of the first frame,
 - 15 e) Moving of the first and second frames in abutment with each other, so that the groups of wires in the second frame are aligned at a relative angle of 60° to the wire segment in the first frame,
 - f) Welding of the group of wires in the second frame with the wire segment in the first frame,
 - 20 g) Continuous insertion of wire segments into the first frame and welding of the wire segment to the group of wires in the second frame, in order to thus form a substructure of welded wires,
 - h) Arrangement of the substructure of welded wires in the second frame, the substructure having a group of wires which are held in the second frame and the
25 wire segments which were held in the first frame,
 - i) Arrangement of a wire segment in the first frame,
 - j) Welding of the partial structure of wires with the wire segment arranged in the first frame,
 - k) Continuous insertion of wire segments in the first frame and welding of
30 this wire segment with the partial structure of welded wires, in order to thus form the wire grid which has a flat construction,

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1) Removal of the wire grid from the first and second frames.

11. A method according to Claim 10, which additionally has the step that the
wire grid is bent in order to thereby form a wire grid which has a corrugated or
05 folded construction.

12. A method according to Claim 11, which additionally has the step that a
first section of a wire grid which has the flat construction is welded on one side
of the wire grid which has the corrugated or folded construction.

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13. A method according to Claim 12, which additionally has the step that a
second section of the wire grid which has the flat construction is welded to a
second side of the wire grid which has the corrugated construction, the second
side of the wire grid which has the corrugated construction being arranged
15 opposite the first side of the wire grid with the corrugated construction.

14. A wire grid with several groups of parallel wires, characterised in that the
grid has at least three groups wires respectively parallel to each other, that the
wires of various groups form an angle of at least 10° and a maximum of 90° with
20 each other, and that the wires are welded with each other at their crossover
points.

15. A grid according to Claim 14, characterised in that the spacings between
the wires within each group and the relative angles between wires of different
25 groups are selected so that in each case one wire from each of the three groups
runs through each crossing point.

16. A wire grid according to Claim 14 or 15, characterised in that the grid is
folded in the manner of a concertina.

30

17. A wire grid according to Claim 16, characterised in that the fold lines run



along parallel rows of crossing points.

18. A wire grid according to Claim 17, characterised in that the fold angle and the length of the folded sections, measured perpendicular to the fold lines, are selected so that the grating dimension of crossing points lying in one plane of the folded grid coincides with the grating dimension of the crossing points of a flat, unfolded grid.
19. A grid according to Claim 17, characterised in that the grating dimension of the crossing points in one plane of a folded grid is in a ratio of small whole numbers to the grating dimension of the crossing points of a flat, unfolded grid.
20. A wire grid according to Claim 16 or one of the claims referred back to Claim 16, characterised in that with the flat, still unfolded grid the angle between in each case two wires of different groups amounts to 60° , that the fold lines run along the wires of a group of parallel wires and that the fold angle amounts to approximately 51.3° , so that the spacing of crossing points on a fold line is equal to the spacing of adjacent fold peaks or troughs with respect to each other.
21. A grid structure of filaments, the filaments being arranged in parallel in groups and the filaments of different groups forming an angle of at least 10° and a maximum of 90° with each other, characterised in that at least a portion of the filaments are produced from a flat web material by the removal of regularly arranged area regions of the web material.
22. A grid material according to Claim 21, characterised in that the removed area regions have approximately the form of triangles, preferably with rounded corner regions.
23. A grid structure according to Claim 22, characterised in that the triangles are arranged in at least two groups, the orientation of the triangles within a group



in each case being identical and between the two groups different, in particular turned through 180° to the triangles of the other group.

24. A grid structure according to one of Claims 21 to 23, characterised in that
05 the at least one initial grid is produced from a sheet metal material.

25. A method for the production of a wire grid, characterised in that three
groups of parallel wires are placed one over the other or woven with each other,
the wires of one group forming with the wires of another group an angle of at
10 least 10° and a maximum of 90° and the wires of the different groups being
welded with each other at their crossing points.

26. A method according to Claim 25, characterised in that the arrangement of
the wires takes place so that each crossing point has three wires and namely in
15 each case one from each of the different groups.

27. A method according to Claim 25 or 26, characterised in that the wire grid
is folded in the manner of a concertina.

20 28. A method according to Claim 27, characterised in that several grids which
are either flat or folded are placed one over another in several layers and are
welded with each other on at least one part of their contact points.

25 29. A method according to Claim 28, characterised in that two folded grids are
connected with each other, preferably by welding, with a fold alignment turned
through 90° with respect to each other.

30 30. A method for the production of the grid material according to one of
Claims 21 to 24, characterised in that regularly arranged area regions are
removed from a web material.

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31. A method according to Claim 30, characterised in that the area regions are punched out from the material.

32. A method according to Claim 31, characterised in that the area regions are
05 removed from the material by etching agents.

33. A method according to Claim 32, characterised in that the structure of the regions to be etched out is produced by photolithographic techniques.

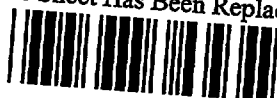
10 34. A method according to one of Claims 30 to 33, characterised in that a sheet metal material is used as web material.

35. A method according to one of Claims 30 to 34, characterised in that the web material, after the removal of the planned regions which leave behind a
15 regular grid or network structure, is folded along the resulting grid or network of parallel node lines which run along the connection lines of adjacent node points.

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