A wall, ceiling, or structural insulated panel having macroencapsulated phase-change materials incorporated therein.
FIG. 6
PHASE-CHANGE STRUCTURAL INSULATED PANELS AND WALLS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] None.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] None.

FIELD OF THE INVENTION

[0003] The present invention relates to structural walls and ceilings, and more specifically to a structural insulated panel and wall having macroencapsulated phase-change materials incorporated therein.

DESCRIPTION OF RELATED ART

[0004] In the construction of various types of buildings, the walls, roofs, ceilings and floors are typically designed to thermally insulate the space enclosed thereby. In this regard, a variety of different construction techniques have been devised.

[0005] Conventional frame construction is widely employed in residential and other types of construction. Typically, a wood frame for the structure is constructed with load-bearing walls comprising studs, top and bottom plates, and headers over the openings. Floor and ceiling joists span between the walls. During or after the framing stage, sheathing is typically applied to the exteriors of the walls. The walls are then insulated with, for example, fiberglass insulation for controlling thermal conduction therethrough. Insulation is also typically placed between the ceiling joists or roof rafters and between the floor joists over unheated areas. The wall interiors generally comprise a layer of drywall, gypsum board, paneling or the like.

[0006] In recent years, structural insulated panels ("SIPs"), "foam-core panels," stress-skin panels, sandwich panels, or structural foam panels have gained increasing acceptance in building construction in replacing the conventional combination of drywall sheets and rolls of fiberglass insulation. The typical SIP includes an inner insulating core and two outer sheathings comprised of a rigid material such as gypsum or cementitious composite, waferboard, metal, plywood, drywall, oriented strand board ("OSB"), or an agricultural board product such as strawboard. See generally Babcock et al., U.S. Pat. No. 6,256,960; Porter, U.S. Pat. No. 5,842,314; Parker, U.S. Pat. No. 4,628,650. SIPs have several advantages over conventional frame construction. First, the use of panels permits the closing of a building in a week’s time (or less) depending on the size of the building. This promotes faster, easier, and lower cost methods of erecting structures. For example, a 2,000-ft² (186 m²) house can usually be erected in less than 3 days. This avoids delay costs and waste and/or losses that result from weather and pilfering of materials lying around. SIPs also provide design flexibility because panels can be manufactured in sizes, typically ranging from about 4 to 24 feet (about 1.2 to 7.3 m). This in turn can save time on engineering and design costs. The use of SIPs also makes the walls stronger, and the buildings more airtight, thereby making them more comfortable, energy efficient, and quieter.

[0007] Even more recently, to improve energy efficiency, phase-change materials ("PCMs") have been imbibed into plywood boards and gypsum boards themselves. See Rudd, Phase Change Material Wallboard for Distributed Thermal Storage in Buildings (1993); Saylor et al., A Review of Phase Change Materials Research for Thermal Energy Storage in Heating and Cooling Applications at the University of Dayton from 1982 to 1996 (1997). However, the imbibed method results in increased flammability of the boards. In addition, the PCMs are often wax-like materials, which decrease the permeability of the board to water vapor, thereby increasing humidity problems indoor. Lastly, the application of paints and other coatings or finishes to the imbibed PCM boards is often problematic.

[0008] The present invention is directed to a phase-change structural insulated panel or wall in which the PCM is macroencapsulated between the two sheathings. The present invention provides a lightweight, high strength, insulated panel which is easily fabricated, modified and installed. The panel also has decreased flammability and coatability as compared to imbibed phase change boards. In fact, the panels of the present invention do not compromise the mandated 15-minute fire rating for SIPs.

BRIEF SUMMARY OF THE INVENTION

[0009] It is an object of the present invention to provide a lightweight, high strength, PCM structural insulated panel.

[0010] It is a further object of the present invention to provide a PCM structural panel that has decreased flammability.

[0011] Yet another object of the present invention is to provide a PCM structural panel that can accept common coatings and finishes, such as paints.

[0012] Still a further object of the present invention is to provide a PCM panel that does not significantly affect the water vapor transfer across the panel.

[0013] It is still another object of the present invention to provide a wall having macroencapsulated PCMs therein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 illustrates an exploded view of a phase-change structural insulated panel in accordance with the present invention.

[0015] FIG. 2 is a cross-section of the panel illustrated in FIG. 1.

[0016] FIG. 3 is a cut-away perspective view illustrating how the macroencapsulated PCMs are incorporated into a SIP by heating a housing containing the PCMs or by removing a volume of the core of about equal volume to the pipe.

[0017] FIG. 4 illustrates a wall having macroencapsulated phase-change materials in accordance with the present invention with the exterior sheathing removed.

[0018] FIG. 5 shows how the phase-change structural insulated panels of the present invention incorporated the capsules into a test house.

[0019] FIG. 6 summarizes the wall heat fluxes depicting the potential demand reduction of PCM-enhanced wall
panels. The data plotted are from a west-facing panel with 4 inch (10.2 cm) of insulation and 10% PCM by OSB weight.

**DETAILED DESCRIPTION OF PREFERRED EMBODIMENT**

[0020] Referring to FIGS. 1-2, a structural panel in accordance with the present invention is shown. Structural panel 10 includes first and second sheathings 20 and 22 disposed on and affixed to opposed outer surfaces of a generally planar, insulating core 30. One or more PCMs 40 are macroencapsulated between the sheathings 20, 22.

[0021] Various types of sheathings 20, 22 are known to those skilled in the art. The sheathing is preferably comprised of a rigid material such as gypsum or cementitious composite, waferboard, metal, plywood, drywall, OSB, or an agricultural board product such as strawboard or wheatboard. Most preferably, the sheathing comprises OSB.

[0022] The sheathings 20, 22 of the present invention are of any suitable thickness. The sheathing is preferably an expanded polystyrene (“EPS”). Other suitable materials include, but are not limited to, molded expanded polystyrene (“MEPS”), extruded polystyrene (“XEPS”), expanded polystyrene (“EPS”), urethane, polyurethane and isocyanurate, fiberglass, cementitious or fibrous core insulating materials, and compressed straw insulation.

[0023] The insulation 30 of the present invention can be of any suitable thickness. The insulation preferably has a thickness between about 1.25 to 3 inches (7.18 mm to 7.62 cm), more preferably between about 0.25 to 2 inches (6.35 mm to 5.08 cm), and most preferably about 0.5 to 0.75 inches (1.27 to 1.91 cm). Common commercially available sheathing material has a thickness of about ⅛th, ⅜th, and ⅝th inch (1.11, 1.27, 1.90, and 2.54 cm).

[0024] The insulation can be of any suitable thickness. The insulation preferably has a thickness between about 1.25 to 3 inches (2.54-8.1 cm), more preferably between about 2 to 3 inches (5.08-7.62 cm), and most preferably between about 0.25 to 3 inches (7.62-17.78 cm). Commercially available insulation usually has a thickness ranging between about ⅛th to 11⅛ inches (0.21-28.89 cm).

[0025] The first and second sheathings 20, 22 are preferably attached to the respective opposed facings of the panel’s insulating core 30 by any of the more conventional adhesive materials such as urethane or epoxy cement, glue or a mastic coating (not shown). It will be appreciated that the panel 10 may be constructed with sheathing only on one face of the panel with the insulating core 30 exposed. Such panels are well suited for unfinished warehouses and unfinished basements. In such an embodiment, the other sheathing is preferably added as or after the panel 10 is installed in the building.

[0026] Suitable PCMs 40 within the scope of the present invention include but are not limited to solid-to-liquid PCMs. The PCM materials preferably change from solid to liquid and back to solid as a function of the wall temperature. The PCMs preferably have their solid-to-liquid transition between about 72°F and 86°F (about 22°C and 30°C).

[0027] Suitable inorganic PCMs 40 include water, sodium sulphate, decahydrate, calcium chloride hexahydrate, sodium acetate trihydrate, quaternary ammonium/water clathrates or mixtures thereof. Organic solid-to-liquid PCMs include linear crystalline alkyl hydrocarbons, polyethylene glycols, pentaerythritol, pentaglycerine, neo pentylglycol, acetamide, tetrahydrofuran, butyl stearate, butyl palmitate, lauric acid, capric acid, and other fatty acids and esters, primary long chain alcohols, or mixtures thereof. Silica gels can also be used to help reduce problems with leakage and volume change.

[0028] Most preferably, the PCMs 40 are selected from the group consisting of paraffin hydrocarbons, salt hydrates, fatty acids and eutectic mixtures, fatty alcohols, and neopentyl glycol. Preferred PCMs are commercially available from Rubitherm GmbH (Hamberger, Germany) and sold in the United States by Energy Storage Technologies (Dayton, Ohio). A most preferred PCM is RUBITHERM® R-26.

[0029] The PCMs 40 of the present invention are macroencapsulated between the sheathings 20, 22 in a housing 45. In the preferred embodiment, as illustrated in FIGS. 1-3, the PCM is macroencapsulated in a housing 45 comprising a tube. The tube may be of any suitable size but preferably has a diameter of between about 0.5 inch and 3 inch, and most preferably about 1 inch. The tube 45 is preferably capped at one or both ends 42 to prevent leakage. The housing is comprised of any suitable material, such as PVC, copper, aluminum, and the like.

[0030] The housing 45 containing the PCM is oriented in any suitable manner, e.g. horizontally, vertically, diagonally, or any variation thereof. As illustrated in FIGS. 1-3, the housing is most preferably oriented horizontally within the panel 10. Further, the housing 45 may be oriented between the sheathings 20, 22 in any suitable manner, e.g. centered, proximal to the outer sheathing, directly adjacent the outer sheathing, proximal to the inner sheathing, directly adjacent to the inner sheathing. Most preferably, as illustrated in FIGS. 1-3, the housing 45 is in close proximity to the internal sheathing 22. The housing containing the PCM may span all or part of the length, L, of the panel 10.

[0031] As shown in FIG. 3, the housing 45 containing the PCM 40 is preferably positioned between the sheathings 20, 22 by heating the housing 45 or by cutting a volume of insulation 30 similar to the volume of the housing so that the insulation 30 is removed (by melting or cutting) upon contact with the heated housing 45. As such, the insulation 30 itself can support the housing 45 without the aid of additional materials. Alternatively, brackets, screws, and conventional adhesive materials such as urethane or epoxy cement, glue or a mastic coating can be used to position the macroencapsulated PCM 40.

[0032] A suitable amount of PCM is encapsulated in the structural panel. The PCM preferably comprises about 5 to 30%, and most preferably about 10 to 20% of the weight of the sheathing of the panel 10. It will be appreciated that this percentage is useful to compare the amount of macroencapsulated PCM in the panels and walls of present invention to conventional boards in which the PCM is imbibed in the board and therefore % PCM was expressed as a percentage of the overall board weight.

[0033] The panels 10 of the present invention are used in buildings in a manner well known to those skilled in the art for SIPs. See generally Morley, Michael, 2000, Structural
Insulated Panels (SIPs), The Taunton Press, Newborn, Conn., which is incorporated by reference. For example, a 12-foot (3.66 m) wall can have two 6-foot (1.83 m) panels of the present invention located between 2×4 (5.08×10.2 cm), 2×6-inch (5.08×15.2 cm) or other studs about 12 feet apart.

[0034] Structural panel 10 is shown as generally rectangular in shape, but may assume virtually any of the more common shapes assumed by structural panels in building construction. The phase-change structural panels 10 of the present invention are preferably custom manufactured to meet building specifications. Common sizes on structural panels that are commercially available range from about 4 ft×8 ft (1.22 m to 2.44 m) to about 8 ft×24 ft (2.44 m to 7.32 m).

[0035] In a second embodiment of the present invention, the macroencapsulated PCMs 40 of the present invention are incorporated into conventional walls 100, as opposed to the structural insulated wall panels 10 of the first embodiment. As illustrated in FIG. 4, as is typical in wall construction, a plurality of substantially vertical splines 50 are preferably spaced about every 10 to 20 inches (25.4 to 50.8 cm), even more preferably about every 14 inches (35.6 cm). The splines 50 are typically 2×4 inch (5.08×10.2 cm) wood studs, but can be any suitable size and material, such as metal I- or H-beams. Insulation 30 resides between the splines. Sheathing 20, 22 are attached to the splines in a conventional manner.

[0036] The macroencapsulated PCMs 40 of the present invention are positioned between one or more of the splines 50 using any suitable means. As shown in FIG. 4, the PCMs are preferably housed in a housing comprised of a copper pipe that is suspended from the splines 50 using a bracket 49. Those skilled in the art will appreciate that the housing 45 containing the PCMs 40 could be positioned in holes drilled through the splines 50; however, this approach is not preferable because it may decrease the structural stability of the splines. As discussed above, the PCMs are preferably positioned near the inner sheathing 22 and are horizontal; however, any suitable orientation and position may be utilized.

[0037] FIG. 5 illustrates an unfolded-box type test house using the macroencapsulated PCMs of the present invention in the walls 100. Preliminary findings from research conducted at the University of Kansas show that the integration of PCMs in insulated frame walls offer the potential to reduce wall peak heat flux by as much as about 40 percent based on wall orientation, quantity of PCM used, and wall insulation level.

[0038] More specifically, a test house with dimensions illustrated in FIG. 5 was constructed. The splines were comprised of 2×4-inch (5.08×10.2 cm) pine. PCMs comprising linear crystalline alkyl hydrocarbons, or paraffin wax, commercially available under the trade name of RT-26, which is manufactured by Rubitherm GmbH (Hamberger, Germany) and sold in the United States by Energy Storage Technologies (Dayton, Ohio), were placed into copper pipes capped at both ends with closed-ends copper caps. The macroencapsulated PCM pipes were then placed horizontally and secured to the studs with steel brackets and into the fiberglass insulation having a thickness of 4 in. (10.2 cm). Both sides of the wall were covered with OSB, manufactured by Georgia Pacific Corporation, and having a thickness of 0.5 in. (1.27 cm).

[0039] As a control, a wall of similar dimensions and construction without any macroencapsulated PCMs was constructed. Heat flux meters, Model 10, manufactured and calibrated by International Thermal Instrument Company (Del Mar, Calif.) were used to measure the energy transferred. As shown in FIG. 6, the maximum wall heat flux reduction recorded was about 40 percent, which occurred in the west-facing wall. The average wall heat flux reduction was 20 percent when all orientations were taken into account when 10 percent of PCM (by OSB weight) was used. The peak heat flux reductions were lowest in north-facing walls. Total heat transferred across the envelope over a seven-day period was reduced by approximately 14 percent. The reductions were highest in west-facing walls (19 percent) and least in north facing walls (8 percent).

[0040] While specific embodiments have been shown and discussed, various modifications may of course be made, and the invention is not limited to the specific forms or arrangement of parts and steps described herein, except inssofar as such limitations are included in the claims. Further, it will be understood that certain features and sub-combinations are of utility and may be employed without reference to other features and sub-combinations. This is contemplated by and is within the scope of the claims.

What is claimed and desired to be secured by Letters Patent is as follows:

1. A structural panel comprising:
   a first sheathing disposed on a first outer surface of an insulating core; and
   a macroencapsulated phase change material positioned within said insulating core.

2. The structural panel of claim 1 further comprising a second sheathing disposed on a second outer surface of said insulating core, said second outer surface opposing said first outer surface, and

   wherein said insulating core is positioned between said first sheathing and said second sheathing.

3. The structural panel of claim 1 wherein said first sheathing is comprised of a material selected from the group consisting of oriented strand board gypsum, waferboard, metal, plywood, drywall, oriented strand board, strawboard and wheatboard.

4. The structural panel of claim 1 wherein said insulating core is comprised of a material selected from the group consisting of polystyrene, urethane, polyurethane, isocyanurate, fiberglass, and straw insulation.

5. The structural panel of claim 1 wherein said first sheathing is affixed on said first outer surface of said insulating core using a material selected from the group consisting of urethane cement, epoxy cement, glue and mastic.

6. The structural panel of claim 1 wherein said macroencapsulated phase change material is one or more solid-to-liquid phase change materials.

7. The structural panel of claim 1 wherein the macroencapsulated phase change material has a solid-to-liquid transition between about 72° F. and 86° F. (22° C. to 30° C.).
8. The structural panel of claim 1 wherein the phase change material is macroencapsulated in a housing.

9. The structural panel of claim 8 wherein said housing comprises a tube.

10. The structural panel of claim 9 wherein said tube is capped at both ends.

11. The structural panel of claim 8 wherein the housing is comprised of a material selected from the group consisting of PVC, copper, and aluminum.

12. The structural panel of claim 8 wherein said housing is orientated substantially horizontally within the panel.

13. The structural panel of claim 8 wherein said housing is proximal to the first sheathing.

14. The structural panel of claim 8 wherein said housing is substantially centered between said first and second sheathings.

15. The structural panel of claim 1 wherein said panel is substantially rectangular in shape.

16. A wall comprising:
   a plurality of spines; and
   a macroencapsulated phase-change material positioned between at least two of said spines.

17. The wall of claim 16 further comprising insulation between at least two of said spines.

18. The wall of claim 17 wherein said insulation is comprised of a material selected from the group consisting of polystyrene, urethane, polyurethane, isocyanurate, fiberglass, and straw insulation.

19. The wall of claim 16 wherein at least two of said spines are substantially vertical.

20. The wall of claim 16 further comprising a sheathing positioned over at least two adjacent spines.

21. The wall of claim 20 wherein said sheathing is comprised of a material selected from the group consisting of oriented strand board gypsum, waferboard, metal, plywood, drywall, oriented strand board, strawboard and wheatboard.

22. The wall of claim 16 wherein said macroencapsulated phase change material is one or more solid-to-liquid phase change materials.

23. The wall of claim 16 wherein the phase change material has a solid-to-liquid transition between about 72°F and 86°F (22°C to 30°C).

24. The wall of claim 16 wherein the phase change material is macroencapsulated in a housing.

25. The wall of claim 16 wherein said housing comprises a tube.

26. The wall of claim 25 wherein said tube is capped at one or both ends.

27. The wall of claim 24 wherein the housing is comprised of a material selected from the group consisting of PVC, copper, and aluminum.

28. The wall of claim 24 wherein said housing is orientated substantially horizontally.

29. The wall of claim 24 wherein a first and second sheathing are positioned on opposing sides of at least two adjacent spines, and said macroencapsulated PCM is proximal to the said first sheathing.

30. The wall of claim 16 wherein said wall is substantially rectangular in shape.

31. A method for constructing a wall or wall panel comprising:
   providing an insulating core for said wall; and
   inserting a macroencapsulated phase change material within said insulating core.

32. The method of claim 31 wherein said insulating core is comprised of a material selected from the group consisting of polystyrene, urethane, polyurethane, isocyanurate, fiberglass, and straw insulation.

33. The method of claim 31 further comprising the step of providing a sheathing over at least one surface of said insulating core.

34. The method of claim 33 wherein sheathing is comprised of a material selected from the group consisting of oriented strand board gypsum, waferboard, metal, plywood, drywall, oriented strand board, strawboard and wheatboard.

35. The method of claim 31 wherein said macroencapsulated phase change material is one or more solid-to-liquid phase change materials.

36. The method of claim 31 wherein the phase change material has a solid-to-liquid transition between about 72°F and 86°F (22°C to 30°C).

37. The method of claim 31 wherein the phase change material is macroencapsulated in a housing comprising a tube.

38. The method of claim 37 wherein the housing is being comprised a material selected from the group consisting of PVC, copper, and aluminum.

39. The method of claim 37 wherein said housing is orientated substantially horizontally.

40. The method of claim 37 further comprising the step of positioning a first and second sheathing over said insulating core such that said macroencapsulated phase change material is proximal to said first sheathing.

41. The method of claim 31 wherein said macroencapsulated phase change materials are inserted by heating a housing containing the phase change materials and then melting the insulation of said insulating core.

42. The method of claim 31 wherein said macroencapsulated phase change materials are inserted by cutting away a portion of said insulating core.

43. The method of claim 31 further comprising the step of providing a plurality of spines whereby said insulating core containing said macroencapsulated phase change materials is positioned between at least two of said spines.

44. The method of claim 43 further comprising the step of securing said macroencapsulated phase change materials to said two spines.

45. The method of claim 44 wherein said securing step comprises attaching a bracket to said spines for holding said macroencapsulated phase change materials.