Title of the Invention: Composite panel assemblies
Abstract Title: Latent heat storage panel

The present invention provides an encasement panel having an interior region, in which the interior region includes a phase change material in an organic or inorganic form encapsulated in a binder, such as a cement binder, and provided in a layer. The interior region further includes a honeycomb structure of heat transfer material including a number of cells partitioned by partition walls and extending across the interior region, and wherein the latent heat storage material is disposed in the cells. The shape of a section of the cell can be a polygonal shape. The polygonal shape can be a square shape, a rectangular shape, a triangular shape, or a hexagonal shape or alternatively ribbed, ribbed or finned walls. The partition walls can comprise a metal or plastic. The metal can be aluminium, stainless steel, mild steel or copper. The plastic can be glass-reinforced plastic (known as fibreglass), carbon fibre reinforced plastic. Nomex reinforced plastic, and Kevlar reinforced plastic. The panel can be regular, for use in a ceiling grid.
(74) Agent and/or Address for Service:
Pure Ideas Limited
20 Mandeville Road, HERTFORD, Hertfordshire,
SG13 8JG, United Kingdom
LAYOUT OF TEST CELL AND THERMOCOUPLE POSITIONS

**Diagram 1**  
Wall 1 (Outside)

**Diagram 2**  
Wall 2 (Outside)
Composite Panel Assemblies

Field of Invention

The present invention relates to composite panel assemblies. It is particularly applicable, but in no way limited, to composite panel assemblies containing latent heat storage material.

In one embodiment the invention relates to an encasement incorporating a polygonal cell structure having an interior region that is filled with an infill material comprising a bi-product from industrial or agricultural waste that is generally disposed of by burying in landfill sites, and an organic or inorganic phase change material. The encasements may be used as ceiling tiles, chilled ceiling systems, wall panels, computer room floor tiles, raised access floor panels, curtain walling sections, suspended ceiling sections, sleeving for heating and ventilation pipe work or ducting, walls, floor and ceiling panels for telecommunication and data rooms, furniture and workstations.

Background of the Invention

A composite honeycomb is a material used as a core material in sandwich structured composite structures. The material takes its name from its visual resemblance to a bee's honeycomb - a hexagonal sheet structure. A wide variety of materials can be formed into a honeycomb composite.

Composite honeycombs may be constructed from a variety of materials such as a metal, usually aluminium, mild steel, stainless steel or copper, or from a composite material such as glass-reinforced plastic (also known as fibreglass), carbon fibre reinforced plastic, Nomex (RTM) or reinforced plastic, Kevlar (RTM) reinforced plastic. These lists are not intended to be exhaustive but simply illustrate the wide range of materials that may be used in the present invention. The choice of materials will be made by a materials specialist.

Phase change materials and compositions are well known. These are materials which reversibly undergo a change of state and act as a sink for thermal energy, absorbing or releasing heat as necessary. For example, they can be used to regulate temperatures within a desired range, or provide a degree of protection against extremes of heat or cold.
Thus, Phase Change Material (PCM) is a latent heat storer, which makes it possible to combine the advantages of modern architecture and the efficiency of lightweight construction with the use and compensating effect of thermal storage capacity for a pleasant indoor climate.

Phase Change Materials present a durable and efficient possibility for isothermal storage of the peak loads, which usually occur during the day, in a defined temperature range, and releasing these again with a time delay (e.g. in the evening time or at night). Integrated into various kinds of building materials and building systems, Phase Change Materials contribute to an improved indoor climate, more comfortable living conditions and better energy efficiency, using intelligent temperature management.

There are three main categories of Phase Change Materials; Organic, Inorganic and Eutectics;

Organic PCMs

Latent heat accumulator materials are by definition substances which have a phase change transition in the temperature range in which heat transfer is to be carried out. The latent heat accumulator materials preferably have a solid/liquid phase transition in the temperature range from –20 to 120°C.

As a rule, the latent heat accumulator material is an organic preferably lipophilic substance.

The following may be mentioned by way of example only as suitable substances:
Aliphatic hydrocarbon compounds such as saturated or unsaturated C10-C40-hydrocarbons, which are branched or preferably linear, for example such as n-tetradecane, n-pentadecane, n-hexadecane, n-heptadecane, n-octadecane, n-nonadecane, n-eicosane, n-heneicosane, n-docosane, n-tricosane, n-tetracosane, n-pentacosane, n-hexacosane, n-heptacosane or n-octacosane, and cyclic hydrocarbons, e.g. cyclohexane, cyclooctane or cyclodecane, paraffin \((C_nH_{2n+2})\);
Aromatic hydrocarbon compounds, such as benzene, naphthalene, biphenyl, ortho, meta or para-terphenyls, polychlorinated terphenyls, C1-C40-alkyl-substituted aromatic hydrocarbon such as dodecylbenzene, tetradecylbenzene, hexadecylbenzene, hexynaphthalene or decynaphthalene;

Saturated or unsaturated C6-C30-fatty acids, including fatty acids having the formula \( \text{CH}_3(\text{CH}_2)_n\text{COOH} \), such as lauric, stearic, oleic or behenic acid, preferably eutectic mixtures of decanoic acid with, for example, myristic, palmitic or lauric acid;

Fatty alcohols, such as lauryl, stearyl, oleyl, myristyl or cetyl alcohol, mixtures such as coconut fatty alcohol and so-called oxo alcohols which are obtained by hydroformylation of \( \alpha \)-olefins and further reactions;

C6-C30-fatty amines, such as decylamine, dodecylamine, tetradecylamine or hexadecylamine;

Esters, such as C1-C10-alkyl esters of fatty acids, such as propyl palmitate, menthyl stearate or menthyl palmitate, and their eutectic mixtures, or methyl cinnamate;

Natural and synthetic waxes, such as montanic acid waxes, montanic ester waxes, carnauba wax, polyethylene wax, oxidized waxes, polyvinyl ether wax, ethylene/vinyl acetate wax or hard waxes obtained by the Fischer-Tropsch process;

Halogenated hydrocarbons, such as chlorparaffin, bromooctadecane, bromopentadecane, bromononadecane, bromoeicosane or bromodocosane.

Inorganic PCMs

These consist mainly of chemicals such as hydroxides or oxides, which have been diluted in an acid solution and are termed as salt hydrates or molten salt. The advantages that salt hydrates offer are; low cost in comparison to organic PCMs, they have a high latent heat per unit mass and volume, they possess a high thermal conductivity compared to organic compounds and offer a wide range of melting points from 7-117°C. However, they can also suffer from loss of water when subjected to long-term thermal cycling due to vapour pressure, although the use of airtight containerisation can prevent this.
Examples of inorganic phase change materials include:
calcium chloride hexahydrate (CaCl₂·6H₂O), sodium sulfate decahydrate – Glauber’s
salt (Na₂SO₄·10H₂O), sodium carbonate decahydrate (Na₂CO₃·10H₂O), and other
salt hydrates (MₙH₂O).

Eutectic PCMs

A eutectic PCM is a combination of two or more compounds of either organic, or
inorganic nature or both, which combination may have a more interesting melting
point compared to their individual and separate compounds. They behave
themselves as salt hydrates. The main problem with these compounds is the cost,
which is typically some two or three times greater than organic or inorganic PCMs.

Examples of Eutectic phase change materials include:
Palmitic acid (organic), Mistric acid (inorganic), Stearic acid (organic); Organic-
organic, organic-inorganic, inorganic-inorganic compounds.

These lists are not intended to be exhaustive but simply illustrate the wide range of
materials that may be used in the present invention. The choice of materials will be
made by a materials specialist.

Paraffin wax and similar organic compounds have been used as phase change
materials for building applications (such as in wallboards, sheetrock, drywall,
plasterboard, and fibreboard for absorbing or releasing heat energy into or from a
room environment). However products commercially available have a low content of
phase change material and therefore low heat storage capacity. By incorporating the
phase change material into a composite assembly, such as an encasement, allows
for a higher concentration of phase change material to be incorporated giving a
higher heat storage capacity. The use of a metal encasement and honeycomb core
for example, particularly whereby the encasement and/or honeycomb core is made
of aluminium, copper, mild or stainless steel, improves the heat conductivity as the
thermal conductivity of aluminium is 237W/(m·K), copper 401W/(m·K) and steel
between 45-65W/(m·K). This has been proven through thermal chamber testing
using a panel containing a high PCM content, which had better thermal conductivity
than other tiles that were tested in comparison and as detailed in Table 10. ‘Comparison of Aluminium Honeycomb Tile with latent heat storage material’.
Pozzolanas

Pozzolanas are materials containing reactive silica and/or alumina, which on their own have little or no binding properties. When mixed with calcium Oxide (CaO) or lime as it is more commonly known, and with water, they will set and harden into a cement. These cements are referred to collectively as pozzolan cement which is used, amongst other things, as a mineral admixture with Ordinary Portland Cement (OPC) to significantly enhance the performance characteristics of cement based concretes, mortars, screeds and related products.

A wide variety of siliceous or aluminous materials may be pozzolanic, including Pulverized Fuel Ash (PFA), Rice Husk Ash (RHA) and a Metakaolin.

Rice Husk Ash (RHA) has been identified as having the greatest potential of the agricultural wastes as it is widely available.

Pulverized Fuel Ash (PFA)

Pulverized Fuel Ash (PFA), which is often referred to as Fly Ash, has probably the greatest potential of the industrial wastes due to its widespread availability and its high alumina content. There are two types of PFA, depending upon the type of coal used. These are high lime and low lime, with the former having a lime content above 10% and therefore possessing some cementing properties on its own. Low lime PFA has a lime content below 10%. Both types of PFA can be used as a pozzolana.

PFA is available, in large quantities, in countries or regions using coal fired electricity generating stations. These include most of Europe, North America, the Indian sub-continent, China and Southern Africa.

The chemical composition of PFA will depend upon the type of coal used and can vary considerably, as can pozzolanic reactivity. Acceptable limits of composition, derived from various national standards are:

- The percentage of the main oxides, $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$, should not fall below 70%;
• The SO$_3$ content should not exceed 5% (Some standards specify 2.5%);
• The MgO content should not exceed 5%;
• The loss on ignition should not exceed 12% (Some standards give a 5 or 6% limit).

In addition some standards specify that the alkali metal (Na$_2$O) content should not exceed 1.5% although this is only relevant if it is used with reactive aggregate.

Physically, PFA is a fine (less than 75 micron) powder, with a rounded particle shape and a colouring ranging from cream to dark grey. Its loose bulk density is approximately 800Kg/m$^3$, which is roughly two-thirds that of Ordinary Portland Cement (OPC). As with all pozzolanas, fineness is critical to the performance of PFA, with finer pozzolanas giving faster pozzolanic reactions. Electrostatically collected PFA will be finer than PFA collected mechanically and is therefore normally preferred as a pozzolana. The Blaine method of measuring fineness is felt to be unreliable for PFA and the simpler sieving technique is often better. Standards give a maximum to be retained on a 45 micron sieve of 12.5 to 50% depending upon the country of origin.

PFA is not normally ground to produce a finer material as this will break up the rounded particle shape which is important for its water reduction and increased workability properties.

Unlike most other pozzolanas, PFA requires no processing before use. It is normally transported in bulk to the cement factory or construction site where it is blended with OPC and/or lime to form a pozzolanic cement.

Pozzolanas can be used in combination with Calcium Oxide (CaO) and phase change materials (PCM). They can also be blended with ordinary Portland cement and various fillers to improve the thermal properties of lime based mortar concrete and renders, for use in a wide range of building applications.
Pulverized Fuel Ash (PFA) is commercially available from the majority of coal-fired power stations around the world and in the UK, from E.ON UK and Scot Ash. Calcium Oxide (CaO) or lime as it is also known, and is commercially available from companies such as Singleton Birch Ltd.

Typical percentage compositions of PFA include:

<table>
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<tr>
<th>Origin</th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>Alkalis</th>
<th>SO₃</th>
<th>LOI</th>
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<td>12.3</td>
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<td>19.2</td>
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<td>23.7</td>
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<td>2.6</td>
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<td>-</td>
<td>0.03</td>
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</tbody>
</table>

Rice Husk Ash (RHA)

Rice Husk Ash (RHA) is a carbon neutral green product available worldwide. Traditionally, rice husk has been considered a waste material and has generally been disposed of by dumping or burning. Nevertheless, Rice Husk Ash (RHA) has been successfully used as a pozzolana in commercial production. There is a growing demand for fine amorphous silica in the production of cement and concrete mixes. This market is currently filled by silica fume or microsilica.

Other uses of Rice Husk Ash (RHA) include green concrete, high performance concrete and flame-retardants.

Rice Husk Ash is commercially available from companies such as Mid-Link International Co. Ltd, Germany

Metakaolin

Metakaolin is a dehydroxylated form of the clay mineral kaolinite. Rocks that are rich in kaolinite are known as china clay or kaolin, which is traditionally used in the manufacture of porcelain. Kaolin is a white soft plastic clay composed of well-ordered kaolinite with a low iron content.

Chemical Name: Anhydrous aluminum silicate

Chemical Formula: \(2\text{H}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 2\text{SiO}_2\) or \(\text{H}_2\text{Al}_2\text{Si}_2\text{O}_9\)

The meta prefix in the term is used to denote change. In the case of metakaolin, the change that is taking place is dehydroxylation, brought on by the application of heat over a defined period of time. Beyond the temperature of dehydroxylation, kaolinite
retains two-dimensional order in the crystal structure and the product is termed metakaolin. The introduction of High Reactivity Metakaolin to the High Strength Concrete market has provided an alternative to the use of silica fume. Equivalence in strength development and durability properties along with several additional features of High Reactive Metakaolin including colour and workability have effectively expanded the design boundaries of High performance concrete materials.

The particle size of Metakaolin is smaller than cement particles but not as fine as silica fume. It is commonly used as a high performance, high strength, lightweight concrete that is perfect for precast and mould poured products, mortars and stuccos.

Kaolin powder is commercially available worldwide and from companies such as Imerys Performance Minerals, Cornwall, UK.

Magnesium Oxide Cement

Magnesium oxide cement with organic PCM or eutectic PCM formed using organic PCM, gives enhanced fire-retardant properties to the latent heat storage material and improved strength performance as a binder. One process for making a latent heat storage material comprising magnesia cement and a phase change material, involves the steps of: (a) dissolving magnesium chloride in water to form a solution having a Baumé value of 26° or less; (b) adding magnesium oxide to the magnesium chloride solution; (c) adding a phase change material to the mixture of magnesium chloride and magnesium oxide. Other processes may also be used.

Summary of the invention

According to a first aspect of the present invention there is provided a composite panel assembly containing a latent heat storage material, said composite panel assembly comprising:-

(i) a panel front having a first face and an opposing second face, said panel front comprising a thermally conductive material;

(ii) a latent heat storage material layer comprising a phase change material;
(iii) a plurality of support elements;

wherein the support elements are embedded in the latent heat storage material layer to provide structural support to that layer. These support elements provide strength and rigidity to the latent heat storage material layer, which otherwise may not have the necessary strength during transportation, installation and other handling procedures.

Preferably the plurality of support elements segregate part or all of the latent heat storage material layer into discrete sections. This reduces the tendency of the latent heat storage material layer to distort over time. Such distortion would result in a panel changing shape. Such shape changes are particularly noticeable in the case of ceiling tiles, which are highly visible.

Preferably the plurality of support elements extend from the opposing second face of the front panel into and substantially through the latent heat storage material layer.

In a particularly preferred embodiment some or all of the support elements are formed from a thermally conductive material and are thus adapted to convey heat between the panel front and the latent heat storage material layer. By incorporating support elements which are also thermally conductive and that extend substantially through the latent heat storage material layer means that heat may be transported more rapidly into and out of the body of the latent heat storage material, making more effective use of the phase change material. The support elements then become heat conduction elements.

Preferably the plurality of support elements comprise structures selected from the group comprising:-
honeycomb structures; polygonal structures formed from regular or irregular polygons; fins; ribs; ribbons; crenulations; mesh; protrusions; and combinations thereof.

It is particularly preferred that these structures are also heat conducting in which case these features all result in rapid heat exchange between the latent heat storage material layer, the front/outside of the composite panel assembly and the environment.
In an alternative preferred embodiment the latent heat storage material layer further comprises a heat conducting matrix material. By introducing heat conducting material into the latent heat storage material layer this increases the heat transfer to and from the phase change material. This can be used in conjunction with or instead of heat conduction elements.

Preferably the heat conducting matrix material comprise a matrix selected from the group comprising:-

- graphite;
- a metal including a powdered metal or metal fragments or strips;
- expanded metal foam;
- heat conducting plastics;
- carbon fibre; and combinations thereof.

Preferably the latent heat storage material further comprises a binder. A binder retains the phase change material within the body of the assembly and also retains it in close structural and thermal contact with the heat conduction elements.

Preferably the binder is selected from the group comprising:-

- an Ordinary Portland Cement (OPC); a magnesia cement; a pozzolan cement; a magnesium chloride binder; a copolymer binder; and mixtures thereof.

This group is not intended to be limiting and is not intended to be exhaustive. Rather it illustrates that a large range of binders find application in the present invention. Any suitable binder, known or yet to be discovered, as determined by the materials expert can be used.

Preferably the phase change material comprises up to 99% by weight of the latent heat storage material, and preferably 30% - 95% by weight of the latent heat storage material. It will be appreciated that the greater the proportion of phase change material within the panel, the greater the heat storage capacity.

In a particularly preferred embodiment the heat storage capacity of the panel is in the range 300 – 3500 kJ/m², based on a 20 mm thick panel.
Preferably the panel front further comprises one or more panel edges, said panel edges depending from the first face of the panel front or from the opposing second face of the panel front, and preferably the panel assembly further comprises a second panel element or a lid, the panel front, panel edges and lid, forming an encasement. By creating an encasement of this type, the latent heat storage material is substantially contained within a structure, and the structure is preferably fire resistant or fire retardant. Alternatively, the edges may be attached to the lid.

Preferably the lid is bonded to or otherwise attached to the panel front and/or panel edges, and/or the lid is bonded to the latent heat storage material layer.

Preferably the panel assembly further comprises a square or regular edge, enabling the panel to sit on or below a ceiling grid.

Preferably the panel assembly comprises a structure selected from the group comprising:-

- a ceiling tile, including an acoustic ceiling tile; a floor tile; a raised access/computer floor tile; a chilled ceiling panel; a wall panel; a panel e.g. for use in heat exchange systems; a desk surface; a work surface; a sleeve e.g. for heating and ventilation pipes; an encasement.

Preferably the panel assembly further comprises one or more tubes adapted to carry a cooling or heating fluid, wherein the tube(s) pass through the latent heat storage material layer.

Preferably the panel assembly further comprises an insulating layer and preferably the insulating layer is located on the side of the latent heat material layer furthest from the panel front.

Importantly, panel assemblies according to the present invention can be formed from existing tiles or encasements by incorporating a latent heat storage material together with a plurality of heat conduction elements. Thus, an existing ceiling or floor tile, or other suitable encasement, can be converted into a composite panel assembly according to the present invention by way of a retro-fit operation. If
desired an insert of the correct size, shape and thickness, consisting of latent heat storage material cast around a plurality of heat conduction elements, may be pre-formed and inserted into an existing tile or encasement. Such inserts can be cemented into the tile for added security and improved heat transfer.

According to a second aspect of the present invention there is provided a process for the manufacture of a composite panel assembly comprising the steps of:-
(a) providing a first panel element and a plurality of support elements;
(b) providing a phase change material in a binder in an unset form;
(c) locating the plurality of support elements adjacent to the first panel element;
(d) substantially surrounding the support elements with the phase change material and allowing it to set;
(e) optionally providing and fitting a second panel element over the phase change material/support elements combination and optionally securing the second panel element to the first panel element.

According to a third aspect of the present invention there is provided a process for the manufacture of a composite panel assembly comprising the steps of:-
(a) providing a first panel element and a plurality of support elements;
(b) securing the support elements to one face of the first panel element;
(c) providing a second panel element with upstanding edges which, in combination, form a shallow tray;
(d) substantially filling the tray with a phase change material in a binder in unset form;
(e) placing the first panel element over the second panel element such that the support elements become embedded in the phase change material.

According to a fourth aspect of the present invention there is provided a process for manufacturing a composite panel assembly comprising the steps of:-
(a) providing a tile comprising a tray element and, optionally, a back or lid element;
(b) providing a plurality of support elements with a latent heat storage material precast around the support elements in a size and shape that will fit into said tray element;
(c) placing a binder cement layer into the bottom of said tray element;
(d) placing the precast element from step (b) into the tray element and optionally fitting the back or lid element.
The present invention also extends to cover the latent heat storage materials described herein, their methods of manufacture, and to the methods of manufacture of composite panel assemblies. Also encompassed within the present invention are methods of improving the environmental performance of a space using composite panel assemblies.

**Brief Description of Drawings**

The present invention will now be described, by way of example only, with reference to the accompanying drawing in which:

Figure 1 shows a composite panel assembly in the form of an encasement for a ceiling tile, with the lid removed and part of the edge of the encasement not shown for clarity purposes;

Figure 2 shows details of the honeycomb structure of the encasement shown in Figure 1; of the present invention;

Figure 2a shows details of ribbed, ribboned and finned wall sections of the heat conducting elements used in encasements of the present invention;

Figure 3 shows an encasement of the present invention for a ceiling tile encasement having a square mesh honeycomb;

Figure 4 shows an encasement of the present invention for a ceiling tile encasement having a tegular edge.

Figure 5 shows a further encasement of the present invention for an infill for ceiling tile encasement having a tegular edge;

Figures 6 and 6A show front and rear views of an encasement according to the present invention for a wall or a ceiling panel;

Figure 7 shows perspective and side views of an encasement of the present invention for a raised access floor tile;

Figure 8 shows close up and perspective views of an encasement of the present invention for a worktop or desk;

Figures 9a-c show an encasement of the present invention for a cooling tile; and

Figure 9d shows a cooling circuit for use with the encasement of Figures 9a-c;
Figure 10 illustrates graphically the change in surface temperature over time of a conventional metal ceiling tile and a tile according to the present invention in a thermal test chamber experiment. Together with a graph showing the power usage over time of the air conditioning unit under those test conditions;

Figures 11 to 15 inclusive illustrate perspective and outside elevations respectively of a test cell;

Figure 16 illustrates a cross-section of the ceiling of the test cell illustrated in Figures 11 to 15

Description of the preferred embodiments

Preferred embodiments will now be described, by way of example only. These embodiments represent the best ways known to be applicant of putting the invention into practice, but they are not the only ways in which this can be done. Embodiments of the present invention and their technical advantages may be better understood by referring to the following disclosure.

From the foregoing, it may be appreciated that a need has arisen for products that allow for a reduction in the consumption of energy derived from fossil fuels, and which can be manufactured in a way that has a low impact on the environment. Phase change materials work by absorbing heat from a room where the temperature exceeds a comfortable working environment. The heat is stored as latent heat and thermal mass, and is released as the temperature of the building falls. This is a continuous cycle involving no mechanical intervention.

According to various, but not necessarily all, embodiments of the invention there is provided a composite panel assembly in the form of an encasement having an interior region, in which the interior region includes a latent heat storage material encapsulated in a pozzolana cement binder and where the interior region further includes a honeycomb structure including a number of cells partitioned by partition walls and extending substantially across the interior region, and wherein the latent heat storage material is disposed within the cells. The shape of a section of the cell can be a polygonal shape. The polygonal shape can be a square shape, a rectangular shape, a triangular shape, or a hexagonal shape.
The honeycomb structure serves a number of functions. Firstly, because it is formed from a heat conductive material, it acts as a plurality of heat conductive elements to conduct heat from the front of the panel assembly into the body of the latent heat storage material layer. This results in a significant improvement in performance since the binders used to bind the phase change material generally have insulating properties. The binders can therefore have the effect of delaying somewhat heat transfer into the bulk of the latent heat storage material.

The honeycomb structure also acts as a support element and adds strength and rigidity to the composite panel assembly encasement without adding significantly to the weight. In this disclosure the terms “composite panel assembly” and “encasement” are used interchangeably. This additional strength and rigidity is particularly important in certain applications such as ceiling tiles and floor tiles. A further advantage of a honeycomb structure is that it segregates the latent heat storage material into small, discrete pockets or cells. Certain cement binders used to bind the PCM have a tendency to distort over time. By dividing the bulk of the latent heat storage material into discrete cells or aliquots, this tendency is very much reduced and often substantially eliminated. This means that a very much wider range of cements can be used than would otherwise be the case.

Furthermore, it is not necessary that the support elements or the heat conducting elements take the form of a honeycomb or other polygonal structure. They can also be fins or ribs, optionally the length and width of the panel as shown in diagram 2a. In fact, these elements can take a wide variety of structural form, including ribbons, crenulated divisions, mesh and a plurality of protrusions. This list is not intended to be exhaustive but simply illustrates the wide range of structures that can be used to create the desired effect(s).

It will be appreciated that it is advantageous that the support elements/heat conducting elements extend substantially throughout the latent heat storage material layer. However this is not essential and the elements may extend only partially through the latent heat storage material layer. Thus, in this context, the term substantially means more than at least about 30% through the latent heat storage material layer, and preferably more than at least about 50% through that layer.
The partition walls of the honeycomb, or other support elements/heat conducting elements, can comprise a metal, and the metal can be aluminium, copper, stainless steel, mild steel or a plastic such as glass-reinforced plastic (also known as fibreglass), carbon fibre reinforced plastic, Nomex (RTM) reinforced plastic, Kevlar (RTM) reinforced plastic. The latent heat storage material can include a binder and a phase change material. The binder can include calcium oxide and a pozzolana material in a ratio range of 1:1 to 1:50 (CaO: pozzolana) by (wt/wt), preferably 1:1 to 1:30 and more preferably 1:1 to 1:20 by (wt/wt).

Referring now to Figure 1, which shows an encasement having a tray part 102 and a lid part 104 forming in combination an interior region, where the interior region includes a honeycomb structure 108.

Referring now to Figure 2, which shows a plan view of the honeycomb structure 108, the structure of which includes a number of cells 110 partitioned by partition walls 112 and extending across the interior region. Individual cells tessellate or interlock with their neighbours. The shape of a section of the cell can be a polygonal shape. The shape can be, for example, a square shape, a rectangular shape, a triangular shape, or a hexagonal shape.

Referring to Figure 2a this shows a plan view of alternative heat conducting elements, being ribbed, ribboned or finned wall structures extending substantially across the interior region.

In both Figures 2 and 2a, the partition walls can comprise a metal, for example aluminium, copper, mild steel or stainless steel or a plastic such as glass-reinforced plastic (known as fibreglass), carbon fibre reinforced plastic, Nomex (RTM) reinforced plastic, and Kevlar reinforced plastic. Thermally conductive plastics are also known, and can be used in the present invention. The walls extend substantially through the layer of latent heat storage material.
Referring now to Figure 3, which shows an encasement having a tray part 102 and a lid part 104 forming an interior region, the interior region includes a polygonal structure 108 having cells of a square shape.

Referring again to Figure 1 and 3, the latent heat storage material 106 is disposed in the cells, ribbed, ribboned or finned interior region. The interior region of the tray is enclosed at its side by edges. Although only part of the edges 102A are shown in Figures 1 and 3, it will be appreciated that these edges surround substantially all sides of the encasement, to form what is, in effect, a tray. The tray has a front panel which has a first, front face, which is usually the side of the assembly which is on view when the panel assembly is in its “in use” position. The front panel also has an opposing, second face which faces inside the tray. The terms “panel front” and “front panel” are used interchangeably in this context.

Example ceiling tile sizes can be 300mm x 300mm, 595mm x 595mm, 600mm x 600mm or 600mm x 1200mm to suit standard manufactured sizes, but can also be of any size. The tiles can be used in either a new build or retrofit project without the need to replace the suspended ceiling grid. The number of ceiling tiles required in a project is determined by the cooling capacity requirements of the building.

The encasement is formed from a material providing strength, heat conductance and fire-resistance. A number of such materials will suggest themselves to the person of ordinary skill in the art; particularly suitable materials include aluminium, copper, graphite, mild steel or stainless steel. Such an encasement can be used as a ceiling tile, particularly a ceiling tile which forms part of a suspended ceiling. It is also equally applicable to floor tiles or to the group of structures set out above.

The tile can, for example, incorporate an aluminium honeycomb (hexagonal cells) or mesh core (square cells) or incorporate ribbed, ribboned or finned wall sections. These can be bonded with a two part solvent free polyurethane or acrylic adhesive to what will be the underside of the surface finish of the tile and that should preferably be made of aluminium, copper, graphite, mild steel, magnesium oxide board or calcium silicate board, or gypsum plasterboard. Around the perimeter of the
tile, an edge strip 102A can be incorporated which is applied to the same height as the honeycomb core. The cells within the honeycomb or mesh core, or the ribbed, ribboned or finned sections are filled with the latent heat storage material. Dependent on the latent heat storage material, which will have different fire retardant properties, a lid component can be bonded with, for example, a two part solvent free polyurethane or acrylic adhesive, to the adjacent side of the honeycomb or mesh core, and/or the edges of the front panel, thus encasing the latent heat storage material. The lid can be made of different materials but preferably aluminium, copper, graphite, mild steel, stainless steel, magnesium oxide board, calcium silicate board, gypsum plasterboard or woven glass fibre mesh. Alternatively, the lid can be formed from or incorporate an insulating material such as mineral wool, Expanded Polystyrene (EPS), polyurethane (PU), polyisocyanurate (PIR) or Aerogel blanket.

Referring now to Figure 4, which shows a ceiling tile infill comprising a honeycomb or mesh core 108 bonded to a lid 104, the cells within the honeycomb or mesh core are filled with latent heat storage material 106. The honeycomb can be aluminium. The honeycomb can be bonded with a two part solvent free polyurethane or acrylic adhesive to a sheet of material 104 that is made preferably either of aluminium, copper, graphite, mild steel, stainless steel, magnesium oxide board, calcium silicate board, gypsum plasterboard or woven glass fibre mesh and which forms the lid of the tile. With the honeycomb or mesh core face down, the tile infill is inserted into any preformed metal ceiling tile tray 102 that may form part of an existing metal ceiling system.

In this case of a retro-fit operation, one would take the empty metal ceiling tile, spread a thin layer of aqueous compound or cement onto the inner surface of the empty tile and embed the honeycomb panel that has been pre-filled with latent heat storage material into the cement. It is important to ensure that substantially 100% contact is made between the ceiling tile and honeycomb core. If contact between both elements is not good then air gaps will be formed, which reduce the conductivity of heat as air is an insulating element.
Referring now to Figure 5, which shows an alternative method of assembly for the ceiling tile infill, the aluminium honeycomb or mesh 108 can be bonded to a sheet of lid 104. The lid can be made preferably either of aluminium, copper, graphite, mild steel, stainless steel, magnesium oxide board, calcium silicate board, gypsum plasterboard or woven glass fibre mesh. The honeycomb can be bonded to the lid using a two part solvent free polyurethane or acrylic adhesive. The latent heat storage material 106 can then be cast into the preformed tray 102 and the ‘lid’ component embedded honeycomb or mesh face down into the latent heat storage material and left to cure, ensuring that the honeycomb or mesh of the lid makes contact with the inside surface of the preformed tile.

Where the depth of honeycomb or mesh is not of the same depth as the preformed tile and so contact with the internal surface of the preformed tile is not made, the preferred method of assembly is for the honeycomb or mesh to be inserted into the preformed tile prior to the casting of the latent heat storage material. A lid component that is made preferably either of aluminium, copper, graphite, mild steel, stainless steel, magnesium oxide board, calcium silicate board, gypsum plasterboard or woven glass fibre mesh can still be embedded onto the surface of the latent heat storage material.

Referring now to Figure 6 and Figure 6A, which show a wall or ceiling panel which comprises a honeycomb 108 bonded to the internal surface of tray or panel 102. The tray or panel provides the surface finish of the wall panel. The honeycomb, which can be aluminium, copper, stainless steel, mild steel or a plastic such as glass-reinforced plastic (also known as fibreglass), carbon fibre reinforced plastic, Nomex (RTM) reinforced plastic, Kevlar(RTM) reinforced plastic can be bonded to the lid using a two part solvent free polyurethane or acrylic adhesive. The surface finish can be of varying materials but preferably made either of aluminium, copper, graphite, mild steel, stainless steel, magnesium oxide board, calcium silicate board, gypsum plasterboard, ceramic or marble. The cells within the honeycomb core are filled with the latent heat storage material 106. Once cured, a lid 104 comprising insulating material is bonded to the exposed side of the honeycomb core. The insulating material can be bonded to the honeycomb with a two part solvent free polyurethane or acrylic adhesive, or other adhesive as selected by the materials
expert. The insulation material can be preferably mineral wool, Expanded Polystyrene (EPS), polyisocyanurate (PIR) or an Aerogel blanket.

The thickness and composition of the material used in construction of the panel front 102 and the panel back or lid 104 may vary, depending on the application requirements, and as determined by the material specialist. A further example is illustrated in Figure 6A.

The panels can also be of varying thickness and used as part of a metal or timber stud partitioning system or fixed directly to existing substrates. Panels are fixed to the substrate using either a mechanical fixing or adhesive bonding. They can also incorporate an inter-locking mechanism such as a cam-lock device.

The design of the wall or ceiling panels can vary, examples of which can include canopy or sails. These can be architectural features that are suspended over areas where there are specific areas with high heat gains such as refrigeration units or display lighting such as in retail environments.

Referring now to Figure 7, which shows a raised access floor tile, beneath which electrical, data and communication cabling and services are hidden. These can generate a substantial amount of heat that contributes to the overall internal heat gains of the building. In listed or old buildings with limited floor to ceiling heights where it is impossible to install modern HVAC systems, the raised access floor system with phase change material can be used as an alternative.

Most modern buildings are constructed from lightweight materials with high heat gains. Installing a raised access floor system with phase change material gives the building thermal mass using a passive system.

Used with raised flooring accessories including pedestals and bearers 702 and 703 that are already commercially available, this embodiment consists of honeycomb 108 bonded to the underside of lid 104 which can be made from a number of
materials, preferably aluminium, copper, graphite, mild steel, stainless steel, ceramic or marble. The honeycomb can be an aluminium foil core and typically can have a thickness/depth of between 25mm – 50mm. The honeycomb core can be bonded with a two part solvent free polyurethane or acrylic adhesive to the underside of the finished surface material. The cells within the honeycomb core are filled with the latent heat storage material 106 and left to cure / semi-cure, before edge strips and a sheet to the underside of the raised access floor tile are bonded with a two part solvent free polyurethane or acrylic adhesive, so that the latent heat storage material is fully encased in a tray structure 102. These panels can replace existing raised access floor panels or form part of a new installation.

Referring now to Figure 8, this shows a worktop or desk 802. The principle of the invention can be used for a wide number of items of furniture or work surfaces. For example, the honeycomb core 108 of a desk can be aluminium honeycomb foil that can be of any thickness. However for the purpose of this example, an overall thickness/depth of between 15mm – 25mm for the worktop/desktop is preferred. The honeycomb is bonded to the underside of lid 104. The honeycomb can be bonded to the lid with a two part solvent free polyurethane or acrylic adhesive on one side to what will be the underside of the worktop / desktop. The cells within the honeycomb core are filled with the latent heat storage 106 material and left to cure / semi-cure, before edge strips and a sheet 102 are bonded to the underside of the worktop/desktop. The edge strips and sheet can be bonded using a two part solvent free polyurethane or acrylic adhesive, so that the latent heat storage material is fully encased. The preferred material used as the surface finish, edge detail and underside of the worktop/desktop would be a good thermal conductor such as aluminium, copper, graphite, ceramic, mild steel or stainless steel that can receive various finishes including high pressure laminates (HPL), timber and plastic laminates or paint/powder coat finishes.

It will be appreciated that composite panel assemblies according to the present invention consists of a panel front, a first face of which will be visible when the panel assembly is in use, one or more support elements or heat conducting elements which transmit heat through the body of the panel, and, optionally, a panel back or lid. The interior region between the panel front and panel back is substantially filled with a latent heat storage material. The heat conducting element(s) can take a wide
variety of forms but a honeycomb structure is preferred for many applications. The heat conducting elements(s) may be attached by some attachment means to the internal surface of the panel front or the panel back by some attachment means such as chemical bonding or welding. In this description the term “plurality” means one or more.

As an alternative to heat conducting support elements, or as an adjunct to them, a thermally conductive matrix can be added to the body of the latent heat storage material. This matrix can take a wide variety of forms and a number of materials are known which can increase heat conduction within a composite solid, such as a cement. These materials include graphite, powdered metal or metal fragments or strips, expanded metal foam, heat conducting plastics, carbon fibre, or combinations thereof. This list is not intended to be exhaustive but simply illustrates the wide range of materials that can be used to improve heat conduction.

Referring now to Figures 9a-c, which show a cooled ceiling panel, a honeycomb core 108 is bonded to the reverse side of what will be the finished surface 102. The honeycomb, which can be aluminium, copper, mild steel, stainless steel or a plastic such as glass-reinforced plastic (also known as fibreglass), carbon fibre reinforced plastic, Nomex (RTM) reinforced plastic, Kevlar (RTM) reinforced plastic, can be bonded to surface 102 with a two part solvent free polyurethane or acrylic adhesive. The surface material should have good thermal conductivity and can be aluminium, copper, graphite, mild steel, stainless steel or ceramic. Through the cell walls of the aluminium honeycomb, along the length of the panel, pipes 902 are bored. The number of pipes through the honeycomb is determined by the width of the panel and also the speed at which the stored latent heat is to be discharged from the phase change material. The greater the number of pipes the faster the stored latent heat is discharged. The pipes are preferably copper tubes, and have connectors to allow connections to other adjoining panels or connections to the main cooling circuit to be made. In one embodiment, at either end of the panel, the ends of the tubes are bent vertically at 90° in order to protrude through the encasement lid part 104. The lid can be made of a good thermal conductive material.
Before the lid is fixed into place the cells within the honeycomb core are filled with latent heat storage material 106 and left to cure. The copper pipe returns are connected to a chilled water circuit and/or to a series of chilled ceiling panels.

Through the copper pipes a supply and return flow of water with a temperature of between 13°C and 17°C passes through a circuit. As the water passes through the panels, heat stored in the phase change material is conducted into the flow of chilled water, which returns to a chiller unit. At the chiller unit, the return flow of water, which has an increased temperature, is chilled to 13°C and 16°C before restarting the circuit.

Referring now to Figure 9d, this shows a typical circuit for cooling water. Cooled water with a temperature of between 13°C and 17°C is pumped through the copper pipe work circuit and through the ceiling tile. As the water passes through each tile, the latent heat that is stored within the high enthalpy compound is transferred through the copper tube and into the flow of cooled water. The water, which has now increased in temperature, continues through the circuit back to a heat-exchange unit such as the water coils supplied by S & P Coil Products Limited, Leicester. The heat exchange unit will contain a high heat conductive metal encasement that is also filled with a high enthalpy compound such as those described above. This is to allow the heat from the returning water supply to be transferred to the panel and thus cool the water back to between 13°C and 16°C, ready to restart the circuit.

Tempered or chilled air for night time cooling and purging daytime heat gains can also be passed through the pipes as an alternative method for discharging the stored latent heat within the building. In this instance the pipes can be connected to an external vent with a fan unit to pull the external night air through the pipe work circuit.

The diameter of the copper tube varies and can be of a diameter such as those of standard copper tubing i.e. from 15mm, 22mm, 28mm, 35mm, 42mm, 54mm, 67mm, 76mm and 108mm. The preferred diameter of copper tube is between 15mm
and 28mm so as to minimise the weight and dimensions of the tile and subsequent need for structural support.

The encasement or panel assembly can be formed from a metal sheet by cutting, folding or pressing. For example, the metal sheets can be aluminium, copper, stainless steel or mild steel sheets manufactured and supplied preformed by companies such as Armstrong World Industries, Inc, USA, USG (United States Gypsum), USA, Lidner GmbH, Germany, SAS International, UK. The thickness of gauge is generally in the range 0.5 – 1.5mm.

The two parts of an encasement, a tray part 102 and a lid part 104 form an interior region which together encases an infill component 106. The encasement is a material providing strength, heat conductance and fire-resistance. Strength may be provided by incorporating honeycomb, ribbed, ribbed, or finned sections on the inside of the tray part. A number of such materials will suggest themselves to the person of ordinary skill in the art; particularly suitable materials include aluminium, copper, graphite, mild steel and stainless steel. For example, the tray part is a pressed aluminium, copper, mild steel or stainless steel base section manufactured and supplied preformed.

The latent heat storage material used as an infill component can take a wide variety of forms. It must contain a phase change material and usually contains a binder. A non-exhaustive range of suitable phase change materials are described above and it is intended that any suitable phase change material could be used, including those not yet discovered. Likewise, a wide variety of suitable binders are described above. This disclosure is intended to include all suitable binders, including those binders yet to be discovered.

One suitable range of binders is magnesia cements. Examples of latent heat storage materials including suitable magnesia cements are described in GB 2462740A (Berry and Scanlon), the entire text of which is hereby imported by reference and is intended to form an integral part of this disclosure.
The use of support elements which segregate the latent heat storage material into discrete segments is particularly beneficial when using magnesia cements. This is because magnesia cements have a tendency to deform and distort over time. Without these elements a ceiling tile would inevitably deform after a period of time.

The infill component can advantageously be provided by formulations based on the pozzolana cements disclosed below, such as those disclosed in samples 1 - 4. Sample 5 is a formulation based on a magnesium chloride cement. The compound may be cast into the encasement in various ways, including the method shown in Figure 5.

The lid part is typically manufactured from aluminium, copper, graphite, mild steel or stainless steel sheet but can also be magnesium oxide board, calcium silicate board, gypsum board, woven glass fibre mesh or a plastic such as a plastic such as glass-reinforced plastic (also known as fibreglass), carbon fibre reinforced plastic, Nomex (RTM) reinforced plastic, Kevlar (RTM) reinforced plastic. The lid part is bonded to the cast aluminium base section, for example by using a polyurethane adhesive. The latent heat storage material includes a pozzolana binder and a phase change material. For example the latent heat storage material can be a pozzolana cement, and a number of different pozzolana cement formulations are described below.

In a first step, magnesium chloride is dissolved in water of reasonable purity (such as tap water) by mixing for a minimum of 15 minutes at high speed and then left for a minimum of 24 hours to ensure that the magnesium chloride is completely dissolved. The dissolution step is performed under ambient conditions, typically 10 - 13°C for the tap water and 15 - 18°C for the resulting solution. Magnesium chloride hexahydrate preparations are commercially available and suitable for use in the present invention. For example NEDMAG (RTM) C flakes, which are small white flakes of magnesium chloride hexahydrate (MgCl₂.6H₂O) with a MgCl₂ content of 47%, are available from Nedmag Industries Mining & Manufacturing B.V. The Baumé is measured in order to be able to determine the density of the MgCl₂(H₂O)ₓ solution. The Baumé measures the density of a liquid, which can be either heavier or lighter than water. In the case of the present invention, the liquid density is
heavier than water. Typically the weight ratio of magnesium chloride:water is about 1:1, which gives a Baumber reading of 26°; this corresponds to a molar ratio of magnesium chloride:water of about 1:17. The Baumber range is generally between 10° and 40°, preferably between 12° and 30° but more preferably between 15° and 26°. The desired quantities of PCM, pozzolan, CaO and glass fibre are then added in subsequent steps.

In a second step the phase change material (PCM) is added to the MgCl₂(H₂O)ₓ solution. Typically the weight ratio of phase change material to MgCl₂(H₂O)ₓ solution is below 5:1 by (wt/wt).

Preferred PCM's are organic or inorganic, water insoluble materials that undergo solid-liquid/liquid-solid phase changes at temperatures in the range of 0° to 80°C. Candidate materials include substantially water insoluble fatty alcohols, glycols, ethers, fatty acids, amides, fatty acid esters, linear hydrocarbons, branched hydrocarbons, cyclic hydrocarbons, halogenated hydrocarbons and mixtures of these materials. Alkanes (often referred to as paraffins), esters and alcohols are particularly preferred. Alkanes are preferably substantially n-alkanes that are most often commercially available as mixtures of substances of different chain lengths, with the major component, which can be determined by gas chromatography, between C₁₀ and C₅₀, usually between C₁₂ and C₃₂. Examples of the major component of an alkane organic phase change materials include n-octacosane, n-docosane, n-eicosane, n-octadecane, n-heptadecane, n-hexadecane, n-pentadecane and n-tetradecane. It is also possible to include a halogenated hydrocarbon along with the main organic phase change material to provide additional fire protection, for example as disclosed in U.S. Pat. No. 5,435,376. Suitable ester organic phase change materials comprise of one or more C₁ – C₁₀ alkyl esters of C₁₀ – C₂₄ fatty acids, particularly methyl esters where the major component is methyl behenate, methyl arachidate, methyl stearate, methyl palmitate, methyl myristate or methyl laurate. Alcohol organic phase change materials include one or more alcohols where the major component is, for example, n-decanal, n-dodecanol, n-tetradecanol, n-hexadecanol, and n-octadecanol. These materials are substantially water insoluble, which means they can be formulated in an emulsion form or encapsulated form. The phase change material can be an inorganic phase change material, for example inorganic microencapsulated salt.
hydrate phase change material such as Thermusol, available from Capzo International BV / Salco BV, in The Netherlands.

Preferably, the phase change material is a commercially available encapsulated formulation, such as Micronal® from BASF, Germany which has an enthalpy of 110kJ/kg or the RT product range from Rubitherm GmbH, Germany which has an enthalpy of up to 198kJ/kg. These materials are provided in granular form and may be added to the MgCl₂(H₂O)ₙ solution straight out of the container.

In a third step glass fibre strands can be added to the phase change material and MgCl₂(H₂O)ₙ solution to prevent cracking during curing and also shrinkage that can occur through the evaporation of the water content.

In a fourth step the pozzolana, which can be Pulverised Fuel Ash, Risk Husk Ash, Metakaolin, or the like, is dry blended in a slow mixer with calcium oxide (CaO). Typically the weight ratio of pozzolana to calcium oxide is in the range of 1:1 to 30:1, but preferably 1:1 to 20:1 by (wt/wt).

In a fifth step, the pozzolana and calcium oxide blend is added to the phase change material and MgCl₂(H₂O)ₙ solution. The mixture is homogenized using a Greaves mixer with a dissolver stirrer to produce a paste which is smooth and mobile. Typically the weight ratio of pozzolana and calcium oxide blend to phase change material and MgCl₂(H₂O)ₙ solution is in the range below 1:50 by (wt/wt).

In an optional sixth step, filler materials can be added whereby the filler materials can include silica sand, magnesium oxide, stone dust, quartz, perlite, marble, ceramic powders, wood dust, flax sheaves, hemp, straw and graphite.

In a seventh step the mixture, which provides a heat absorbing material that is in its liquid state, is typically moulded or cast to suit any shape or form for use.

These are the preferred order of addition but the various components can be added to the magnesium chloride solution in a different order if desired.
Some samples of pozzolan cement/PCM compositions are given in Tables A - D.

**Table A**

<table>
<thead>
<tr>
<th>Sample using Organic Microencapsulated Phase Change Material</th>
<th>Sample 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASF Micronal® DS 5000X (grams)</td>
<td>3000</td>
</tr>
<tr>
<td>MgCl₂(H₂O)ₓ solution, Baume 15° (grams)</td>
<td>2000</td>
</tr>
<tr>
<td>Pulverised Fuel Ash (High lime) (grams)</td>
<td>400</td>
</tr>
<tr>
<td>Calcium Oxide (grams)</td>
<td>100</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on 20mm thick panel, with a density of 1000kg/m³:

| Heat Storage Capacity:                                      | 914.10kJ/m² |
| 1 kWh cooling capacity:                                     | 4.01m²      |

**Table A1**

<table>
<thead>
<tr>
<th>Sample using Organic Microencapsulated Phase Change Material</th>
<th>Sample 1a</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASF Micronal® DS 5000X (grams)</td>
<td>1500</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>300</td>
</tr>
<tr>
<td>Pulverised Fuel Ash (High lime) (grams)</td>
<td>400</td>
</tr>
<tr>
<td>Calcium Oxide (grams)</td>
<td>100</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on 20mm thick panel, with a density of 1000kg/m³:

| Heat Storage Capacity:                                      | 457.05kJ/m² |
| 1 kWh cooling capacity:                                     | 8.10m²      |
### Table A2

<table>
<thead>
<tr>
<th>Sample using Organic Microencapsulated Phase Change Material</th>
<th>Sample 1b</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASF Micronal® DS 5000X (grams)</td>
<td>4500</td>
</tr>
<tr>
<td>MgCl₂(H₂O)ₙ solution, Baume 19° (grams)</td>
<td>3000</td>
</tr>
<tr>
<td>Magnesium Oxide</td>
<td>500</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on 30mm thick panel, with a density of 1000kg/m³:

- Heat Storage Capacity: 1372kJ/m²
- 1 kWh cooling capacity: 2.7m²

### Table A3

<table>
<thead>
<tr>
<th>Sample using Organic Microencapsulated Phase Change Material</th>
<th>Sample 1c</th>
</tr>
</thead>
<tbody>
<tr>
<td>BASF Micronal® DS 5000X (grams)</td>
<td>6000</td>
</tr>
<tr>
<td>MgCl₂(H₂O)ₙ solution, Baume 19° (grams)</td>
<td>4000</td>
</tr>
<tr>
<td>Pulverised Fuel Ash (High lime) (grams)</td>
<td>800</td>
</tr>
<tr>
<td>Calcium Oxide (grams)</td>
<td>200</td>
</tr>
<tr>
<td>Magnesium Oxide</td>
<td>500</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on 20mm thick panel, with a density of 1000kg/m³:

- Heat Storage Capacity: 1828.2kJ/m²
- 1 kWh cooling capacity: 2.02m²
### Table B

<table>
<thead>
<tr>
<th>Sample using Organic Phase Change Material</th>
<th>Sample 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubitherm® RT21 (grams)</td>
<td>3000</td>
</tr>
<tr>
<td>MgCl₂(H₂O)₅, solution, Baume 15° (grams)</td>
<td>2000</td>
</tr>
<tr>
<td>Pulverised Fuel Ash (High lime) (grams)</td>
<td>400</td>
</tr>
<tr>
<td>Calcium Oxide (grams)</td>
<td>100</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on 20mm thick panel, with a density of 1000kg/m³:

| Heat Storage Capacity:                     | 1113.54kJ/m² |
| 1 kWh cooling capacity:                    | 3.33m²       |

### Table C

<table>
<thead>
<tr>
<th>Sample using Inorganic Microencapsulated Phase Change Material</th>
<th>Sample 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capzo International BV – Thermosol® HD60 GE (grams)</td>
<td>3000</td>
</tr>
<tr>
<td>Water (H₂O) grams)</td>
<td>2000</td>
</tr>
<tr>
<td>Rice Husk Ash (grams)</td>
<td>1000</td>
</tr>
<tr>
<td>Calcium Oxide (grams)</td>
<td>200</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>50</td>
</tr>
</tbody>
</table>

Based on 20mm thick panel, with a density of 1000kg/m³:

| Heat Storage Capacity:                                     | 1662kJ/m² |
| 1 kWh cooling capacity:                                     | 2.22m²    |
Table D

<table>
<thead>
<tr>
<th>Sample using Eutectic Phase Change Material</th>
<th>Sample 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubitherm® SP25 A8 (grams)</td>
<td>3000</td>
</tr>
<tr>
<td>MgCl₂(H₂O)ₙ solution, Baume 15° (grams)</td>
<td>2000</td>
</tr>
<tr>
<td>Pulverised Fuel Ash (High lime) (grams)</td>
<td>400</td>
</tr>
<tr>
<td>Calcium Oxide (grams)</td>
<td>100</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on 20mm thick panel, with a density of 1000kg/m³:

| Heat Storage Capacity:                  | 1495.8kJ/m² |
| 1 kWh cooling capacity:                | 2.48m²      |

Table E provides an example of a latent heat storage material using magnesium chloride as a binder.

Table E

<table>
<thead>
<tr>
<th>Sample using Organic Microencapsulated Phase Change Material</th>
<th>Sample 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ciba Encapsulance® (grams)</td>
<td>3000</td>
</tr>
<tr>
<td>MgCl₂(H₂O)ₙ solution, Baume 23° (grams)</td>
<td>1500</td>
</tr>
<tr>
<td>Glass Fibre Strands (grams)</td>
<td>10</td>
</tr>
</tbody>
</table>

Based on 20mm thick panel, with a density of 1000kg/m³:

| Heat Storage Capacity:                  | 1246.5kJ/m² |
| 1 kWh cooling capacity:                | 2.97m²      |
The performance of an encasement or panel assembly of the present invention has been investigated in a thermal test chamber. The encasements were placed in a thermal test chamber, which itself was located in a larger environmental test chamber. This allows control of conditions outside the test chamber so that temperature differentials between the interior and exterior of a building, room, or office could be simulated. Honeycomb ceiling panels were repeatedly subjected to typical summer day and night temperatures under different degrees of ventilation. The experiment examined the effect of the honeycomb ceiling panels on the temperature inside a test cell repeatedly subjected to typical summer day and night temperatures under different states of ventilation in a climate chamber. The test cell was to simulate an actual room, and contained a heater to simulate typical thermal heat loads that result from the human body, electrical and mechanical equipment, lighting, and the like. The panels contain microencapsulated PCM composite and the tests were to determine the efficiency of the tiles in maintaining lower indoor temperature compared to a situation without them. For discharging the panels, conditions of low and high ventilation rates using 17°C overnight temperature from 17hrs – 9hrs in the climate chamber was tested. In charging, 25°C was used as daytime temperature from 9hrs – 17hrs under zero, low and high ventilation rates. Results from the experiment showed that indoor temperatures were reduced by margins between 2°C and 7°C for different ventilation rates when the panels are installed.

<table>
<thead>
<tr>
<th></th>
<th>Melting Temperature (°C)</th>
<th>Freezing Temperature (°C)</th>
<th>Latent Heat of Melting (J/g)</th>
<th>Latent Heat of Freezing (J/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 73</td>
<td>22.16</td>
<td>23.28</td>
<td>56.51</td>
<td>58.71</td>
</tr>
<tr>
<td>Sample 74</td>
<td>22</td>
<td>23.27</td>
<td>86.736</td>
<td>90.876</td>
</tr>
</tbody>
</table>
The aim of this experiment was to test and determine the thermal performance of honeycomb ceiling tiles/panels in a semi-active cooling application. The product tested, honeycomb ceiling panels consists of a composite impregnated with microencapsulated phase change material in a 600mm x 600mm x 15mm ceiling panel. This was experimentally investigated in an 1800mm x 1800mm x 1700mm test cell before DSC analysis was carried out. Differential scanning calorimetry or DSC is a thermoanalytical technique in which the difference in the amount of heat required to increase the temperature of a sample and a reference is measured as a function of temperature. This is used to determine enthalpy (kJ/kg). Phase change materials store energy in a latent form. They undergo an endothermic process of phase change to store heat energy when ambient temperature rises and an exothermic process to release this energy when the temperature drops. In building applications, these processes are desirable in a narrow temperature range close to the human comfort temperature with a large amount of heat being absorbed and released. Phase change materials can be incorporated into different building materials. They have been used in gypsum wallboards, plaster and concrete, and which absorb heat energy in summer to reduce peak cooling loads and this can be of serious economic benefit in reducing HVAC systems running costs.
1. Equipment and Materials

<table>
<thead>
<tr>
<th>EQUIPMENT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate chamber</td>
<td>Typical summer temperatures of 25°C and 17°C at night were maintained in the climate chamber with humidity left as ambient. Humidity didn't vary much and was similar for subsequent day and night experiments</td>
</tr>
<tr>
<td>Test cell</td>
<td>See the structure of the test cell in the Figure II below.</td>
</tr>
<tr>
<td>Type K thermocouples</td>
<td>These are installed in various points in and out of the test cell. The position, tag and description of each thermocouple are given in Figures 12 to 16 and table 4.</td>
</tr>
<tr>
<td>8-port data loggers</td>
<td>These provided logging at 1 minute intervals</td>
</tr>
<tr>
<td>Globe thermometer</td>
<td>This contains a type K thermocouple at the centre of a 101.6mm diameter black copper sphere to measure the mean radiant temperature as described by EN ISO 7726. This is another indicator of thermal comfort and sometimes considered better than ordinary air temperature.</td>
</tr>
<tr>
<td>Heat flux sensors</td>
<td>These are installed on opposite surfaces of the tiles during the experiment. Data from these sensors gave the experimental heat transfer coefficients and their variation under the different conditions simulated.</td>
</tr>
<tr>
<td>Speed Controller</td>
<td>The fan and test cell has been calibrated to deliver a maximum ventilation flow rate of 14.9l/s at normal voltage and 11.7l/s at 130V. This was used in changing the flow rates between these two values</td>
</tr>
<tr>
<td>Electric Heater</td>
<td>The Heater provides 150W of cooling load</td>
</tr>
<tr>
<td>Intake &amp; Outlet guard</td>
<td>A zero ventilation scenario was tested using this guards to block the vents</td>
</tr>
<tr>
<td>Fan</td>
<td>The fan was installed in the outlet vent above the ceiling grid to draw air over the tiles from the inlet. I believe this is a possible way of discharging these tiles in real building applications when the heat is not needed.</td>
</tr>
<tr>
<td>Differential Scanning Calorimeter</td>
<td>Brand: TS instruments</td>
</tr>
</tbody>
</table>
## 2. Experimental Procedure

### Climate Chamber Tests

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Run</th>
<th>Start Time &amp; Date</th>
<th>Stop Time &amp; Date</th>
<th>Climate Chamber Set point</th>
<th>Ventilation Rate</th>
<th>Heat (W)</th>
<th>Relative Humidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/6/2010 17:00hrs</td>
<td>16hrs Initial Discharge</td>
<td>17:00hrs 7/6/2010</td>
<td>9:00hrs 8/6/2010</td>
<td>17°C</td>
<td>High</td>
<td>0</td>
<td>51</td>
</tr>
<tr>
<td>8/6/2010 9:00hrs</td>
<td>8hrs Charge</td>
<td>9:00hrs 8/6/2010</td>
<td>17:00hrs 8/6/2010</td>
<td>25°C</td>
<td>Zero</td>
<td>150</td>
<td>69.31</td>
</tr>
<tr>
<td>8/6/2010 17:00hrs</td>
<td>16hrs Discharge</td>
<td>17:00hrs 8/6/2010</td>
<td>9:00hrs 9/6/2010</td>
<td>17°C</td>
<td>High</td>
<td>0</td>
<td>51.52</td>
</tr>
<tr>
<td>9/6/2010 9:00hrs</td>
<td>8hrs Charge</td>
<td>9:00hrs 9/6/2010</td>
<td>17:00hrs 9/6/2010</td>
<td>25°C</td>
<td>Low</td>
<td>150</td>
<td>68.92</td>
</tr>
<tr>
<td>9/6/2010 17:00hrs</td>
<td>16hrs Discharge</td>
<td>17:00hrs 9/6/2010</td>
<td>9:00hrs 10/6/2010</td>
<td>17°C</td>
<td>High</td>
<td>0</td>
<td>51.39</td>
</tr>
<tr>
<td>10/6/2010 9:00hrs</td>
<td>8hrs Charge</td>
<td>9:00hrs 10/6/2010</td>
<td>17:00hrs 10/6/2010</td>
<td>25°C</td>
<td>Low</td>
<td>150</td>
<td>71.9</td>
</tr>
<tr>
<td>10/6/2010 17:00hrs</td>
<td>16hrs Discharge</td>
<td>17:00hrs 10/6/2010</td>
<td>9:00hrs 11/6/2010</td>
<td>17°C</td>
<td>Low</td>
<td>0</td>
<td>54.12</td>
</tr>
<tr>
<td>11/6/2010 9:00hrs</td>
<td>Test End</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69.95</td>
</tr>
</tbody>
</table>
Table 4: Thermocouples

<table>
<thead>
<tr>
<th>name</th>
<th>meaning</th>
<th>Inside/Outside</th>
</tr>
</thead>
<tbody>
<tr>
<td>EW1</td>
<td>External wall 1 (wood)</td>
<td>Outside</td>
</tr>
<tr>
<td>EW2</td>
<td>External wall 2 (wood)</td>
<td>Outside</td>
</tr>
<tr>
<td>WB</td>
<td>Wall Bottom (plasterboard)</td>
<td>Inside</td>
</tr>
<tr>
<td>WM</td>
<td>Wall Middle (plasterboard)</td>
<td>Inside</td>
</tr>
<tr>
<td>WT</td>
<td>Wall Top (plasterboard)</td>
<td>Inside</td>
</tr>
<tr>
<td>CS1</td>
<td>Ceiling Surface 1 (plasterboard)</td>
<td>Inside</td>
</tr>
<tr>
<td>CS2</td>
<td>Ceiling Surface 2 (plasterboard)</td>
<td>Inside</td>
</tr>
<tr>
<td>CS3</td>
<td>Ceiling Surface 3 (plasterboard)</td>
<td>Inside</td>
</tr>
<tr>
<td>AI</td>
<td>Air Inlet</td>
<td>Inside</td>
</tr>
<tr>
<td>AO</td>
<td>Air Outlet</td>
<td>Inside</td>
</tr>
<tr>
<td>BB</td>
<td>Black Ball</td>
<td>Inside</td>
</tr>
<tr>
<td>AHL</td>
<td>Air High Level</td>
<td>Inside</td>
</tr>
<tr>
<td>ALL</td>
<td>Air Low Level</td>
<td>Inside</td>
</tr>
<tr>
<td>OA1</td>
<td>Outside Air 1</td>
<td>Outside</td>
</tr>
<tr>
<td>OA2</td>
<td>Outside Air 2</td>
<td>Outside</td>
</tr>
<tr>
<td>OA3</td>
<td>Outside Air 3</td>
<td>Outside</td>
</tr>
<tr>
<td>AHL2</td>
<td>Air High Level 2</td>
<td>Inside</td>
</tr>
<tr>
<td>AHL3</td>
<td>Air High level 3</td>
<td>Inside</td>
</tr>
<tr>
<td>AHL R2</td>
<td>Air High Level Recessed 2</td>
<td>Inside</td>
</tr>
<tr>
<td>AHL R3</td>
<td>Air High Level Recessed 3</td>
<td>Inside</td>
</tr>
<tr>
<td>CEILING</td>
<td>Heat Flux Sensor on PCM Surface</td>
<td>Inside</td>
</tr>
<tr>
<td>WALL</td>
<td>Heat Flux Sensor on Tile Surface</td>
<td>Inside</td>
</tr>
<tr>
<td>Tile 1</td>
<td>Tile Middle Corner</td>
<td>Inside</td>
</tr>
<tr>
<td>Tile 2</td>
<td>Tile Surface Centre</td>
<td>Inside</td>
</tr>
<tr>
<td>Tile 3</td>
<td>Tile Middle centre</td>
<td>Inside</td>
</tr>
<tr>
<td>Tile 4</td>
<td>PCM Surface Centre</td>
<td>Inside</td>
</tr>
</tbody>
</table>
DSC Analysis

Three samples from each of the two tiles where tested, one from the centre and two from the extreme edges of each on opposite sides to eliminate any error that could be introduced by varying concentration of the PCM within the composite. The initial test runs were done at a slow ramp rate of 2°C/min but subsequent ones were sped up to 4°C/min and isothermal times to 3min. Results from the two ramp rates exhibited similar behaviors. The test run is as follows:

- Equilibrate at 20°C
- Ramp at 2°C/min to 40°C
- End of cycle 1
- Isothermal for 5mins
- Ramp at 2°C/min to -20°C
- End of cycle 2
- Isothermal for 5min
- Ramp at 2°C/min to 40°C
- End of cycle 3
- Isothermal for 5mins
- Ramp at 2°C/min to -20°C
- End of cycle 4
- Isothermal for 5min
- End of run

The two thermocouples AHL2 and AHL3 recorded similar values as they were at the same level, just spaced apart to eliminate any effect the heater might have by being directly below either thermocouple. In zero ventilation conditions the tiles containing PCM composite sample 74 maintained air temperatures which peaked at just above 26°C after an 8 hour period. Compared to the temperature profile of an ordinary test cell without the tiles, between 2°C and 7°C difference was observed.
The DSC thermal analysis is presented for the range -20°C to 40°C. The results of three DSC runs on sample 73, including average melting temperature, freezing temperature and latent heats, are given in the table 5 below.

Table 5: Sample 73 Thermal Properties

<table>
<thead>
<tr>
<th></th>
<th>Freezing Temperature (°C)</th>
<th>Melting Temperature (°C)</th>
<th>Latent Heat of Freezing (J/g)</th>
<th>Latent Heat of Melting (J/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st RUN</td>
<td>22.29</td>
<td>23.35</td>
<td>51.98</td>
<td>56.89</td>
</tr>
<tr>
<td>2nd RUN</td>
<td>22.09</td>
<td>23.26</td>
<td>59.08</td>
<td>58.86</td>
</tr>
<tr>
<td>3rd RUN</td>
<td>22.1</td>
<td>23.23</td>
<td>58.48</td>
<td>60.38</td>
</tr>
<tr>
<td>Average</td>
<td>22.16</td>
<td>23.28</td>
<td>56.51</td>
<td>58.71</td>
</tr>
</tbody>
</table>

Table 6: Sample 74 Thermal Properties

<table>
<thead>
<tr>
<th></th>
<th>Freezing Temperature (°C)</th>
<th>Melting Temperature (°C)</th>
<th>Latent Heat of Freezing (J/g)</th>
<th>Latent Heat of Melting (J/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st RUN</td>
<td>22</td>
<td>23.32</td>
<td>89.71</td>
<td>95.84</td>
</tr>
<tr>
<td>2nd RUN</td>
<td>22.05</td>
<td>23.27</td>
<td>83.63</td>
<td>86.12</td>
</tr>
<tr>
<td>3rd RUN</td>
<td>21.95</td>
<td>23.23</td>
<td>86.87</td>
<td>90.67</td>
</tr>
<tr>
<td>Average</td>
<td>22</td>
<td>23.27</td>
<td>86.73</td>
<td>90.87</td>
</tr>
</tbody>
</table>

To determine the percentage of microencapsulated PCM in the different samples, additional DSC runs were performed on the Micro-encapsulated PCM. The results are presented in Table 7 below.
Both DSC runs on the Micro-encapsulated PCM revealed the thermal properties as follows:

Freezing temperature of 22°C

Melting temperature of 23.24°C

Latent heat of Freezing of 122.2 J/g

Latent heat of Melting of 124 J/g

Table 7: Latent heat comparison

<table>
<thead>
<tr>
<th></th>
<th>Latent heat of Freezing J/g</th>
<th>Latent Heat of Melting J/g</th>
<th>% PCM constituent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro-encapsulated PCM</td>
<td>122.2</td>
<td>124</td>
<td>100</td>
</tr>
<tr>
<td>sample 73</td>
<td>56.51</td>
<td>58.71</td>
<td>48</td>
</tr>
<tr>
<td>sample 74</td>
<td>86.74</td>
<td>90.87</td>
<td>72</td>
</tr>
</tbody>
</table>

Further tests were carried out in the thermal chamber to compare the performance of an aluminium honeycomb tile with that of a standard metal tile, a drywall tile and a standard metal tile containing the latent heat storage material without the honeycomb structure. The results of these tests are shown in Table 10 below and Figure 10.
### Table 10. Comparison of Aluminium Honeycomb Tile with latent heat storage material

<table>
<thead>
<tr>
<th></th>
<th>Standard Metal Tile</th>
<th>Drywall Tile</th>
<th>Metal Tile with RACUS® PCM</th>
<th>Aluminium Honeycomb Tile with RACUS® PCM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions of a single tile, length x width x thickness [mm]</strong></td>
<td>600 x 600 x 16</td>
<td>603 x 603 x 12.5</td>
<td>600 x 600 x 16</td>
<td>595 x 595 x 20</td>
</tr>
<tr>
<td><strong>Elapsed time for return air to reach 26°C or 80°F [mins]</strong></td>
<td>207</td>
<td>273</td>
<td>340</td>
<td>407</td>
</tr>
<tr>
<td><strong>Time delay of AC Unit relative to standard metal tile [mins]</strong></td>
<td>0</td>
<td>63</td>
<td>134</td>
<td>174</td>
</tr>
<tr>
<td><strong>Energy used during the 8 simulated &quot;occupied hours&quot; [Wh]</strong></td>
<td>1591</td>
<td>1140</td>
<td>1128</td>
<td>744</td>
</tr>
<tr>
<td><strong>Number of AC Unit ON cycles during &quot;occupied hours&quot;</strong></td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

**Summary:**

The thermal chamber was subjected to a cooling load of 300W (31 W/m²) and the AC Unit (air conditioning unit) had a set point of 26.7°C. Tests were conducted over a simulated working day period over two days. The heat gains during the day were purged through night time cooling by setting the air conditioning unit at a low operating mode of 17°C.

The result of the tests shows a reduced energy requirement of 55% by utilizing the honeycomb tile with RACUS PCM compared to a standard metal tile without PCM. The heat gains that were stored in the honeycomb tile with RACUS PCM throughout the day, resulted in the air conditioning only starting running after 6 hours 47 minutes compared to a standard metal tile whereby the air conditioning started running after 3 hours 27 minutes, a difference of 3 hours 20 minutes.
Conclusion

From the experimental results, the PCM composite tested has an important potential of thermal energy storage in ceiling tiles. Importantly, the possibility exists to incorporate much more PCM latent heat storage material per unit area than was present in the tiles used in these experiments.
CLAIMS

1. A composite panel assembly containing a latent heat storage material, said composite panel assembly comprising:
   (i) a panel front having a first face and an opposing second face, said panel front comprising a thermally conductive material;
   (ii) a latent heat storage material layer comprising a phase change material;
   (iii) a plurality of heat conduction elements each comprising a thermally conductive material and adapted to convey heat between the front panel and the latent heat storage material layer;

wherein the plurality of heat conduction elements extend from the opposing second face of the front panel into and substantially through the latent heat material layer.

2. A composite panel assembly according to Claim 1 wherein the plurality of heat conduction elements comprise structures selected from the group comprising:-
   heat conducting honeycomb structures;
   heat conducting polygonal structures formed from regular or irregular polygons;
   heat conducting fins;
   heat conducting ribs;
   heat conducting ribbons;
   heat conducting crenulations
   heat conducting mesh;
   heat conducting protrusions; and combinations thereof.
3. A composite panel assembly according to Claim 1 or Claim 2 wherein the latent heat storage material further comprises a binder.

4. A composite panel assembly according to Claim 3 wherein the binder is selected from the group comprising:-

   a cement;

   an Ordinary Portland Cement (OPC)

   a magnesia cement;

   a pozzolan cement;

   a magnesium chloride binder;

   a copolymer binder; and mixtures thereof.

5. A composite panel assembly according to Claim 3 or Claim 4 wherein the phase change material comprises up to 99% by weight of the latent heat storage material, and preferably 30% - 95% by weight of the latent heat storage material.

6. A composite panel assembly according to any proceeding claims wherein the heat storage capacity of the panel is in the range 300 – 3000 kJ/m², based on a 20 mm thick panel.

7. A composite panel assembly according to any preceding claim wherein the panel front further comprises one or more panel edges, said panel edges depending from the first face of the panel front or from the opposing second face of the panel front.

8. A composite panel assembly according to Claim 7 further comprising a lid, the panel front, panel edges and lid forming an encasement.

9. A composite panel assembly according to Claim 8 wherein the lid is bonded to or otherwise attached to the panel front and/or panel edges.
10. A composite panel assembly according to any preceding claim further comprising a tegular edge, enabling the panel to sit in a ceiling grid.

11. A composite panel assembly according to any preceding claim wherein the panel assembly comprises a structure selected from the group comprising:

- a ceiling tile, including an acoustic ceiling tile;
- a floor tile;
- a raised access/computer floor tile;
- a chilled ceiling panel;
- a wall panel;
- a panel e.g. for use in heat exchange systems;
- a desk surface;
- a work surface;
- a sleeve e.g. for heating and ventilation pipes;
- an encasement.

12. A composite panel assembly according to any preceding claim further comprising one or more tubes adapted to carry a cooling or heating fluid, wherein the tube(s) pass through the latent heat storage material layer.

13. A composite panel assembly according to any preceding claim further comprising an insulating layer.

14. A composite panel assembly according to Claim 13 wherein the insulating layer is located on the side of the latent heat material layer furthest from the panel front.
15. A composite panel assembly substantially as herein described, with reference to and as illustrated in any combination of the accompanying drawings.

16. A process for the manufacture of a composite panel assembly comprising the steps of:-

(a) providing a first panel element and a plurality of heat conduction elements;

(b) providing a phase change material in a binder in an unset form;

(c) locating the plurality of heat conduction elements adjacent to the first panel element;

(d) substantially surrounding the heat conduction elements with the phase change material and allowing it to set;

(e) optionally providing and fitting a second panel element over the phase change material/heat conduction elements combination and optionally securing the second panel element to the first panel element.

17. A process for the manufacture of a composite panel comprising of the steps of:-

(a) providing a first panel element and a plurality of heat conducting elements;

(b) securing the heat conducting elements to one face of the first panel element;

(c) providing a second panel element with upstanding edges which, in combination, form a shallow tray;

(d) substantially filling the tray with a phase change material in a binder in unset form;

(e) placing the first panel element over the second panel element such that the heat conducting elements become embedded in the phase change material.
18. A process for manufacturing a composite panel assembly comprising the steps of:-

(a) providing a tile comprising a tray element and, optionally, a back or lid element;

(b) providing a plurality of heat conduction elements with a latent heat storage material precast around the heat conduction elements in a size and shape that will fit into said tray element;

(c) placing a binder cement layer into the bottom of said tray element;

(d) placing the precast element from step (b) into the tray element and optionally fitting the back or lid element.

19. A process for manufacturing or refurbishing a composite panel assembly substantially as herein described, with reference to and as illustrated in any combination of the accompanying drawings.
Amendments to the Claims have been filed as follows

CLAIMS

1. A composite panel assembly containing a latent heat storage material, said composite panel assembly comprising:

(i) a panel front having a first face and an opposing second face, said panel front comprising a thermally conductive material;

(ii) a latent heat storage material layer comprising a phase change material and a binder;

(iii) a plurality of support elements, wherein the support elements are embedded in the latent heat storage material layer to provide structural support to that layer;

wherein said binder is selected from the group comprising:-

an Ordinary Portland Cement (OPC)
a magnesia cement, formed from magnesium chloride solution and magnesium oxide, wherein the Baumé of the magnesium chloride solution used in the preparation of said magnesia cement is in the range 15º to 26º;
a pozzolan cement;
a magnesium chloride binder;
a copolymer binder; and mixtures thereof.

2. A composite panel assembly according to Claim 1 wherein the plurality of support elements segregate the latent heat storage material layer into discrete sections.

3. A composite panel assembly according to Claim 1 or Claim 2 wherein the plurality of support elements extend from the opposing second face of the front panel into and substantially through the latent heat material layer.

4. A composite panel assembly according to any preceding claim wherein some or all of the support elements comprise a plurality of heat conduction elements, formed from a thermally conductive material and adapted to convey heat between the panel front and the latent heat storage material layer.
5. A composite panel assembly according to any preceding claim wherein the plurality of support elements comprise structures selected from the group comprising:
- honeycomb and other polygonal structures formed from regular or irregular polygons;
- fins;
- ribs;
- ribbons;
- crenulations
- mesh;
- protrusions; and combinations thereof.

6. A composite panel assembly according to any preceding claim wherein the latent heat storage material layer further comprises a heat conducting matrix material.

7. A composite panel assembly according to Claim 6 wherein the heat conducting matrix material comprise a matrix selected from the group comprising:
- graphite;
- a powdered metal;
- a metal including powdered metal or metal fragments or strips;
- expanded metal foam;
- heat conducting plastics;
- carbon fibre; and combinations thereof.

8. A composite panel assembly according to any preceding claim wherein the latent heat storage material comprises up to 99% by weight phase change material.

9. A composite panel assembly according to Claim 8 wherein the latent heat storage material comprises 30% - 95% by weight phase change material.

10. A composite panel assembly according to any proceeding claims wherein the heat storage capacity of a 20 mm thick panel is in the range 300 – 3500 kJ/m².
11. A composite panel assembly according to any preceding claim wherein the panel front further comprises one or more panel edges, said panel edges depending from the first face of the panel front or from the opposing second face of the panel front.

12. A composite panel assembly according to Claim 11 further comprising a lid, the panel front, panel edges and lid forming an encasement.

13. A composite panel assembly according to Claim 12 wherein the lid is bonded to or otherwise attached to the panel front and/or panel edges.

14. A composite panel assembly according to Claim 12 wherein the lid is bonded to the latent heat storage material layer.

15. A composite panel assembly according to any preceding claim further comprising a tegular edge, enabling the panel to sit in a ceiling grid.

16. A composite panel assembly according to any preceding claim wherein the panel assembly comprises a structure selected from the group comprising:-
   a ceiling tile, including an acoustic ceiling tile;
   a floor tile;
   a raised access/computer floor tile;
   a chilled ceiling panel;
   a wall panel;
   a panel for use in heat exchange systems;
   a desk surface;
   a work surface;
   a sleeve e.g. for heating and ventilation pipes;
   an encasement.

17. A composite panel assembly according to any preceding claim further comprising one or more tubes adapted to carry a cooling or heating fluid, wherein the tube(s) pass through the latent heat storage material layer.
18. A composite panel assembly according to any preceding claim further comprising an insulating layer.

19. A composite panel assembly according to Claim 18 wherein the insulating layer is located on the side of the latent heat material layer furthest from the panel front.

20. A composite panel assembly substantially as herein described, with reference to and as illustrated in any combination of the accompanying drawings.

21. A process for the manufacture of a composite panel assembly according to any of Claims 1 to 20 inclusive comprising the steps of:-
(a) providing a first panel element and a plurality of support elements;
(b) providing a phase change material in a binder in an unset form;
(c) locating the plurality of support elements adjacent to the first panel element;
(d) substantially surrounding the support elements with the phase change material and allowing it to set, wherein the support elements are embedded in the latent heat storage material layer to provide structural support to the phase change material.

22. A process according to Claim 21 comprising the step of:-
(e) providing and fitting a second panel element over the phase change material/support elements combination and optionally securing the second panel element to the first panel element.

23. A process for the manufacture of a composite panel assembly according to any of Claims 1 to 20 inclusive comprising the steps of:-
(a) providing a first panel element and a plurality of support elements;
(b) securing the support elements to one face of the first panel element;
(c) providing a second panel element with upstanding edges which, in combination, form a shallow tray;
(d) substantially filling the tray with a phase change material in a binder in unset form;
(e) placing the first panel element over the second panel element such that the support elements become embedded in the phase change material to provide structural support to the phase change material.
24. A process for manufacturing a composite panel assembly according to any of Claims 1 to 20 inclusive comprising the steps of:-

(a) providing a tile comprising a tray element and, optionally, a back or lid element;
(b) providing a plurality of support elements with a latent heat storage material precast around the support elements, wherein the said support elements provide structural support to the latent heat storage material, in a size and shape that will fit into said tray element;
(c) placing a binder cement layer into the bottom of said tray element;
(d) placing the precast element from step (b) into the tray element.

25. A process according to Claim 24 comprising the step of:-
(e) fitting the back or lid element.

26. A process for manufacturing or refurbishing a composite panel assembly substantially as herein described, with reference to and as illustrated in any combination of the accompanying drawings.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

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<th>Category</th>
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Categories:

- X: Document indicating lack of novelty or inventive step
- Y: Document indicating lack of inventive step if combined with one or more other documents of same category.
- &: Member of the same patent family
- A: Document indicating technological background and/or state of the art.
- P: Document published on or after the declared priority date but before the filing date of this invention.
- 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
- E04C; F28D

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

- EPODOC, WPI

International Classification:

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