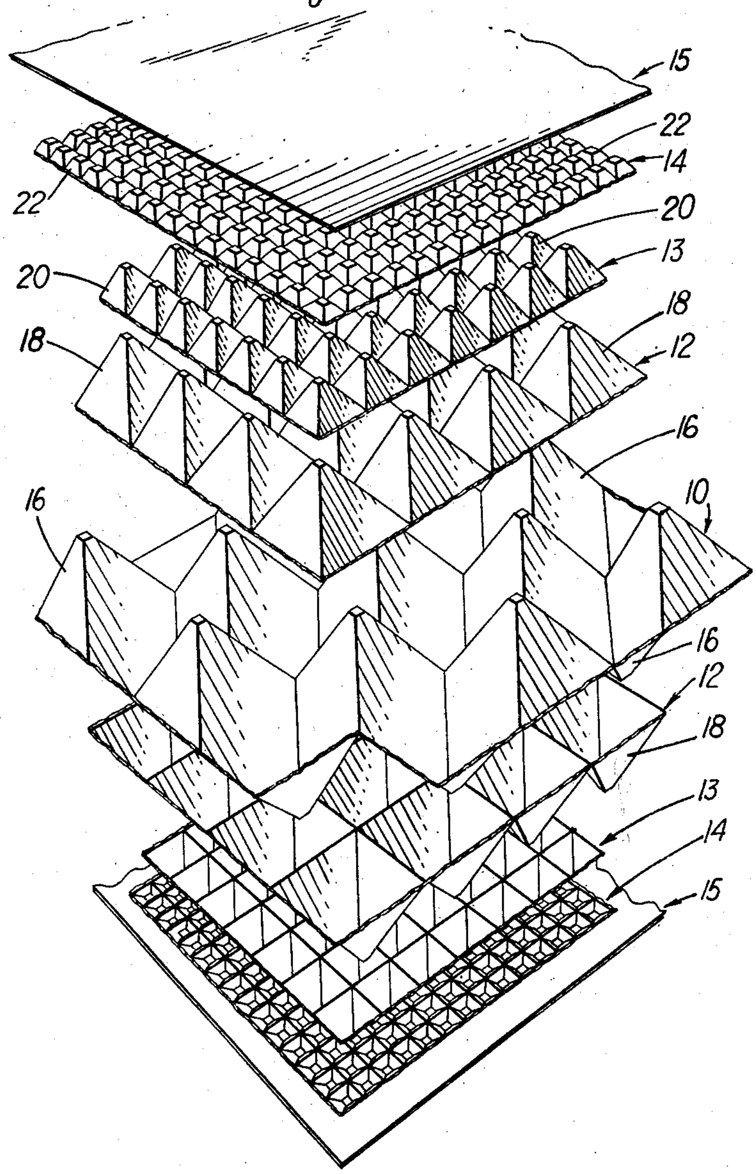
Oct. 29, 1963 G. M. ADIE 3,108,924

STRUCTURAL ELEMENT

Filed April 7, 1960 2 Sheets-Sheet 1

Fig. 1



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2 Sheets-Sheet 2

Fig. 2.

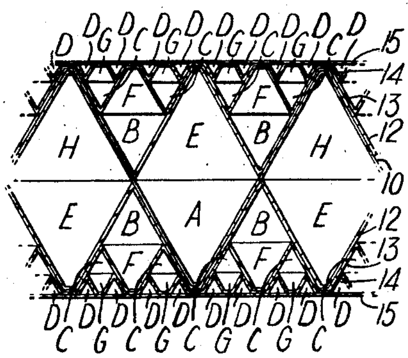


Fig. 3.

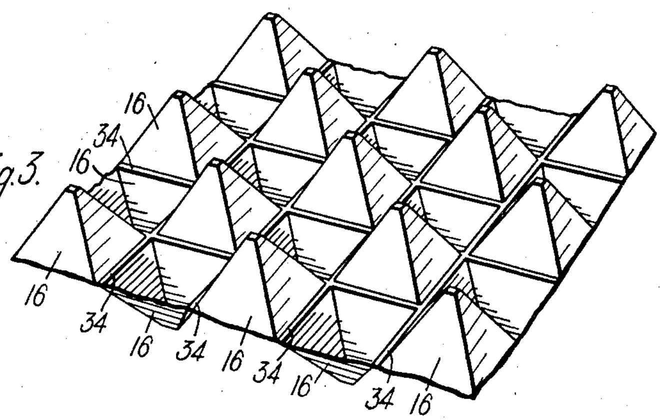
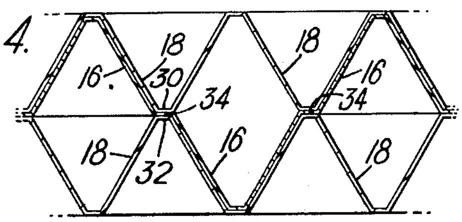


Fig. 4.



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STRUCTURAL ELEMENT

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This invention relates to materials and elements for use in building constructions and the like and is an improvement in or modification of prior materials or elements consisting of a slab, panel, block or the like of cellular material in which the density of the material is graded so as to be a maximum in the neighbourhood of one or both of its faces and a minimum in the neighbourhood of the opposite face or the median plane as the case may be. Such prior material or elements have been formed by the juxtaposition of thin sheets of mouldable material, such as a thermoplastic, having dimples or cups formed in them, the open sides of the dimples being brought opposite each other to provide cells which were spherical in shape. The cells were so arranged that the density of the material was a maximum in the neighbourhood of both of its faces and a minimum in the neighbourhood of the median plane of the material. Each outer load-bearing face was bounded by a skin of non-cellular material.

According to the present invention, a cellular slab, panel, block or like element is formed of a number of juxtaposed sheets having dimples formed therein of square, circular, hexagonal or other polygonal cross section. The size of the dimples in the sheets decreases from sheet to sheet away from the median plane of the element or from one of its faces to the other and the sheets are disposed so that the apex of the dimples in each intermediate sheet being nested with a dimple in an adjacent intermediate sheet and in contact with the apex of the dimples with which they are nested, the depth of the dimples in the sheets decreasing in amount by a factor of two from sheet to sheet from one side to the other of the slab, and all of the apices lying substantially within the same plane.

The dimples may for example be pyramidal or conical in shape or some may be pyramidal and some conical. The sheets are preferably of mouldable material such as thermoplastic or thermosetting plastic, metal, such as mild steel or any other suitable substance. One very suitable material for all the sheets is pressed fibre because of its cheapness, ease of moulding and lightness. When pressed fibre sheets are used throughout the element then two identical centre sheets are used so that the element is balanced to counteract any variation which may occur due to the variation in a sheet of pressed fibre of one of its surfaces as compared with the other surface. When pressed fibre, thermoplastic or other suitable material is used for the sheets then they can be riveted together as well as or instead of being stuck with adhesive.

The pyramidal dimples are preferably truncated so that the apices of the dimples in all the sheets are flat surfaces all of the same size subject to the necessary allowance for the thickness of the sheet material. The pitch of the pyramidal dimples in the various sheets is preferably doubled from sheet to sheet from the outermost dimpled sheet where the density of the element is to be

greatest to the middle sheet or the opposite outermost dimpled sheet where the density is to be least. The word "pitch" wherever used herein is intended to refer to the distance between the apices of the dimples, or in other words, the number of dimples occupying a given area. Thus the depth of the pyramids in any relatively outer sheet is approximately half that of the depth of the pyramids in the next relatively inner sheet. This leads to the production of an element having a system of voids constituting a two-dimensional rectangular or triangular grid of which the grid lines are channels of triangular cross section.

Embodiments of the invention are illustrated in the drawing accompanying the provisional specification in which:

FIGURE 1 is an exploded view showing nine sheets which can be assembled together to make an element of which

FIGURE 2 is a cross sectional view, and in the accompanying drawing in which:

FIGURE 3 is an isometric view of a modified centre sheet, and

FIGURE 4 is a section of a part of a slab incorporating the centre sheet shown in FIGURE 3.

The element shown in FIGURES 1 and 2 comprises a centre sheet **10**, three intermediate sheets **12**, **13** and **14** on each side of the centre sheet and an outer skin or sheet **15** which forms a flat face on each side of the element. The centre and each of the intermediate sheets is formed with a series of dimples in the form of hollow truncated pyramids.

The centre sheet **10** is formed with two series of identical pyramidal dimples **16** extending in opposite directions so that the bases of the pyramids occupy the whole of the projected area of the sheet.

Each of the two intermediate sheets **12** which are identical is dimpled with identical truncated pyramids **18** which, however, extend all in the same direction from the sheet. The pitch of the dimples **18** is half that of the dimples **16** on one side of the centre sheet **10** and their bases occupy the whole of the projected area of the sheet. The next pair of intermediate sheets **13** are also dimpled, the pitch of the dimples **20** in them being one half of that of the dimples **18**. The sheets **14** are formed with still smaller dimples **22** at one half the pitch of the dimples **20**.

The flat surface at the truncated apex of each pyramidal dimple is the same size and shape for each pyramid on each sheet allowing, of course, for the thickness of the sheet material and the slope of the sides of each pyramid is the same so that they can be fitted together one over the other.

The outermost sheets **15** shown in FIGURE 1 are plane.

The nine sheets shown in FIGURE 1 can be assembled to produce a slab having the cross section shown in FIGURE 2. Alternate pyramidal dimples in the sheets **12** are engaged over the apices of the pyramidal dimples extending to one side or the other of the centre sheet **10**; alternate dimples in the sheets **13** are engaged over the apices of the dimples in the sheets **12**, alternate dimples in the sheets **14** are engaged over the apices of the dimples in the sheets **13**, and the plane sheets **15** lie in contact with the apices of the dimples of the sheet **14**. It will be clear from an inspection of FIGURE 2 that the density of the material forming the element shown therein is greatest in the region of the outside and decreases progressively towards the inside so that material can be saved and the slab have a high strength to weight ratio. By sticking or welding the sheets together where they are in contact with each other, a block will be formed which will be of extremely light weight, which will be highly resistant to penetration and which will have a good load-bearing capacity even though the load is applied over only a small area.

The truncation of the pyramidal dimples is advantageous as it facilitates construction of the dimpled sheets and also in the case of the outermost dimpled sheet which receives the finishing skin **15** provides a good area of contact between the dimples and the outer skin.

A cross section taken at right angles to that shown in FIGURE 2 will be identical with FIGURE 2. Therefore, the system of voids defined by the sheets will consist of (i) two series of passages of approximately triangular section B, C, D, intersecting each other at right angles and forming two-dimensional grids, (ii) the hollow interiors E, F, G of the alternate pyramidal dimples **18**, **20**, **22**, and (iii) the interior A and H of dimples **16**.

The intermediate sheets **12**, **13** and **14** serve to reinforce not only the outer portions of the element but also the sloping sides of the centre sheet and enable the element to withstand highly concentrated loads at points along its length. Such an element may be weakest at its median plane where there is only one thickness of material to resist the load and therefore it may be advantageous to use a central sheet **10** of a material more highly resistant or stronger than adjacent sheets or to provide a double centre sheet. For example, the centre sheet may be of steel while the outer sheets of the composite element could be of thermoplastic material. Owing to the thickness of the material of the sheets a small web equal in width to the sheet thickness is left between the dimples. Thus the sheets in each side of the central sheet are not in line and the centre sheet is subjected to shear force when the slab is loaded. In order to minimize this shear force the centre sheet or sheets may be formed with a dog leg, where it passes between the dimples in the sheets on each side of it. The dog leg has a width equal to that of the webs between the dimples or in other words equal to the thickness of the material. Thus the webs of the dimples in the sheet on one side of the centre sheet lie immediately in line with the corresponding webs in the sheet on the other side of the centre sheet, separated only by the dog leg portion of the centre sheet. In this way stresses are transmitted from one sheet to the other without subjecting the centre sheet to any substantial shear force.

An example of a slab incorporating such a dog legged centre sheet is shown in FIGURE 4. This figure shows the width of the webs **30**, **32** between the dimples **18** of the sheets much exaggereated to show the construction clearly. In fact the width and that of the dog leg **34** is only equal to that of the thickness of the material of the sheet. The small webs **30** between the dimples of one sheet lie immediately above the corresponding webs **32** between the dimples of the sheet on the other side of the centre sheet the webs **30**, **32** being separated only by the dog leg portion **34** of the centre sheet. When the webs **30**, **32** and dog leg portion **34** of the centre have their correct widths, equal to the thickness of the sheets, then the sides of the pyramidal dimples of one sheet will be in line with the sides of the pyramidal dimples of the sheet on the other side of the centre sheet.

Instead of the centre sheet **10** being formed with pyramidal dimples on both of its faces, two sheets having dimples formed only on one of their faces can be secured together with their open faces next to each other to provide a layer having dimples on each side. The pyramids on one sheet can be either staggered with respect to those on the other sheet, can be opposite them or can be di-

agonally disposed one to another. Further layers are then built up on the same manner as in the elements described above.

Alternatively a plane centre sheet may be used or indeed no centre sheet at all. In these cases a series of closed cells will be provided in the centre of the slab.

If the sheets are made of thermoplastic they will conveniently have a thickness of the order of four thousanths of an inch. This results in an element of very low weight, for example, a square foot of the seven sheet element without the outside sheets as described above and stuck together weighs approximately 7 ozs. and has a resistance to collapse exceeding a quarter of a ton per square foot.

If it is desired that the element have some particular properties such for example as acoustic or insulating properties than a sheet or "blanket" of material having such a property or properties may be included in the element. Such a blanket if it is very thin say only a few thousandths of an inch thick, could be placed between each of any two dimpled sheets but if it is of greater thickness then it is preferably placed between the two centre sheets.

The blanket could act as an adhesive, a hardener, a heating element, a heat containing or reflecting element, a weather-proofing or fire-proofing element or as a strengthening sheet. If desired it can be arranged to isolate all the grids of ducts between the dimples on one side of the central sheet from the grids of ducts between the dimples on the other side on the central sheet.

I claim:

1. A building slab or element comprising a number of superimposed relatively thin sheets consisting of spaced outermost sheets and at least three intermediate sheets, the intermediate sheets having a regular series of truncated dimples formed therein arranged on a rectangular grid, said dimples having their sides all disposed at the same slope, the said sheets being disposed in juxtaposition, the apex of the dimples in each said intermediate sheet being nested with a dimple in an adjacent intermediate sheet and in contact with the apex of the dimples with which they are nested, the depth of the dimples in the sheets decreasing in amount by a factor of two from sheet to sheet from one side to the other of the slab, and all of the apices lying substantially within the same plane.

2. A building element as claimed in claim 1 in which the dimples are pyramidal in shape.

3. A slab comprising a number of relatively thin superimposed sheets consisting of spaced outermost sheets and at least three intermediate sheets and including a center sheet, said center sheet being formed with two regular series of dimples extending in opposite directions, the other intermediate sheets being formed with only one regular series of dimples extending in one direction, all of said dimples being arranged on rectangular grids with their sides all disposed at the same slope and having truncated apices, the said sheets being disposed in juxtaposition, the apex of the dimples in each said intermediate sheet being nested with a dimple in an adjacent intermediate sheet and in contact with the apex of the dimples with which they are nested, the depth of the dimples in the sheets decreasing in amount by a factor of two from sheet to sheet away from the median plane of the slab, all of the apices on one side of the median plane of the slab lying substantially within a single plane, and all of the apices on the other side of the median plane lying substantially within another single plane.

4. The slab of claim 3, wherein the truncated apices of the dimples are all substantially of the same size.

5. The slab of claim 3 wherein the distance between the truncated apices of the dimples in each intermediate sheet is halved from sheet to sheet away from the median plane of the slab.

6. The slab of claim 3 wherein the bases of the dimples in the center sheet occupy the whole of the area of the center sheet.

7. The slab of claim 3 wherein the center sheet is formed with a dog-leg between the bases of the oppositely extending dimples.

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