HIGH STRENGTH LIGHT-WEIGHT FIBER ASH COMPOSITE MATERIAL, METHOD OF MANUFACTURE THEREOF, AND PREFABRICATED STRUCTURAL BUILDING MEMBERS USING THE SAME

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ABSTRACT

A prefabricated structural building panel is disclosed. The panel includes a first sheet having inner and outer planar surfaces. A plurality of structural ribs are disposed on the inner surface of the first sheet and are interconnected to form a geometric design having a plurality of chambers. The first sheet and the structural ribs are integrally formed as a single unit from a fiber and fly ash composite material. In preferred form, the cement composite includes a mixture of a commercial grade fly ash having a high lime content and a dry flue-gas desulfurized fly ash.
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RELATED APPLICATIONS

[0001] This is a continuation-in-part of co-pending U.S. patent application Ser. No. 09/552,849, filed Apr. 20, 2000, the contents of which are specifically incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates generally to the field of prefabricated building or construction materials and, more particularly, to prefabricated wall, roof, floor and decking panels. Specifically, the present invention relates to prefabricated building panels that are lightweight and environmentally friendly by utilizing recycled waste materials to produce a green, low-cost family of products with superior strength characteristics and the composite material therefor.

[0004] 2. Description of the Prior Art

[0005] The present invention pertains to the production of structural insulated panels (SIP) in a highly advantageous and inexpensive manner and pertains in particular to the use of fiber and fly ash cement composites to produce such panels. More than 50 million tons of fly ash are produced in the United States as a result of the electrical energy generation process. Utilities generally dump the waste material into ponds to hydrate over a period of months and years. Although approximately 25 percent of this material is used, the rest remains waste material at this time. The present technology enables this waste material to be utilized as a main component in a hydraulic cement capable of high strength and performance. Examples of such cementitious products are illustrated in U.S. Pat. Nos. 5,714,002, No. 5,714,003 and No. 5,352,288.

[0006] There is a tremendous problem in the world today of having to deal with the disposition of waste material. Landfills are becoming filled, and the burden on prime natural resources is increasing. By recycling waste materials, the pressure on landfills, air pollution and the like are reduced. At the same time, trees are saved, and waste materials, such as used carpeting and fly ash, may be reclaimed and put to use.

[0007] Many different techniques are used in the building industry for construction. In the United States, perhaps the most common is the frame or stick building. However, there are numerous other techniques and materials, such as various types of concrete block with various insulation performance, poured-in-place construction, panelized construction, tilt-up panels, poured-in-place concrete panels, and brick structures. Examples of such systems include those disclosed in U.S. Pat. No. 5,581,969 and No. 5,729,936.

[0008] Block construction falls into two classes: mortar-based systems and mortar-less. Various block systems are available with many incorporating special insulation systems to improve thermal performance of a building. Most of these known block systems may also be constructed with reinforced steel in order to improve wind and earthquake performance as well as general building strength and durability. Most of these systems require both interior and exterior finishing, although there are numerous techniques where interior and exterior finishes such as painting can be applied with a minimum cost. Many block systems require internal plaster surfacing or the addition of drywall to the inside surface. Exterior siding or other finishing, such as stucco, is optional and will depend upon design requirements. In general, this type of construction yields a cost-efficient system that is often as good as a frame building, is more durable, has a higher appeal to quality buyers, is well understood by the building industry, and has good fire, moisture, rot, insect, wind, and earthquake performance. On the other hand, while insulation is generally minimally sufficient to meet code, it is not exceeded by much of a margin. In addition, construction time is about the same as or more than that for a frame building.

[0009] Frame buildings are generally low cost, relatively fast to construct, and widely used. There are many variations on frame building, but in general, it has limited fire and moisture performance, is subject to rot and insect attack, has modest energy efficiency, requires both internal and external treatment once the frame has been constructed, and has limited performance in high wind and earthquake regions unless special precautions are taken.

[0010] Pour-in-place concrete systems, particularly the more modern stay-in-place form systems, have good durability, good fire and moisture performance and are resistant to insects. With suitable reinforcing, these systems have reasonable performance in high-wind and earthquake regions. However, they generally require interior and exterior treatment after the structure has been erected, and insulation value is limited.

[0011] Panelized systems, particularly SIPs, have limited fire performance unless they are concrete based. Panelized concrete systems have similar performance and characteristics to block systems. The new panelized SIPs, consisting of a sandwich of two layers of oriented strandboard (OSB) with a layer of expanded polystyrene (EPS), seek to provide higher thermal performance than other building systems. However, they are less water and moisture resistant and can be subject to rot and insect attack. They also still require finishing, both on the interior and exterior of the structure. Their performance in high wind and earthquake conditions varies upon design but is generally considered to be good.

[0012] Consequently, there is still a need in the construction industry for a prefabricated wall, roof, floor and decking panel construction that meets all of the aforementioned objectives yet is lightweight, easy and inexpensive to produce, and takes advantage of environmentally expendable and recyclable materials rather than using limited natural resources.

SUMMARY OF THE INVENTION

[0013] Accordingly, it is one object of the present invention to provide a prefabricated structural building panel that has good durability, good fire and moisture performance, is resistant to insects and has reasonable performance in high-wind and earthquake regions.
It is another object of the present invention to provide high thermal insulation so that panels formed particularly for exterior walls and roofs exhibit good energy efficiency.

It is another object of the present invention to provide a prefabricated structural building panel that is environmentally friendly in that it utilizes fly ash and other materials that are environmentally disposable.

Yet another object of the present invention is to provide a prefabricated building unit that is capable of being manufactured in a continuous process so that it may be made in one large integral wall section.

Still another object of the present invention is to provide a prefabricated structural building panel that is stronger than concrete, has all of the construction advantages of concrete, yet is less than 25% of the weight thereof.

To achieve the foregoing and other objects and in accordance with the purpose of the present invention, as embodied and broadly described herein, a prefabricated structural building panel is disclosed. The panel includes a first sheet having inner and outer planar surfaces. A plurality of structural ribs are disposed on the inner surface of the first sheet and are interconnected to form a geometric design having a plurality of chambers. The first sheet and the structural ribs are integrally formed as a single unit from a fiber and fly ash composite material. In preferred form, the cement composite includes a mixture of a commercial grade fly ash having a high lime content and a dry flue-gas desulfurized fly ash.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings which are incorporated in and form a part of the specification illustrate preferred embodiments of the present invention and, together with a description, serve to explain the principles of the invention. In the drawings:

FIG. 1 is a front perspective view, with portions cut away, of one embodiment of a prefabricated panel constructed in accordance with the present invention;

FIG. 2 is a side perspective view, with portions cut away, of another embodiment of a prefabricated panel constructed in accordance with the present invention;

FIG. 3 is a front perspective view, with portions cut away, of yet another embodiment of a prefabricated panel constructed in accordance with the present invention;

FIG. 4 is a schematic illustrating one process which may be utilized in the panel manufacture of the present invention;

FIG. 5 is a top perspective view of a panel formed from the process of FIG. 4 and illustrating a honeycomb geometric structure therein;

FIG. 6 is a view similar to that of FIG. 5 but illustrating a geometric pattern of a series of offset rectangular boxes;

FIG. 7 is a view similar to that of FIG. 6 but illustrating a geometric pattern of a series of offset square boxes;

FIG. 8 is a view similar to that of FIG. 5 but illustrating a geometric pattern of a series of square boxes with no offset;

FIG. 9 is a front perspective view, with parts broken away, of an extruded structural building panel and/or siding and cladding panel constructed in accordance with the present invention and including substantially parallel interior channels;

FIG. 10 is a view substantially similar to that of FIG. 9 but illustrating the interior channels in the form of triangular cross-section;

FIG. 11 is a perspective view illustrating a panel constructed in accordance with the present invention in the form of a strip of building siding;

FIG. 12 is a perspective view of a wall panel section constructed in accordance with the present invention;

FIG. 13 is a perspective view similar to that of FIG. 12 but illustrating a one joining system incorporated into the edges thereof for connecting adjacent wall panels;

FIG. 14 is a perspective view similar to that of FIG. 13 but illustrating one dovetailed joint section and web joining the adjacent panels;

FIG. 15 is a perspective view similar to that of FIG. 14 but illustrating the joining of adjacent panels at right angles as represented by a corner web piece;

FIG. 16 is a cross-sectional view of a decking panel constructed in accordance with the present invention; and

FIG. 17 is a cross-sectional view of yet another decking panel embodiment constructed in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The cellular panel construction of the present invention is a combination of three technologies. It is a panel which utilizes a new process and material that can produce virtually all the components used for the fabric of a commercial or residential building, such as floors, walls, roof and roof tiles, doors, trim, decking and the like. This new product and process uses a preferably rapid-setting fiber cement composite in a process that forms a lightweight grooved, honeycomb or box structure that can be made in thicknesses varying from 8 mm (⅜ inch) to 150 mm (6 inches) or more. The honeycomb or other geometric shaped cells or chambers may be filled with an insulator, insulating foam, and/or aerated fly-ash cement, or simply left empty.

An example of this construction is illustrated in FIGS. 1-3. Referring to the FIGS. 1-3, a prefabricated structural building panel 10 includes a first sheet or planar element 12 and a second similar sheet 14. The panel 10 also includes a plurality of structural ribs 16 disposed on the inner surface 18 of the first sheet 12. The ribs 16 are preferably arranged in a geometric design to form a plurality of chambers 20. In one preferred form, the geometric design is a honeycomb structure as illustrated in FIGS. 1-3. A second plurality of structural ribs 22 are also provided and extend from the inner surface 24 of the second sheet 14. The
second ribs likewise form a geometric shape or design which creates a plurality of chambers 26. In preferred form, the first sheet 12 and the first ribs 16 are all formed as an integral unit, while the second sheet and ribs 14, 22 likewise are formed as an integral unit. In the embodiment illustrated in FIG. 1, the sheets 12, 14 are arranged facing each other so that the chambers 20 coincide with the chambers 26 to form enclosed enlarged chambers when the sheets 12, 14 are brought together.

[0039] In FIGS. 2 and 3, the honeycomb ribs 16, 22 are spaced from each other so as to form a central space 28 between the ribs 16, 22. The space 28 may remain empty or, as in the illustrated embodiments of FIGS. 2-3, an insulation material 30 may be positioned therein. In the illustrated embodiment, the insulation 30 also fills the pockets 20 and 26 along with the space 28. The insulation 30 may be any desired type of insulating material but is preferably selected from an insulating foam such as polyisocyanurate, polyurethane, polycyrene or aerated fiber fly ash. The insulation material selections are discussed in greater detail below.

[0040] The structural components of the panels of the invention are made from a fiber and fly ash composite. In preferred form, the composite material includes a mixture of fly ash, fly ash cement and fiber. In certain instances, fine aggregates can be added to the composite mixture. More preferably, the composite includes 24-99% fly-ash and fly ash cement mixture, 0-20% fine aggregate, and 1-12% fiber. The fiber may be cellulose or other materials, new or reclaimed, such as wood, carbon, metal, glass, and petrochemical or agricultural product fiber. Examples include corrugated cardboard and liner board, steel, polypropylene, a variety of agricultural fibers including kenaf, rice and wheat straw, and oil palm fronds, ash, black spruce, southern juniper, cedar, and other wood fiber.

[0041] The cement may be a preferably rapid-setting Portland cement, or preferably a cement based on fly ash, a waste product of the energy generation utilities. It may also be made from slag, rice-hull ash, as well as a host of other ashes. Two preferred embodiments of the cement are fly-ash cement based upon Powder River Basin (PRB) coal ash and fly ash from the SYNAG process developed at Western Research Institute, Laramie, Wyoming. A particularly preferred material is disclosed in the aforementioned patent references. The composite of the present invention is a unique material in that it draws upon three established technologies, implementing each and the combination of all of them in a new way, to produce a highly flexible, wide range of products that can be produced under an automated manufacturing system.

[0042] The third component of the present invention panel is insulation in the preferred form of aerated fly ash. Several companies such as Wehrhahn and Hebel in Germany have developed autoclave-based processes for cellular concrete, as this type of material is known. In this application we refer to aerated fly ash cement (AFA) or aerated fiber fly ash cement (AFFA). One company in Australia, Pan Pacific Engineering (PPE), has several licenses already established in the U.S. PPE does not require expensive autoclaving as part of its process. They are able to produce AFA weighing one-fifth the regular weight of solid concrete. Although the panels of the present invention can be filled with other insulation materials, AFA/AFFA is an ideal filler and also has some limited insulation value. In addition to PPE's process there are several other similar processes for aerating cement, including those developed by Cementitious Foam Insulation, Weedsport, N.Y. and Cellular Concretex, I.C.C., Roselle Park, N.J. The panels of the present invention are filled to a depth of typically between one-half and one inch with AFA or AFFA, depending on economics and required performance. AFA/AFFA provides a means of fixing screws and nails to the panels. Front and back panels may be cemented together and/or fixed together with an insulating layer of typically polyisocyanurate or polyurethane for greater strength and performance. In the alternative, they can be extruded to simultaneously produce a single integral unit. The panels of the invention can come finished with a texture, e.g., stucco, on the exterior face, primed and ready for painting. It requires no further cladding, making for a very high value panel at modest cost. The interior face is finished in a similar manner.

[0043] A wide variety of products can be formed using the present invention. In addition to the previously mentioned wall, roof and floor members, thin-section products such as doors, roof-tile panels, and trim can be made with the same process. These panels are made in complex forms. The same type of process is used for construction panels. Because these rib can be formed using very high strength materials, most of the component can be air, or filled with aerated cement or another insulator. This provides for very lightweight construction of very strong components. In addition, because the components are lightweight, they can be more easily and economically handled and installed on site. Transport costs are lower, too.

[0044] The same comments apply to a construction panel, which could easily measure in its finished form, 20 ft.x8 ft.x6 in. thick. Such a panel made in a solid material would weigh well over 7 tons. A panel made using the construction of the present invention has a weight of less than a quarter of this figure.

[0045] The fibers utilized in the present invention can be cellulose or other sorts, such as various plastics, fiberglass and the like. The fly ash can be of various grades, such as Powder River Basin (PRB), class-C fly ash, but also, using a different process, of other types and combinations as described in greater detail below. In the case of cellulose fiber, the present technology has the advantage of being capable of using fiber from renewable resources, such as agricultural crops like kenaf and other crops, as well as from the smaller limbs of trees that are not otherwise utilized for lumber. Where plastic fibers, such as polypropylene, are used, it is possible to use waste or recycled fiber from the carpet industry. As fiber color is of no importance for the manufacture of the present invention, this is advantageous in that it utilizes fiber that would otherwise be wasted or, at best, underutilized.

[0046] The invention can work with wastepaper and cardboard of all sorts, both cellulose and non-cellulosic fibers. Several preferred solutions are possible, depending upon the kind of ash used in the manufacture of the composite. In the preferred embodiment of this invention, a coarse polypropylene fiber such as that used in carpeting face yarn is used. These fibers must be clean and cut to length. Various cellulosic fibers may also be used, but these fibers must be prepared to insure compatibility with the cement being used.
The structural grids in these composite materials are produced from fiber fly-ash cement mixtures, in the preferred embodiments of this invention. These grids are held in place in a monolithic, one-piece panel by a foam binder, which also acts as insulation. The use of the fly-ash cement composite enables rapid setting of the grid and an environmentally friendly material. Fly-ash cement does not emit any significant amount of greenhouse gas into the atmosphere. Portland cement, on the other hand, emits one ton of CO₂ into the atmosphere for every ton of cement made. Therefore, there is a significant advantage to using the fly-ash cement as used in the composite of this invention.

The closest common art prior to the present invention is the SIP panel. These panels use flat sheets of OSB and an insulating sandwich to provide the structure. They do not include the finishing material, which is generally drywall on the interior surface and some form of siding on the exterior surface. The OSB boards are generally glued or attached as part of a spraying process in the case of polyurethane or polyisocyanurate. These two latter forms of insulation expand to produce an insulating sandwich between the two OSB boards. The present invention is substantially different from and a substantial improvement over that prior art, in that the two main component boards, interior and exterior, are manufactured with an integral grid pattern. This pattern provides considerable structural strength to the composite panel, even though the walls of the grid are relatively thin, typically 3-10 millimeters in thickness. Another feature of the present invention is that a layer of lightweight, aerated, fiber fly-ash composite or other cement is placed in the bottom of each chamber. Our composite panel enables a builder to fix nails and screws into the fiber fly-ash composite layers, the outer skin of the grid, and the aerated fly-ash composite layer in the bottom of the chamber just under the outer skin. In many ways it behaves like wood, and very little cracking results when a screw is driven into it. This invention provides a step forward in the art in that very complex structures can be produced. In the prior art, such complex, thin-walled structures have not been possible, resulting in much higher weight and considerably lower strength-to-weight ratio.

The present invention is also to be distinguished from various other kinds of SIPs. An important characteristic of the invention is the use of a belt-press molding process or an extrusion technique, which enable the material to be produced on a continuous basis. Another important characteristic of the material is that the insulation between the two structural components of the composite panel can be formed with cavities or chambers. These allow services, such as plumbing and electrical as well as HVAC, to be run through structures like floors or walls. In addition, an exterior cavity may be formed to allow for a primary and secondary moisture barrier. In the case of an exterior wall, a complex structure can be formed as a complete, integral wall unit including the exterior cavity. This is not found in any other SIP or construction panel that is manufactured as opposed to fabricated. Another feature of fly-ash cement is that it is resistant to sulfur attack. In addition, other features of the panel are that it is resistant to fire, moisture, rot, insects, high wind, and earthquakes. It has high-energy efficiency and may be rapidly constructed on site.

Referring now to FIG. 4, several forms of this invention produce material continuously. This is a substantial improvement over all of the prior art processes that are of a batch nature. The panels of the present invention are created by one of three primary process techniques, all of which produce panels of any desired size on a continuous basis. The building panel forming process of the invention is reasonably complex and state-of-the-art. Under computer control, material will be delivered to the mixing system in either process in the appropriate quantity and rate. To achieve both a uniform and continuous material, the fiber and fly ash composite is processed in a high-intensity mixing system.

Three preferred processes for forming the panel of the invention are possible including compression molding, specifically illustrated in FIG. 4. Extrusion die molding and injection molding. The illustrated process of FIG. 4 first conveys the material to an infinite-end, compression forming machine. This is similar to the two illustrated conveyor belts traveling parallel to one another. The material will be on the bottom system or belt, while the top system or belt contains the geometric pattern to be impressed into it. During the molding process, the material is held in compression until an initial set is reached and then released as the upper mold rotates away.

Another related belt method is best described as a single-use incorporated-mold system. In operation, a pattern of spheroids 40 of expanding foam are extruded directly onto an endless, moving, steel sheet 42 from an array of nozzles 44. The spheroids 40 adhere to the steel sheet 42, forming the geometric pattern of the mold. The fiber cement 46 is then applied over the spheroids 40, filling the voids between. A surface skin with a thickness from 0 to 75 mm can also be applied in this same process if desired. The rapid setting cement sets around the spheroids, locking them into position. As the steel belt 42 reaches its return roller 48, the formed sheet 50 containing the foam spheroids encapsulated by fiber cement would be directed onto another conveyance system 52, lifting it off the steel sheet used in the forming process.

Referring further to FIG. 4, an expanding insulating volume of material, typically but not necessarily, shaped as a sphere is deposited onto belt 42 via nozzle 44. These volumes of material form a mold which also acts as insulation in the final panel. The mold deposit expands to fill a spherical or other volume, while it is being drawn along the belt. Some distance down belt 42, a composite 46 of fly-ash cement mixed with fiber 46 is fed onto the belt via a fiber-cement discharge header. The fiber fly-ash cement mix is deposited on the insulating volumes of material, typically made from polyisocyanurate or polyurethane foam. The mix then travels under the second belt 54 which compresses the cement-laden belt 42. The length of belt 54 is chosen so as to allow sufficient time for the panel to be formed by the cement, and for the cement mix to set. At the end of belt 54 and belt 42, a separation blade 55 immediately above belt one cuts away the molded material which adheres to the steel, or other belt. A similar separation blade 56 ensures that no cement tracks around the guide drum holding belt 54. The formed, and still setting, panel 50 then moves onto belt 52 to complete the setting process.

FIGS. 5-8 illustrate four different geometric patterns that are readily formed as a part of the panel 10. FIG. 5 illustrates the honeycomb ribs 16 previously illustrated in
FIGS. 1-3. FIG. 6 illustrates a series of rectangular boxes 57 pressed out on a moving belt press, while FIG. 7 illustrates a similar series of boxes 58 but with square cross section. FIG. 8 illustrates a series of boxes 59 with no offset between consecutive lines of the 3-D structure. All of these structures of FIGS. 5-8 may be readily formed with a belt press system illustrated in FIG. 4. The different configurations of the cells in FIGS. 5-8 provide for different strengths in orthogonal directions, depending upon the requirements of the application to which the resulting panel is to be applied.

[0055] For each of these forms the product could be made complete with the backing sheet already formed to the box-shaped dividers, or the backing sheet could be added later, with the boxes or other structures open. Once the open structure is formed, a top sheet can be applied, or the spaces formed by the structure may be filled with an insulating material or low-density aerated fly-ash cement as discussed above.

[0056] In another preferred process embodiment of the invention, FIGS. 9-13 illustrate product examples formed by combining extrusion processing technology with a rapid setting fiber fly-ash cement composite. Conceptually, one could think of this production methodology as being the construction industry equivalent of profile extrusion of plastics and composites. One important aspect of extrusion die molding of the composition of the invention includes heating of the extrusion die, electrically or preferably using hot water, to shorten the setting time of the extruded composite structure. In this manner, the composite is heated upon exiting the die thereby accelerating the setting process of the composite structure once formed even beyond its normally quick setting time.

[0057] The illustrations of FIGS. 9-13 show a three-dimensional view of a strip of building wall or panel 31 (FIG. 9) or siding 32 (FIG. 11). These are simply two examples of the many applications of the invention. The exterior surface of panel 31 or siding 32 can be textured for aesthetic appeal as part of the extrusion process or by means of rollers, brushes and other similar means applied to the surface of the web emerging from the heated extruder or from the belt press of FIG. 4. The ribs 33 of the panel 31 are preferably elongated in form to create a plurality of parallel chambers or channels 38 therebetween in lieu of the pockets or chambers 20, 26 of the prior embodiments.

[0058] The panel of FIG. 11 illustrates a flange 34 incorporated along the edge of the siding 32 to allow for fixing of the siding panel to the building. The voids 36 extruded into the material between the ribs 33 in either FIG. 9 or 11 may be left empty or may be filled with an insulating foam such as polyisocyanurate, polyurethane, aerated fly-ash cement or another insulator or filler. The lower part of the drawing of FIG. 11 shows an indent 35 in the bottom of the lowest void 38 and how that fits on to the piece of siding situated immediately below it, locking the sections into place. Other products having similar features could be made using the invention. In a practical sense this would have been very difficult to manufacture in accordance with known prior art techniques because the drying time or setting time for Portland cement is several hours, and this would result in considerable sagging in the production of material containing voids such as the cross sections illustrated therein. By combining the use of rapid-setting fly-ash cement with an extrusion process, it is possible to produce cross sections such as that illustrated by the building siding in FIG. 11.

[0059] Another example of an extrusion using a rapid setting fiber based fly-ash cement is shown in FIG. 10. The panel 36 shows an overall oblong cross section panel or member with reinforcing sections or ribs 37 set at opposing angles along the internal length of the formed section. This results in a very high strength panel. The void 39 between the sections or ribs 37 may either be filled with an insulating or other foam or left empty. FIG. 9 shows another example of an extruded oblong panel section with adjacent closed channels 38 running the length of the panel.

[0060] By combining both panels 31 and 36 illustrated in FIGS. 9 and 10, and filling the space between such panels with, typically, several inches of insulating foam such as polyisocyanurate or polyurethane, complete full thickness panel 60 may be formed. FIG. 12 shows a wall panel 60 cross section where both attributes of the panel described in FIGS. 9 and 10 are embodied in a single panel. FIG. 12 shows a wall panel section 60 including the exterior wall section 64 and the interior wall section 62, with the edges joined by a web 66 creating a central void space 67. Webs 66 could be included in intermediate sections joining the interior and exterior panels. In practice, an exterior wall section 64 might comprise an external extruded section of approximately 1 inch thickness, followed by three to five inches of insulating foam such as polyisocyanurate or polyurethane in the space 67, followed by a 1 inch interior wall section 62. In this way an entire wall section could be extruded simultaneously.

[0061] FIG. 13 shows a wall panel 60 embodying the features illustrated in FIG. 12 but with the addition of a panel joining or connection system on the edges of the panel 60. The case illustrated in this FIG. 13 shows dovetail joint sections 70, 72 at the web edges 74, 78, respectively. FIG. 14 shows one example of a further extrusion of fiber fly-ash cement in an edge matching dovetailed joint section, designed to hold two panels 60, 80 together. The piece 82 may be separated along the centerline 84, forming two pieces 86, 88 that are bolted together at regular intervals 90, typically every 12 to 48 inches of length. This cases assembly of the entire structure. In addition, cement and/or sealant can be added along the length of the joining piece 82 to ensure a solid, sealed joint for the panels.

[0062] FIG. 15 illustrates a structural beam member 92 that may be used to join two panels 60, 80 at a corner. The corner joining piece 92 is extruded from fiber fly-ash cement composite and is designed to match the panel sections that it joins. The example shown in this FIG. 15 is simply one of many such corner joining systems that could be designed using the principles of the present invention. Again, such sections are impractical when made from Portland cement because of the extended setting time. When fiber fly-ash cement is used in the composite, the setting times are fast enough that no significant sagging occurs as long as the mix is dry enough. In this case the panels 60, 80 may be recessed at their edges so that a flange 94 on the edge of the corner joining member 92 can fit precisely to the recess (not illustrated) on the edge of the wall. In the case of an exterior panel, this will help to ensure that no moisture penetration takes place. It would also be possible to design trim such that it overlapped the wall joint and stood out from it as illus-
treated in FIG. 15. Many such variations are possible and are within the scope of the present invention.

[0063] FIG. 16 illustrates a decking panel 95 particularly useful in outdoor patios or decks. In this embodiment, the decking panel 95 includes an upper panel portion 96 and a lower panel portion 97. Longitudinal ribs 98 are disposed between the panel portions 96 and 97, all of which are constructed from the preferred composite material as described in detail below. A pair of flanges 102 and 104 are disposed along the longitudinal side edges of the decking panel 95. The flanges 102 and 104 are sized and shaped to permit a plurality of such panels 95 to be laid next to each other side to side and interconnected at their adjacent flange portions. In this manner, a plurality of such decking panels 95 may be interconnected to create a single large decking area using the present invention.

[0064] An alternate form of a decking panel 95 is illustrated in FIG. 17. In this form of the invention, the panel 95 includes an upper panel portion 96 and a plurality of longitudinal ribs 98. The longitudinal side edges 106, 108 of this particular embodiment each includes a pair of channels 110, 112 separated by an elongated tongue member 114. The channels 110, 112 and the tongue members 114 are designed for interconnection with other deck panels 95 utilizing connection rails 116. In preferred form, the rail 116 is in the form of a "T" bar having a top portion 118 for engaging the channels 112 beneath the associated tongues or lips 114. A base portion or rib 120 depends from the under surface of the top portion 118 to provide structural stability and strength for the connection rail 116 between adjacent panels 95.

[0065] The panel of the invention is designed in such a way that it is preferably produced on a continuous basis. That is to say, a structural panel can be produced in a continuous length with a given web width, preferably 10 ft. wide, using either of the preferred processes outlined above. Because the cement that is to be used in the preferred embodiment of the invention is a rapid-setting cement, the material that emerges from the downstream end of the belt press is already set. After it has traveled down the conveyor to the location of the cutting system on the manufacturing line, it is ready to be cut into either panels, whole walls, floors, or other components, complete with openings for windows, doors, or any other needs. This is one of the key advantages of the present invention.

[0066] In one embodiment illustrated in FIG. 4, walls preferably consist of two structural panels facing each other. This is accomplished in the production line because the computer system knows that the final wall being cut out has certain dimensions of the length and width plus various cut-outs for windows, doors and the like. It uses this information to cut off a length of the emerging structural panel suitable for the entire length of the wall, floor, or whatever is being made. It then cuts off an equal length of a further run of the structural panel. Each of the two panels are then filled with, preferably, a half-inch of aerated fiber fly-ash cement. Foam is then introduced to the panels after a suitable drying period, preferably fifteen minutes or more. All during this time, the cut and part-filled panels continue to move down the production line.

[0067] When the polyurethane foam, or other type of foam to be used for insulation, is introduced, the two panels are presented towards each other with their open cells facing each other as illustrated in FIGS. 1-3. The foam fills the entire cavity between the panels, acting to both insulate and bond the two panels together. The part-finished panel continues to move down the production line, which feeds back on itself so that it is located back at the cutting station, which in the preferred embodiment is an automated water-jet cutting system. The conveyor system must preferably move the material from the belt press through the initial cutting-to-length of the construction panels to the aerated-cement filling station, and then back on itself to the water-jet or other cutting system.

[0068] At this time, openings can be cut in the panels for windows and doors. If a secondary moisture barrier is required, sheet material made from fiber fly-ash cement composite may be fed from another press onto the finished panel before openings are cut for windows and doors. This material is fed onto the part-finished honeycomb panel's outer surface while it is still wet and capable of bonding. Mechanical means may be needed to press both the corrugated drainage cavity 100 (FIG. 2) and the exterior finished surface onto each other and the honeycomb panel.

[0069] In another preferred embodiment of the invention, panels extruded in sections of the type generally illustrated in FIGS. 12 and 13 may include an insulating foam. This foam may be produced by means of a co-extrusion process where, for example, polyisocyanurate or polyurethane liquid is fed through holes in the ends of an extrusion die during the formation of the hollow sections of the panels. In this manner, the hollow cavities may be both thermally insulated and strengthened by the bonding provided by the polyisocyanurate or polyurethane foam after it expands into the hollow formed sections. It is necessary to contain the sections thus formed in a press or other restraining means to ensure that the expanding foam does not distort the extruded sections. This is particularly true while the extruded composite cement is still setting. Once the extrusion has set, it is moved to the automated water-jet or other cutting system. At this location, the panel may be cut to length or be cut for openings for windows and doors as in the previously described embodiment.

[0070] In another embodiment of the invention, pillars separate the primary and secondary moisture barriers. These pillars can be made either from polyurethane or other similar foam, fly-ash cement, aerated fly-ash cement, or other cement. In FIG. 2, a corrugated drainage cavity 100 is provided.

[0071] The combination of the continuous production of honeycomb panel and a cutting system such as an automated water-jet cutting system is another key advantage of the present invention. It means that components are produced on a continuous basis and easily cut in an automated fashion precisely to the needs of the user. It would be quite possible for an individual architect to download an individual design to the cutting system in order to have a single unique wall or other component cut from the emerging assembled material.

[0072] The panel of the invention can be made in a variety of cell sizes, or hollow-section profiles and sizes, depending upon the application to which it is to be put. For interior walls, cell dimensions can be as little as 20 mm across and 20 mm deep. For a wall, roof or floor, cells of 75 mm or 100 mm may be desirable. For hollow extruded sections, cross-
sections may vary from a few mm across to hundreds of mm. For trim to the outside of a house, panels may only be 8 mm thick, with interior cell depths as little as 6 mm or less. Such panels can be used for siding or other trim pieces to be applied to the building. Other components, such as doors, can be manufactured from honeycomb panels that are typically 20 to 30 mm thick, resulting in an overall door thickness of 40 to 60 mm, for example. For extruded sections, which is the preferred method, entire doors can be made in a single drawing operation. These structures can be made in many different geometry’s, depending upon their purpose. Some components may require a greater fire rating and would therefore have a greater wall thickness or utilize aerated cement placed in the base of each honeycomb cell or extruded section. On the other hand, other components may be optimized for lightness, with very thin walls and without an aerated cement layer deposited in the honeycomb cells or extruded sections.

[0073] The present invention has developed a technology consisting of panels made with a thin-wall cellular or tubular structure to produce high strength and low weight, made from cellulosic or polymer fiber. The resulting hollow panels are incredibly strong and lightweight. The actual dimensions of the geometric structure are variable for the intended use. Wall and skin thicknesses as well as section or cell depth and geometry are dependent on the final use of the panel structure. There are several structures capable of filling the design requirements of the invention. These include cells or sections that form squares, spheroids, triangles, hexagons and other suitable patterns. Preferred wall thickness of the shapes can vary from about 2 mm to 20 mm, with cell depths from about 2 to 100 mm, and extruded cross sections from a very few mm to many hundreds of mm.

[0074] Some products that may be made from the present invention include lightweight construction wall, floor, deck- ing and roof panels and lightweight doors, trim and roof-tile panels. Each of these two generic product types is outlined briefly below. Planks come in various thicknesses, from 8 mm (3/4 inch) up, with finishes such as wood grain, smooth, etc., depending upon the application. Doors are typically two inches thick, made from extruded sections or back-to-back honeycomb panels. Wall and floor panels are similar in concept but are much thicker, typically three inches for cellular panels, and can be made back to back to form six-inch or greater building panels. For extruded wall sections, thickness is typically 3 to 8 inches, and typically 10 to 14 inches for roof and floor sections. Thicker sheets in general give better thermal insulation, fire-shield, and structural performance.

[0075] A small practical plant can manufacture from between 1 and 30 million square feet of panel a year, depending on panel thickness and complexity. If the present invention’s design objective of >50 percent fly ash based raw-material content of the production is achieved, significant quantities of this waste material can be put to productive use.

[0076] Referring now more specifically to the fly ash cement composite of the present invention, it has been shown herein that high lime (CaO) content cement, such as those manufactured by Mineral Resource Technologies, LLC (MRT) and ISG Resources (ISG), can be significantly improved in the composition of the invention by the addition of a dry flue gas desulfurized (DFGD) fly ash. Two types of DFGD were used in an experiment based on the sources of the desulfurized fly ash, designated Type F-DFGD and Type C-DFGD. Both types of DFGD, when combined with either of the above listed commercial fly ash cements, produced cement that was both lighter (less dense) and stronger. In some cases, as with a 33 wt % Type F-DFGD and 66 wt % MRT cement, the improvement in modulus of elasticity (MOE) was over 95%. The Class F-DFGD fly ash has a relatively low (12%) CaO content and a relatively high carbon content. These two factors should normally make this ash perform quite poorly as a cementitious material. However, when it was blended with commercially available fly ash cement, the Class F-DFGD fly ash provided exceptional strength increases. The Class C-DFGD fly ash mixes resulted in lower strength gains when compared to the Class F-DFGD fly ash mixes. Traditionally, Class C commercial grade fly ashes have provided a greater cementitious benefit to cement mixes. However, when it is mixed with the Class C-DFGD, this does not appear to be the case. The mechanism for both the strength increase with Class F-DFGD and lower strength gain with Class C-DFGD fly ash is uncertain at the present time.

[0077] This experiment example was designed to determine the effect of dry flue-gas desulfurized fly ash (DFGD) upon incorporation into commercial grade, fly ash based cement. The sample production procedure for the fly ash cement samples used in this example was standardized and adhered to the manufacturer’s specifications. The amount of activation ingredient was fixed relative to the amount of cement. For the MRT cement, the activator to cement ratio was 0.018, while the ISG cement required 0.1 wt % of the total cement mixture weight. The relative amount of DFGD fly ash in the total cement mixture varied by weight amount of the total cement mixture.

[0078] The initial step of this example was to blend the weighed proportions of DFGD fly ash and commercial fly ash cement by dry-mixing for 5 minutes. After the dry mixing, the chemical activators were added per the manufacturers instructions and allowed to mix for 4 minutes. The cement slurry was then placed into a mold and tamped into place such that each sample cavity was completely filled. The sample mold was then placed into a press which consolidated the samples through vibratory action for 90 seconds at 6 psi of pressure. The press pressure was then increased to 12 psi, and the samples were allowed to cure under pressure in the press. A portion of the cement mixture was then placed on a thermocouple and the temperature recorded digitally as the cement set.

[0079] From thermodynamics, it is known that thermal effects accompany phase transitions. In this example temperature data was used to view the cementitious reaction as it occurred. Once set, the samples were removed and allowed to cure in an ambient atmosphere for seven days. Physical testing was then done and the data analyzed. To test the overall effect of a DFGD fly ash included into a commercial fly ash cement mixture, an initial experiment was run for cement mixtures with DFGD fly ash to commercial cement ratios of 1:2 and 1:1 respectively. An analysis of the data showed a change in physical properties.
[0080] Before any DFGD fly ash was added to the commercial cements, the properties of the commercial cements were determined. MRT’s fly ash based cement gave average MOE values of 4.4 GPa and a density of 2.14 g/cm³, while ISG’s fly ash based cement gave average MOE values of 6.8 GPa with a density of 2.18 g/cm³. These values were set as relative values from which to measure any change in physical properties associated with addition of DFGD fly ash.

[0081] The results from the initial DFGD/commercial cement mixture trials showed a marked increase in strength properties and a decrease in density. The largest, average MOE value was 9.9 for a cement mixture that contained 33.3wt % Class F-DFGD fly ash and 66.6wt % ISG cement. This value corresponds to a 95% increase in MOE and was accompanied by an 8% decrease in density. This data set also indicates that lesser amounts of Class F-DFGD have a more drastic effect on the strength characteristics of the cement, i.e. stronger and lighter samples are made from cement mixtures with less than 50% Class F-DFGD fly ash. The results of the MRT cement Class C-DFGD experiments also indicated that a lighter, stronger sample can be made with less than 50% Class C-DFGD fly ash. Of the two DFGD fly ashes used in this particular example, the Class F-DFGD fly ash was capable of a much larger increase in MOE values. When mixed with the MRT cement in a two to one ratio, the increase in MOE was over 93% from the baseline MRT fly ash cement value. However, it was shown explicitly that incorporation of any DFGD fly ash into commercial fly ash cement increased the strength (MOE) of the resulting cement mixture and decreased the density.

<table>
<thead>
<tr>
<th>Mix</th>
<th>0%</th>
<th>33%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRT/Class F-DFGD</td>
<td>4.4</td>
<td>8.6</td>
<td>5.3</td>
</tr>
<tr>
<td>MRT/Class C-DFGD</td>
<td>4.4</td>
<td>5.8</td>
<td>5.1</td>
</tr>
<tr>
<td>ISG/Class F-DFGD</td>
<td>6.8</td>
<td>9.9</td>
<td>8.0</td>
</tr>
<tr>
<td>ISG/Class C-DFGD</td>
<td>6.8</td>
<td>5.7</td>
<td>6.9</td>
</tr>
</tbody>
</table>

[0082] There was a substantial increase in strength associated with the addition of DFGD fly ash into the ISG cement. The ISG and Class C-DFGD mixtures indicated that stronger cement can be made with larger amounts of Class C-DFGD fly ash. The true optimum ratio may lie between the two data points.

<table>
<thead>
<tr>
<th>Mix</th>
<th>0%</th>
<th>33%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRT/Class F-DFGD</td>
<td>2.18</td>
<td>1.94</td>
<td>1.83</td>
</tr>
<tr>
<td>MRT/Class C-DFGD</td>
<td>2.18</td>
<td>1.97</td>
<td>1.92</td>
</tr>
<tr>
<td>ISG/Class F-DFGD</td>
<td>2.00</td>
<td>1.90</td>
<td>1.80</td>
</tr>
<tr>
<td>ISG/Class C-DFGD</td>
<td>2.02</td>
<td>1.98</td>
<td>1.92</td>
</tr>
</tbody>
</table>

[0083] The density decreased with increased DFGD fly ash content. When compared with MOE values, it is clear that there is a decrease in density accompanied by an increase in strength.

[0084] The cementitious reaction that occurs with fly ash cement is exothermic and leaves a distinct thermal signature. On a temperature versus time plot, the initial set time corresponded to the beginning of the reaction curve, and the final set time corresponded to the maximum of this curve. By comparing the final set times for cement mixtures with various amounts of DFGD fly ash, an understanding of the reaction kinetics for cementization was ascertained. The ISG cements reacted quite vigorously, the steep slope of the time vs. temperature plot illustrating this point. The MRT cement reacted more slowly as was seen in the gradual slope of the time versus temperature plot. Thermal data from these experiments showed a reaction delay associated with addition of both types of DFGD fly ashes. For example, the final set time for ISG cement increased from 56 minutes in the raw form to 138 minutes at a 2:1 ISG cement to DFGD fly ash ratio. The same trend held true for MRT cements. There does not, however, appear to be any degradation in the overall intensity or strength of the reaction. The reaction was simply delayed. The mechanism for this is not known.

THERMAL EXAMPLE I

[0085] Sample Run #150: This represents thermal data for an ISG cement without DFGD fly ash. The sharp temperature rise at the set time is characteristic of ISG cements, possibly due to lack of retarders. The initial set occurred at 34 minutes, while the final set occurred at 55.7 minutes. These times are measured from the addition of the activator.

THERMAL EXAMPLE II

[0086] Sample Run #151: This particular experimental example represented thermal data for a 2:1 ISG cement to cement mixture. This illustrated that the cementitious reaction was no less intense with Class F-DFGD, only delayed. The initial set occurred at 108 minutes while the final set occurred at 138 minutes after the activator was added to the cement mixture.

THERMAL EXAMPLE III

[0087] Sample Run #152: This showed thermal data for an MRT cement with 33% Class F-DFGD fly ash. The gradual temperature rise at set time was characteristic of MRT cement, possibly due to the presence of retarders in the mix. Given the gradual slope of this curve, an initial set time was arbitrary, but the final set time, as indicated by the peak temperature, was reached 101.7 minutes after the activator was added.

[0088] During sample preparation, it was noted that the DFGD-added cement mixtures required more water relative to the pure commercial cement to reach the proper consistency. One possible reason for this phenomenon is the smaller particle size of the DFGD fly ash. A smaller particle size is analogous to a larger overall surface area and a larger surface area requires more water for wetting to occur. It is speculated that this smaller particle size also probably contributed to the increases in strength in that the small particles were capable of filling the interstitial spaces in the
commercial cement. According to documentation, cements with fewer or smaller interstitial spaces are typically stronger.

[0089] Notes From Particle Microscopy
[0090] Class F-DFGD
[0091] @80X magnification the scale calibrates to 0.01 mm/division
[0092] Large black particle: 0.05-0.06 mm in diameter
[0093] Black groundmass particles: 0.005-0.03 mm in diameter
[0094] White spherical particle (SiO₂): 0.035 mm in diameter
[0095] MRT Fly Ash Cement
[0096] @80X magnification the scale calibrates to 0.01 mm/division
[0097] Large amorphous white particle (CaO): 0.17 mm across
[0098] White sphere I: 0.04-0.05 mm in diameter
[0099] White sphere II: 0.07-0.08 mm in diameter
[0100] Groundmass particles: 0.005-0.02 mm in diameter
[0101] There is a much larger distribution of particle sizes in this mixture.
[0102] Dry, fly-gas desulfurized fly ash, when mixed with commercial fly ash cement, produced a fly ash cement that was stronger and lighter than commercially available fly ash cements. In one particular mixture of 33.3% Class F-DFGD and 66.6% ISG cement, the increase in MOE was calculated at 95% with an 8% reduction in density. The inclusion of a dry, fly-gas desulfurized fly ash into commercial fly-ash cement produced an increase in strength with a decrease in density. While it is not desired to be limited to this explanation, a possible mechanism for this effect may involve the smaller particle size distribution associated with DFGD fly ash. When smaller particles are incorporated into the commercial fly ash cement matrix, they may fill interstitial spaces and thereby relieve strain on the cement structure, causing fewer cracks to develop. A DFGD cement mixture also has a delayed thermal reaction profile, although there is no drastic difference in the intensity of the reaction.

[0103] As can be seen from the above, the present invention seeks to answer all of these different requirements of a building system in a single solution. It is a composite material combining the advantages of all of the systems referred to above. Because it is made from a cement, it should have good fire performance. For the same reason, its water, moisture and rot performance should be superior compared to frame or SIP. Its resistance to insect attack is also good, because it is a cementitious product. It is capable of very high energy efficiency with estimated R-values above 30 for a 6 inch wall. Because it can be constructed in large panels covering a whole wall or floor, construction time is half of other systems, such as frame buildings.

[0104] The present invention is a complete system. In the case of its being made into a wall, this wall requires no further interior or exterior treatment, other than painting. The interior surface is smooth and the joints may simply be taped and painted like drywall. The exterior surface can be made with a stucco, wood grain, or other surface or again may simply be painted. In addition, when design requires it, exterior surfaces, such as siding or other products, may be fixed to the wall if desired. It is believed that the high wind and earthquake resistance of these composite panels will be exceptionally high due to the fact that the panel is a composite structure and material.

[0105] Another major benefit of the present invention is that major components, such as floors, walls and roofs, may be manufactured as a continuous material. For example, in the case of an exterior wall, the material can be made complete, including structure, interior surface and exterior surface. A wall required for the exterior of a house, for instance, may be cut from material emerging at the end of the production line, using, for example, a five-axis, water-jet cutting system, computer-controlled and linked via the Internet to a remote CAD station located in an architect's or builder's office. It is believed that this capability is unique in the building industry. It will provide the construction industry with precision, factory-made, whole walls, floors and roofs on a very short time cycle, delivered to site for final erection and finishing. This continuous manufacturing is possible because the material used includes a rapid-setting, fly-ash cement as part of the composite in the preferred embodiment of this invention.

[0106] The foregoing description and the illustrative embodiments of the present invention have been described in detail in varying modifications and alternate embodiments. It should be understood, however, that the foregoing description of the present invention is exemplary only, and that the scope of the present invention is to be limited to the claims as interpreted in view of the prior art. Moreover, the invention illustratively disclosed herein suitably may be practiced in the absence of any element which is not specifically disclosed herein.

We claim:
1. A prefabricated structural panel for use in buildings comprising:
a first sheet having inner and outer planar surfaces, and
a plurality of structural ribs disposed on the inner surface of said first sheet and arranged to form a geometric design having a plurality of chambers, said first sheet and said structural ribs being integrally formed as a single unit from a fiber and fly ash composite material.
2. The panel as claimed in claim 1, wherein said panel further comprises a second sheet formed from said fiber and fly ash composite material and having inner and outer planar surfaces, said second sheet inner surface being integrally secured to said structural ribs to close said chambers.
3. The panel as claimed in claim 2, wherein said ribs are interconnected and said geometric design is a honeycomb.
4. The panel as claimed in claim 2, wherein said ribs are interconnected and said geometric design is a plurality of rectangular boxes.
5. The panel as claimed in claim 1, wherein said geometric design is a plurality of substantially parallel channels, the distal ends of each said channel being open.
6. The panel as claimed in claim 1, wherein said chambers are filled with insulation material.
7. The panel as claimed in claim 1, wherein said panel further comprises a second sheet formed from said fiber and
fly ash composite material and having inner and outer planar surfaces, said second sheet inner surface including a second plurality of structural ribs disposed thereon arranged to form a geometric design having a plurality of open chambers facing opposite the chambers of said first sheet structural ribs, said second sheet and said structural ribs being integrally formed as a single unit from a fiber fly ash composite material with said first sheet.

8. The panel as claimed in claim 7, wherein said panel further comprises an insulation layer interposed between said first and second sheets and filling the chambers of said geometric structural ribs of each said first and second sheets to form an integral prefabricated panel.

9. The panel as claimed in claim 7, wherein said panel further comprises a third sheet enclosing the structural rib chambers of said first sheet, and a fourth sheet enclosing the structural rib chambers of said second sheet, and wherein said panel further comprises an insulation layer interposed between said third and fourth sheets and filling the space therebetween, said first, second, third and fourth sheets being a single integrally formed extruded panel unit.

10. The panel as claimed in claim 9, wherein said insulation is aerated fiber fly ash.

11. The panel as claimed in claim 1, wherein said fiber and fly ash composite material is a lightweight, quick-setting cementitious material comprising fly-ash cement and organic or inorganic fibers.

12. The panel as claimed in claim 11, wherein said composite material comprises 24-99% fly-ash cement, 0-20% fine aggregate and 1-12% fiber.

13. The panel as claimed in claim 11, wherein the fiber of said composite material is selected from the group consisting of cellulosic fiber, PVA and polypropylene fiber.

14. The panel as claimed in claim 1, wherein said composite material comprises a blend of fly ash cement and flue-gas desulfurized fly ash.

15. The panel as claimed in claim 14, wherein said composite material further comprises said fly ash blend admixed with fibrous material.

16. The panel as claimed in claim 15, wherein said fibrous material comprises organic fibers.

17. The panel as claimed in claim 14, wherein said blend comprises 30-50% by weight of said flue-gas desulfurized fly ash.

18. A prefabricated building unit designed to form a wall, floor, ceiling or roof of a building, said building unit comprising:

a first panel element including a first sheet having inner and outer planar surfaces and a first plurality of structural ribs disposed on the inner surface thereof with said ribs being aligned to form a geometric design having a plurality of open chambers, said first sheet and said first structural ribs being integrally formed as a single unit from a fiber fly ash composite material;

a second panel element including a second sheet having inner and outer planar surfaces and a second plurality of structural ribs disposed on the inner surface of said second sheet with said second ribs being aligned to form a geometric design having a plurality of open chambers, said second sheet and said second structural ribs being integrally formed as a single unit from a fiber fly ash composite material; and

an insulation layer interposed between said first and second panels and filling the chambers of said first and second geometric structural ribs to form an integral prefabricated building unit.

19. The building unit as claimed in claim 18, wherein said first panel element further comprises a third sheet enclosing said first structural rib chambers of said first sheet, and wherein said second panel element further comprises a fourth sheet enclosing the chambers of said second structural ribs, said insulation layer being interposed between said third and fourth sheets and filling the space therebetween, said first, second, third and fourth sheets being a single integrally formed extruded panel unit.

20. The building unit as claimed in claim 19, wherein said the geometric design of said first plurality of structural ribs is different from the geometric design of said second plurality of structural ribs.

21. The building unit as claimed in claim 19, wherein the chambers of said first plurality of structural ribs remain open while the chambers of said second plurality of structural ribs are filled with said insulation.

22. The building unit as claimed in claim 18, wherein said unit includes a web means disposed along opposed side edges thereof for interconnecting adjacent building units.

23. The building unit as claimed in claim 18, wherein said composite material comprises a blend of fly ash cement and flue-gas desulfurized fly ash.

24. The building unit as claimed in claim 23, wherein said composite material further comprises said fly ash blend admixed with fibrous material of either organic or inorganic origin.

25. A prefabricated wall with inner and outer panels separated by insulation, each said panel comprising a sheet having inner and outer planar surfaces and a plurality of structural ribs disposed on the inner surface thereof with said ribs being arranged to form a geometric design having a plurality of open chambers, said sheet and said structural ribs being integrally formed as a single extruded unit from a fiber fly ash composite material.

26. The prefabricated wall as claimed in claim 25, wherein each said panel further comprises a second sheet formed from said fiber and fly ash composite material and having inner and outer planar surfaces, said second sheet inner surface being integrally secured to said structural ribs to close said chambers.

27. The prefabricated wall as claimed in claim 26, wherein said plurality of chambers disposed in said inner panel are filled with insulation.

28. The prefabricated wall as claimed in claim 27, wherein said insulation comprises aerated fiber fly ash.

29. A process for forming a prefabricated structural panel comprising the steps of:

forming a composite material comprising a fiber and fly ash composite;

forming an extrusion die, sized and shaped to extrude a panel structure of desired shape and geometry;

extruding said composite material through said die where there are a plurality of holes in the mold that allow insulation bonding material to be coextruded and simultaneously deposited into the panel structure as it is extruded;
extruding said composite material and insulation bonding material through said die onto a first conveyor belt; and
compressing said extruded composite with a second conveyor belt traveling substantially parallel with said first conveyor belt to restrain overexpansion of insulation bonding material until said composite structure has set.

30. The process as claimed in claim 29, wherein said extruded composite panel is unitary and integral.

31. The process as claimed in claim 29, wherein said fiber and fly ash composite is formed by admixing fly ash cement with flue-gas desulfurized fly ash to form a blended fly ash cement, and then further admixing fibrous material therewith.

32. A process for forming a prefabricated structural panel comprising the steps of
forming a composite material comprising a fiber and fly ash composite;
extruding or depositing said composite material onto the upper surface of a first conveyor belt onto which insulating volumes have been placed in a geometric pattern;
compressing said extruded or deposited composite material while on said first conveyor belt by pressing said extruded or deposited composite material with a second conveyor belt operating substantially parallel with and over the top of said first conveyor belt; and
removing said compressed composite material from said first conveyor belt onto a third conveyor belt to enable said compressed composite material to set and harden.

33. The process as claimed in claim 32, wherein the geometric pattern in the surface of said extruded composite material is formed by placing said geometric pattern onto the surface of said second conveyor belt so as to imprint the surface of said extruded composite material as the second conveyor belt is pressed into said material.

34. The process as claimed in claim 32, wherein the geometric pattern in the surface of said extruded composite material is formed by placing a pattern of spheroids onto the surface of said first conveyor belt prior to extruding said composite material onto said first belt so that the composite material is applied over said spheroids and fills the voids therebetween to form the predetermined geometric pattern.

35. The process as claimed in claim 32, wherein said fiber and fly ash composite is formed by admixing fly ash cement with flue-gas desulfurized fly ash to form a blended fly ash cement, and then further admixing fibrous material therewith.

36. An extrusion process of forming a prefabricated structural panel comprising the steps of:
forming a composite material comprising a fiber and fly ash composite;
forming an extrusion die, sized and shaped to extrude a panel structure of desired shape and geometry;
extruding said composite material through said die alone or in combination with insulation material to be used in conjunction with said composite material;
heating said die as said composite material is extruded therethrough to accelerate the setting of said composite once extruded; and
removing said extruded composite away from said die with a conveyor mechanism to permit said extruded panel structure to set and harden.

37. A low cost, lightweight cement composite having a high modulus of elasticity and a low density, said composite cement comprising a mixture of a commercial grade fly ash having a high lime content and a dry flue-gas desulfurized fly ash.

38. A cement composite as claimed in claim 37, wherein said commercial grade fly ash comprises a lime content of greater than approximately 20 wt. %.

39. A cement composite as claimed in claim 38, wherein said flue-gas desulfurized fly ash comprises approximately 30-50 wt. % of said fly ash mixture.

40. A cement composite as claimed in claim 37, wherein said cement composite further comprises fibrous material.

41. A cement composite as claimed in claim 40, wherein said composite comprises 24-99% fly-ash mixture, 0-20% fine aggregate and 1-12% fiber.

42. A cement composite as claimed in claim 41, wherein said flue-gas desulfurized fly ash comprises approximately 30-50 wt. % of said fly ash mixture.

43. A low cost light-weight cement composite having a high modulus of elasticity and a low density, said composite cement comprising a mixture of a commercial grade fly ash having a high lime content and a dry flue-gas desulfurized fly ash, and an organic or inorganic fibrous material.

44. A cement composite as claimed in claim 43, wherein said composite comprises 24-99% fly-ash mixture, 0-20% fine aggregate and 1-12% fiber.

45. A cement composite as claimed in claim 44, wherein said flue-gas desulfurized fly ash comprises approximately 30-50 wt. % of said fly ash mixture.