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(56) Documents Cited:
**GB 1539321 A**
**GB 1033063 A**
**DE 003313813 A**
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**US 20030006092 A**
**GB 1046915 A**
**EP 0214524 A**
**DE 002829273 A**
**US 5193318 A**
**US 4244439 A**

(58) Field of Search:
INT CL **E04B, E04C, E04G**
Other: **WPI & EPODOC**

(54) Title of the Invention: **Acoustic surface and method of forming thereof**
Abstract Title: **Acoustic surface comprising structural slab with randomly positioned wells.**

(57) A profiled panel (1) has troughs and peaks along its length that provide wells (4) into which a building material such as concrete is poured to produce a structural building element that on one side has an irregular profile that provides a sound absorbing acoustic surface and a substantially flat surface on the other side of the element. The structural element or slab may comprise a building wall or a building ceiling/floor unit. The panel (1) may be removed from the slab once the concrete has hardened. Other building materials may be a concrete and resin mix or Corion (RTM). The panel (1) may be metal, plastic, timber or fibre-reinforced material and it may have a release coating to separate easily from the concrete. The wells (4) may be rectilinear and are preferably in a random or pseudo-random array. A method of making the acoustic surface is also claimed.

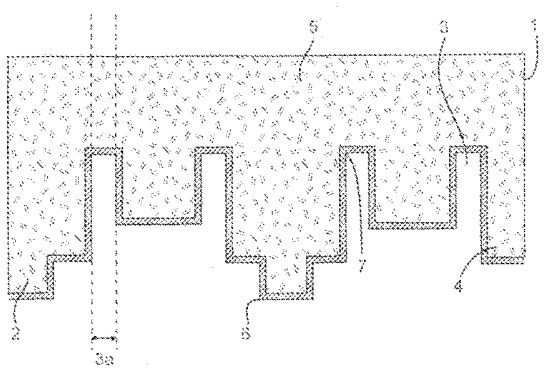


Fig. 1

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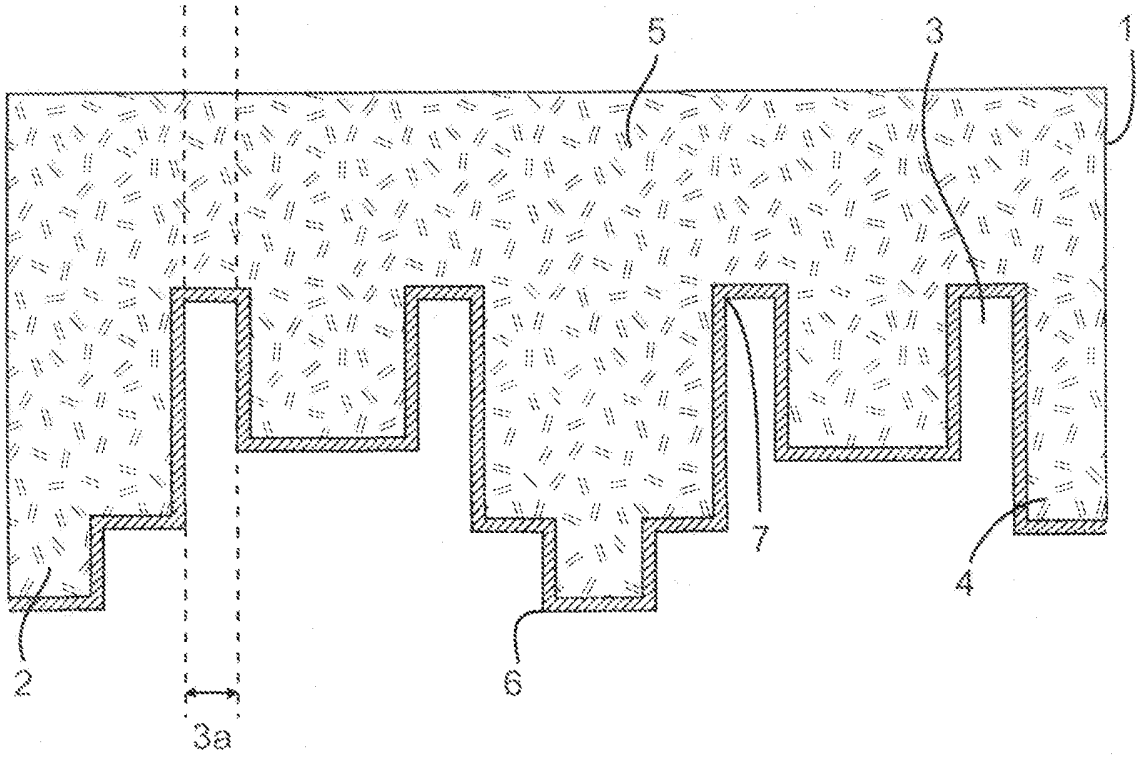


Fig. 1

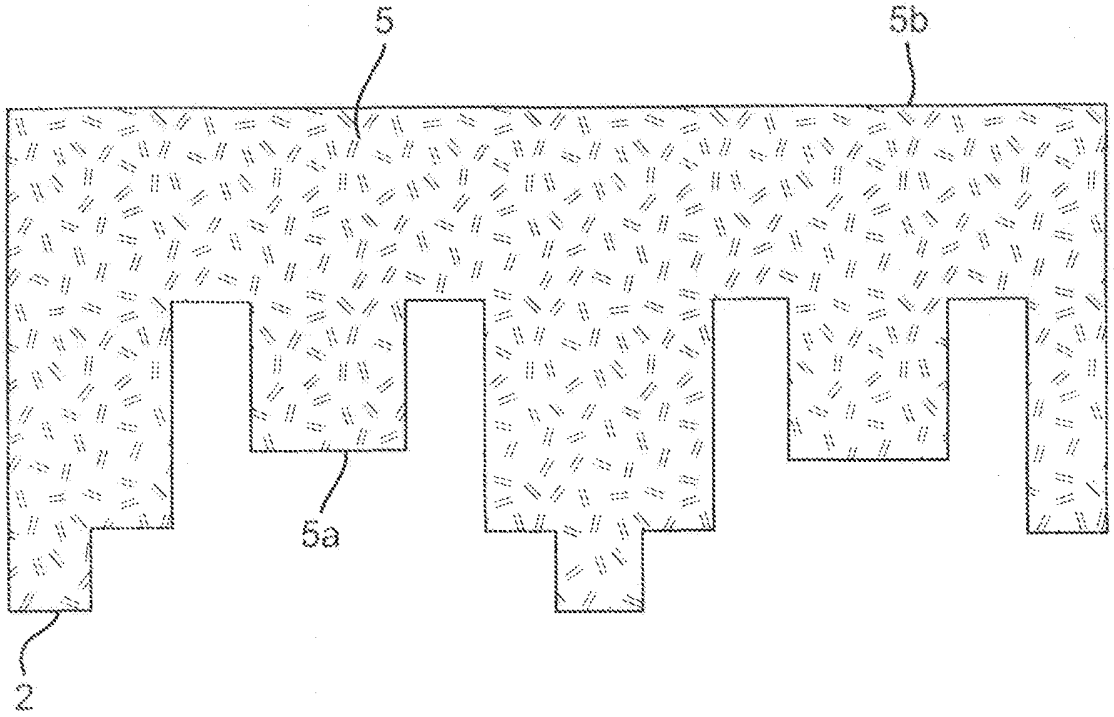


Fig. 2

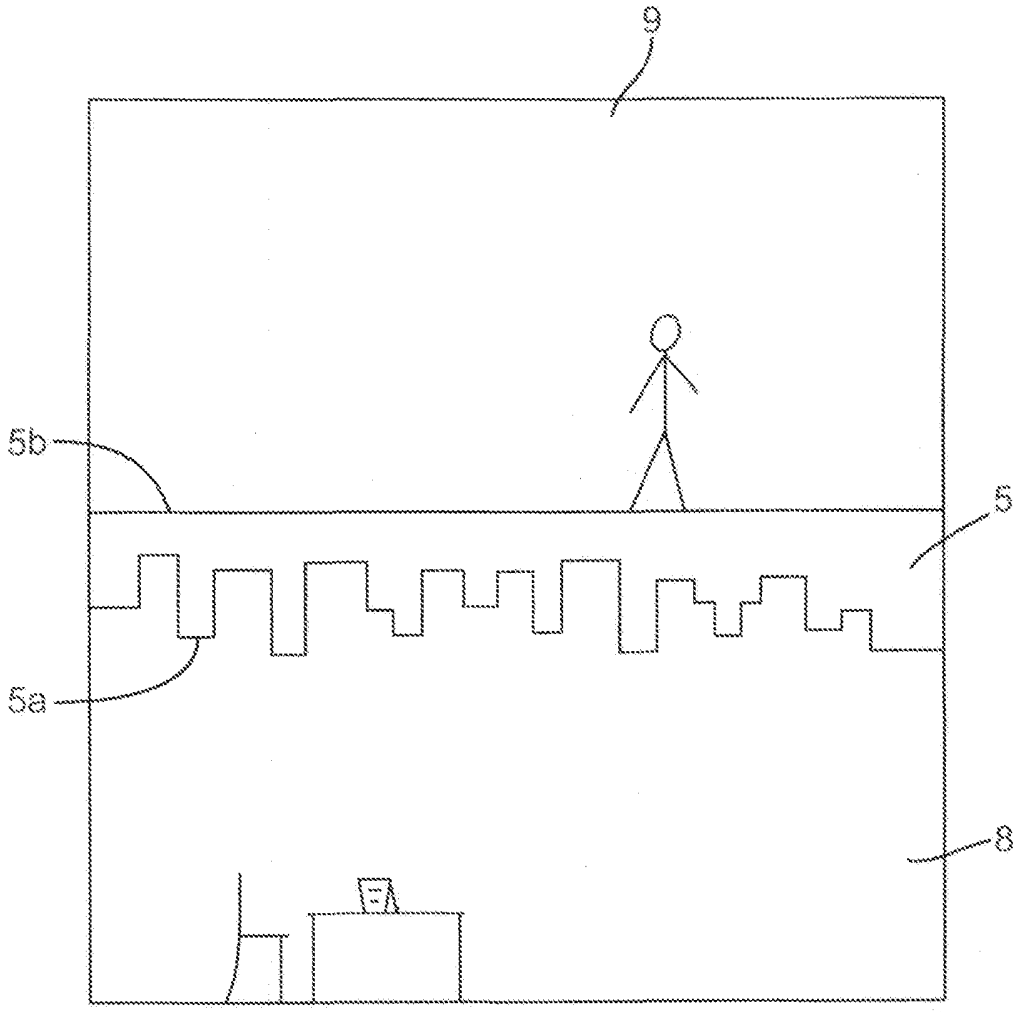


Fig. 3

## Acoustic Surface and Method of forming thereof

The present invention relates to an acoustic surface and a method of forming such a surface. In particular but not exclusively the invention relates to an acoustic surface for use in public buildings such as schools.

## Background to the Invention

Building regulations have become very stringent in respect of the minimizing of sound transmission and in the control of the environment in buildings, for example the temperature or the air quality. Control of air quality and temperature is particularly important in public buildings such as schools where there is a need to maintain an air quality that is within parameters that are set down in legislation, as well as temperature limits that again often have to be within legal limits.

Many schools or large public buildings are built using concrete frames and floors and to minimise energy usage they are often naturally ventilated, for example by opening windows. To achieve ventilation, the lower surface of the concrete is left exposed so it can act as a thermal mass which can control air temperature as air flows unimpeded from one side of a room to another. When constructing a building, concrete is poured into a preformed frame (often referred to as formwork), which support and holds the liquid concrete in position until it sets and depending on the type of building, the formwork is either removed or is allowed to stay in place as a structural component. The formwork provides a frame that forms a generally flat surface for both sides of the concrete.

A problem with having exposed concrete is that sound is very easily reflected from the concrete surface and so it is necessary to have other absorptive surfaces in the room to reduce sound reverberation. Typically sound absorptive surfaces are formed of panels positioned on walls or which may be freestanding or hanging. Also, sounds absorption can be provided by soft furnishings. However, with panels, there may be issues as to where they can be placed or if panels are free standing there may be issues in connection with how they are supported safely. In the case of soft furnishing there are issues concerning health and hygiene should they become dirty or they may also be a fire risk.

In buildings having hard surfaces such as concrete the acoustics in a building can be improved by creating a specific profile on the hard surface and an example of altering the acoustic properties of concrete is by using what is called a Schroeder Diffuser. Diffusers provide acoustic absorption to some degree as a side effect of altering the acoustics. An example of a Schroeder Diffuser is shown in US 7428948. Known Schroeder diffusers are formed of a sheet of material that is formed into a profiled member which has wells of varying depth that cause phase changes in sound impinging on the diffuser. The depth of the wells are different along the diffuser and based on existing numerical theories the depths of the wells can be selected so that waves reflected from the surface interfere with each other. The diffuser is placed over a structural component such as a concrete wall and is used to alter the acoustics in a room.

A problem associated with known prior art is that it can be time consuming in making the necessary calculations to place the diffuser in the correct position for reflecting sound. Further, the diffuser is not itself a structural component and is attached to an existing surface. Also, if the diffuser is positioned to an existing surface, there will be problems if there is no room for the diffuser to be placed in the correct position for reflecting acoustic waves. Further, diffusers cover over thermal masses provided by structural elements so there is no possibility of providing both sound absorption and temperature control using one component. In addition, with the known prior art, there is no facility for putting an acoustic panel in situ as a building structure is being placed in position or for providing a combined acoustic panel and surface that provides a thermal mass to control the temperature of a room.

It is an object of the invention to provide an acoustic surface such as an acoustic panel, which can be incorporated in a building structure easily and which forms a structural component of the building. Also the invention allows for the panel to be placed in position and with there being no need to alter the acoustic surface once the panel is in place.

**Statement of Invention**

According to a first aspect of the present invention there is provided a method of producing an acoustic surface, wherein a profiled panel having a plurality of wells of varying depth along the length of the profiled panel is placed in a substantially horizontal orientation with the wells being on an underside of the panel, building material is poured into the wells until filled and is allowed to settle and harden, the profiled panel allowing for the formation of a first side of the acoustic surface having an irregular profile that provides a sound absorbing surface, the building material having been allowed to settle also forming a substantially even surface that is remote from the irregular profile, such that when the acoustic surface is in position in a building it forms a separating element between two areas in the building so that one area of a building includes the sound absorbing surface and the second area of the building includes the substantially even surface.

Preferably the acoustic surface is a panel, that can be formed in situ in the building or which can be placed in position as a preformed unit.

The acoustic surface provides not only sound absorption but also sound diffusion.

In a preferred arrangement, the acoustic surface is placed in a substantially horizontal axis which is the final position for the partition in the building. However, it may also be placed in a vertical position, so example it is was to provide a wall. The separating element provides in effect a structural building element that has both acoustic properties and which can act as a thermal mass and which allows for different types of surfaces on the building element to be produced at the same time, one surface having the acoustic properties and the other providing an even surface.

Preferably the separating element provides a soffit for the one area of the building and floor or roof for the second area of the building. However, it is envisaged that the profiled panel may be placed on a level surface remote from where the separating element is to be placed in the building, the material is poured into the profiled panel, the building material is allowed to harden and then the panel is placed in position in the building. This allows for separating elements having an acoustic surface on one side to be formed for example offsite and then put into position.

It is desirable that the profiled panel is removed from the pre formed surface of the building material that has hardened in the wells.. It is envisaged however that in some situations the profiled panel may remain in position. An example is where the panel may have a decorative surface or if the panel is made of an intumescent material, it may provide a fire retardant surface.

Preferably the building material is concrete and more preferably it is a cast concrete which can be formed in situ. However, the building material may also be any other type of building material that can form a solid building component that can act as a wall, a soffit, a ceiling, a roof or a floor, for example a concrete and resin mix or Corion ®. In particular the building material has the properties of being able to be formed in situ and which can act as a temperature transfer mass, for example a heat sink or a heat source, when air passes over it. The ability to allow for the transfer and the absorption of air temperature assists in the regulation of the temperature and/or humidity of a room.

It is envisaged that the profiled panel (formwork) if formed of metal or alternatively a plastic or fibre glass based material. In effect any strong material that can contain the building material can be used, which would include timber or reinforced plastic or glass material.

Preferably the profiled panel also has a release coating that allows the panel to be separated from the building material. The release coating may be talc or a silicon based material which allows for separation of the profiled panel without damage to the surface of the building material. A particular advantage of the invention is the fact that it allows for a separating element, which acts as a partition between two areas in a building to be produced in situ and which does not need to be finished once the separating element/partition is in place. This is because the sound absorbing surface has been formed already as it is formed as a result of pouring a building material into the profiled panel and being allowed to harden. The substantially flat upper surface results as a consequence of settling of the building material in the profiled panel under gravity and with some agitation of the mix. Due to the fact that the building material is allowed to settle in the profiled panel it allows for relatively thin panels to be

produced and also the risk of surface blemishes is reduced because there is less of a need to agitate the building material as it is poured into what in effect is a profiled mould.

It is envisaged that the profiled panel is formed of a series of rectilinear wells of varying depth forming the irregular sound absorbing surface.

Preferably, the base of a well in the profiled panel is substantially at right angles to the walls of the well. This provides a profile having sharp edges which improves the absorption characteristics for sound waves by the acoustic surface. The absorption and/or diffusion of sound achieved is greater with squared wells but it is envisaged that in some situations curvilinear wells may be used in at least some of the wells. Further, diffusion of a range of sound frequencies is possible because of the varying well depths rather than uniform well depths.

It is envisaged that the wells are provided in a random or pseudo-random arrangement of depths. The profile of the profiled panel and ultimately the irregular surface of the acoustic surface is based on the Quadratic Residue Number Theory, which is constructed from the prime number N. The prime number N is employed to construct a Quadratic Residue Number Theory sequence based on a formula $n^2$ mod(N) where N is a selected prime number for the sequence. The formula was developed by Karl Frederick Gauss and is conventional.

Preferably the depths of the peaks and troughs that form the wells are in a ratio of 4:1, 3:1 and 2:1,

According to a second aspect of the invention there is provided an acoustic surface wherein the acoustic surface has a profiled irregular surface formed of peaks and troughs that form a sound absorbing surface on one side of the acoustic surface, and the other side of the acoustic surface remote from the peaks and troughs has a second surface provided as a substantially even surface, the acoustic surface being formed from a building material such that when the acoustic surface is in position in a building it forms a separating element that can partition two areas of a building such

that one area of a building includes the sound absorbing surface and the second area of the building includes the substantially even surface.

Preferably the acoustic panel forms a partition where the sound absorbing surface is the soffit of the one area of the building and the floor or roof of the second area of the building.

It is preferred that the building material is cast concrete.

The invention is advantageous in that it provides an acoustic surface, which can be incorporated in a building structure easily and which avoids the need for further alteration of the surface once in place. Further, the invention also has the improved technical advantage of providing an acoustic surface which can be placed in situ at the time of construction as well as providing a surface that can act as a thermal mass that can be used to control the temperature of at least part of a building.

Although the acoustic surface discussed and the method of making the surface is particularly suited to school buildings, it may be used in other types of buildings, for example in theatres, halls, concert halls, sound studios, hospitals, industrial units, leisure facilities, mixed use buildings, sports halls or even residential buildings.

**Description of the Drawings**

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings, in which:

Figure 1 shows a side view of a profiled surface and a building material poured into the peaks and troughs of the profiled surface;

Figure 2 shows a side view of an acoustic surface where the profiled panel has been removed; and

Figure 3 shows a schematic side view of an acoustic surface which forms a soffit/floor partition between two floors of a building.

**Description of Preferred Embodiments**

Referring firstly to Figure 1, a profiled panel is shown generally as 1. The panel, when viewed side on has formations that provide 2 and peaks 3 along its length. The peaks and troughs provide wells 4 in the panel. The peaks and troughs are in a random or pseudo-random array and have depths based on design frequency. The surface of the panel is divided into relatively small sections with different reflective changes. A section is where there is a recess in the profile of the panel shown as 3a. If viewed from the side a recess is bounded by a trough 2 and in effect the recess is provided by a peak 3 in the profiled panel. The troughs and peaks of the profiled panel are rectilinear in shape and the troughs of the panel have corners 6 on the outside surface of the trough and the peaks of the panel, forming the recesses 3a have corners 7 on the inside of a recess. A building material 5 is introduced into the profiled panel with the result that the building material is provided with a two surface, a profiled surface 5a and a flat surface 5b (shown in Figure 2). The building material in effect settles in wells 4 of the panel.

Figure 2 shows an acoustic surface 5 where the profiled panel 1 has been removed. The building material is formed into a building element having an irregular surface 5a which is formed of peaks and troughs in the surface. On the other side of the acoustic panel, remote from the peaks and troughs is a substantially flat surface 5b. The irregular surface can act as a sound absorbing surface, (which also acts as an acoustic diffuser which diffuses sound), while the substantially flat surface can form a floor in a building. The acoustic panel and the way it is constructed allows for the production of a sound absorbing surface and a floor or wall at the same time during construction of a building.

Sound waves are reflected by each section with a different amplitude and phase. The sound pressure distanced from the panel is obtained by the summation over all contributions according to the following formula:

$$P(\Theta) \propto \sum_n \left| Rn \right| e^{(Xn - nkd\sin\Theta)]}$$

If all sections had the same reflective value, and all contributions have the same phase angle, the contributions from all elements would combine to a high pressure amplitude. This is the case for a hard flat concrete surface such as a soffit. By randomising the phase angle values for adjacent elements there is disruption of the phase angle and better scatter of the sound waves. To achieve a large amount of scatter would involve using a large number of different elements which would make construction of a modern building element difficult. Therefore to overcome this difficulty a pseudo random sequence of phase angles is formed for neighbouring elements. A uniform reflected energy over all diffraction orders can be achieved by a suitable function for Xn. One such sequence that fulfils a flat power spectrum in which a uniform distribution of reflected energy over all diffraction orders is based on the Quadratic Residue Equation such that:

$$Xn = (2\pi)( n^2 \mathrm{mod}(N))/N$$

Where n is the well number index and N is a selected prime number. Selection of N is based on the ratio of the upper design frequency to the lower design frequency. In Figure 2, N is 7.

Figure 3 shows an acoustic surface 5 which is in position in a two storey building formed of a ground floor room 8 and an upper room 9. The acoustic panel 5 forms a separating element that partitions the two rooms with the profiled surface of the acoustic panel 5 providing a sound absorbing/diffusing surface as the soffit or part of the ceiling of room 8. Then substantially flat/even surface of the panel 5b provides the floor of room 8.

The fact that the contoured irregular surface and the flat surface are formed at the same time in one process allows for the production of a structural building element that has both acoustic properties and which can act as a thermal mass that can be used to control the environment in a room that is separated by the acoustic panel.

The present invention provides a thermally massive construction which can be used to help regulate the internal temperature of a building without, subject to orientation, impeding airflow in naturally ventilated buildings. In addition, the panel has the advantage of diffusing reflected sound, it reduces the acoustic intensity of sound and hence echo, which is particularly useful in buildings where acoustics are critical. Also standing waves and flutter echo which produce sound distortions are minimized. Further better diffusion of sound waves results in shorter reverberation times, more accurate modelling of sound and also there is the added benefit that dimensionally similar rooms can be designed to have a similar acoustic response and feel, so negating the need to provide additional acoustic treatment of rooms. Further the invention avoids the need for additional work to form the panel into an acoustic shape as the acoustic characteristics of the panel are provided as it is formed. The panel can however, be added to a flat surface as a retrofit component but again the panel has the advantage of being both a structural element as well as providing an acoustic panel. Also, the way that the panel is produced (using a single step) means that the risk of surface blemishes that could affect the acoustic properties of the panel being minimized as the building material is poured into the profile panel. In addition, the panel can be used in single or double span floors and multi-storey buildings.

The invention is envisaged as covering all combinations of the features as described and aspects and embodiments discussed. It will be apparent that modifications and variations of the invention can be made without departing from the scope of the invention as described.

## CLAIMS

1. A method of producing an acoustic surface, wherein a profiled panel having a plurality of wells of varying depth along the length of the profiled panel is placed in a substantially horizontal orientation with the wells being on an underside of the panel, building material is poured into the wells until filled and is allowed to settle and harden, the profiled panel allowing for the formation of a first side of the acoustic surface having an irregular profile that provides a sound absorbing surface, the building material having been allowed to settle also forming a substantially even surface that is remote from the irregular surface, such that when the acoustic surface is in position in a building it forms a separating element between two areas in the building so that one area of a building includes the sound absorbing surface and the second area of the building includes the substantially even surface.

2. A method according to claim 1 wherein the acoustic surface is placed in a substantially horizontal axis when in a final position for the partition in the building.

3. A method according to claim 1 or claim 2, wherein the acoustic surface is placed in a substantially vertical axis when in a final position in the building.

4. A method according to any preceding claim, wherein the separating element provides a soffit for the one area of the building and floor for the second area of the building.

5. A method according to any preceding claim wherein the profiled panel is removed from surface of the building material that has hardened in the wells of the profiled panel.

6. A method according to any preceding claim wherein the building material is selected from one or more of the following, concrete, concrete and resin mix or Corion ®.

7. A method according to any preceding claims wherein the profiled panel if formed of metal, plastic, timber or fibre reinforced material.

8. A method according to claim 5 wherein the profiled panel also has a release coating that allows the panel to be separated from the building material.

9. A method according to any preceding claim wherein the profiled panel is formed of a series of rectilinear wells forming the sound absorbing surface.

10. A method according to claim 9 wherein the base of a well in the profiled surface is substantially at right angles to the walls of the well.

11. A method according to any preceding claim, wherein the wells are provided in a random or pseudo-random arrangement of depths.

12. A method according to claim 11, wherein the wells are formed of peaks and troughs in the profiled panel the depth of which are in a ratio of 4:1, 3:1 and 2:1.

13. An acoustic surface formed by a method according to any preceding claims.

14. An acoustic surface having a profiled surface formed of peaks and troughs to provide an irregular sound absorbing surface on one side of the acoustic surface, and the other side of the acoustic surface remote from the peaks and troughs having a second surface provided as a substantially even surface, the acoustic surface being formed from a

building material such that when the acoustic surface is in position in a building it forms a separating element that can separate two areas of a building such that one area of a building includes the irregular sound absorbing surface and the second area of the building includes the substantially even surface.

15. An acoustic surface according to claim 12, forming a separating element where the sound absorbing surface is a soffit of the one area of the building and the floor of the second area of the building.

16. An acoustic surface according to claim 13, wherein the building material is concrete.

17. An acoustic surface according to any of claims 12 to 14 which is both a sound absorbing surface and a structural building component.

18. An acoustic surface according to claim 15, wherein the structural building component is a heat transfer mass that can be used to regulate the temperature of a room.

19. An acoustic surface according to any of claim 13 to 18 arranged to diffuse sound as well as absorb sound.

20. A method of producing an acoustic surface substantially as described herein with reference to and as illustrated in the accompanying diagrams.

21. An acoustic surface substantially as described herein with reference to and as illustrated in the accompanying diagrams.

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| **Application No:** | GB0920807.5 | **Examiner:** | Dr Hazel Thorpe |
| **Claims searched:** | 1-13 | **Date of search:** | 25 February 2010 |

## Patents Act 1977: Search Report under Section 17

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance |
|---|---|---|
| X | 1,3, 6, 9-13 | US 4244439 A (ELEKTRONIKCENTR), see figures 1-10 & col.7, ll.1-42 in addition to WPI abstract accession no. 1979-C4741B [12]. |
| X | 13 | US 5027920 A (RPG DIFFUSOR SYST); figures 1-18 & abstract. |
| X | 13 | JP 58071134 A (KOBAYASHI BLOCK), figures 1-6, WPI abstract accession no. 1983-54760K [23]. |
| X | 13 | DE 2829273 A (BASALT AG), figures 1, 2, & WPI abstract accession no. 1980-A9911C [05]. |
| X | 13 | GB 1539321 A IRBIT HOLDING AG), figures 1-3 & WPI abstract accession no. 1977-J1404Y [40]. |
| X | 13 | DE 3313813 A (GRAF H BAUUNTERNEHM), figure 4 especially, & WPI abstract accession no. 1984-270451 [44]. |

Categories:

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|---|---|---|---|
| X | Document indicating lack of novelty or inventive step | A | Document indicating technological background and/or state of the art. |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC$^{X}$ :

Worldwide search of patent documents classified in the following areas of the IPC

E04B; E04C; E04G

The following online and other databases have been used in the preparation of this search report

WPI & EPODOC

**International Classification:**

| Subclass | Subgroup | Valid From |
|---|---|---|
| None | | |

**Application No:** GB0920807.5 **Examiner:** Dr Hazel Thorpe

**Claims searched:** 14-19 **Date of search:** 24 June 2010

# Patents Act 1977
# Further Search Report under Section 17

**Documents considered to be relevant:**

| Category | Relevant to claims | Identity of document and passage or figure of particular relevance |
|---|---|---|
| X | 14-17 | GB1033063 A (ENDER); see whole document. |
| X | 14-17 | GB1046915 A (INTERNATIONELLA SIPOREX) see whole document, especially pg.1, col.1. |
| X | 14, 16-18 | EP0214524 A (NUDLING) see figure 1 & 3, & WPI abstract accession no. 1987-065718 [10]. |
| X | 14,16,17, 19 | US5193318 A (D'ANTONIO) see whole document. |
| X | 14,19 | US2003/006092 A (D'ANTONIO), see whole document. |
| X | 14,16,17 | JP 58071134 A (KOBAYASHI BLOCK KOG), see all figures & WPI abstract accession no. 1983-54760K [23]. |
| X | 14,16,17 | DE 3313813 A (GRAF H BAUUNTERNEHM), see all figures and WPI abstract accession no. 1984-270451 [44]. |
| X | 14,16,17 | DE 2829273 A (BASALT-AG), see all figures & WPI abstract accession no. 1980-A9911C [05]. |

Categories:

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|---|---|---|---|
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| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. | P | Document published on or after the declared priority date but before the filing date of this invention. |
| & | Member of the same patent family | E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

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Worldwide search of patent documents classified in the following areas of the IPC

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| E04B; E04C; E04G |

The following online and other databases have been used in the preparation of this search report

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| WPI & EPODOC |

**International Classification:**

| Subclass | Subgroup | Valid From |
|---|---|---|
| E04B | 0001/86 | 01/01/2006 |
| E04C | 0002/288 | 01/01/2006 |